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PROJECT REPORTS OF EEE

A

PROJECT REPORT

On

ADVANCED DRIVE SYSTEM FOR DC MOTOR USING MULTILEVEL DC/DC BUCK CONVERTER CIRCUIT

Submitted by

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in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY
IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

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Dhulapally, Secunderabad – 500 100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled Advanced Drive System for DC Motor using Multilevel DC/DC Buck Converter Circuit, is being submitted by 1.Mr.Godisela Mohan Regd.No.17K81A0214 ,2.Mr.M.Vijay KumarRegd.No.18K85A0218,3.Mr.G.Ruthesh Yadav Regd.No.18K85A0214, 4.Mr.M.Akshith Yadav Regd.No.17K81A0243 in partial fulfillment of the requirement for the award of the degree of BACHELOR OF TECHNOLOGY IN ELECTRICAL AND ELECTRONICS ENGINEERING is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

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Place: Dhulapally

Date:

DECLARATION

We, the student of Bachelor of Technology in Department of ELECTRICAL AND ELECTRONICS ENGINEERING, session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled ADVANCED DRIVE SYSTEM FOR DC MOTOR USING MULTILEVEL DC/DC BUCK CONVRTER CIRCUIT is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

This project presents a new topology of clamped diode multilevel DC/DC buck power converter for a DC motor system. The proposed converter circuit consists of four cascaded MOSFET power switches with three clamping diodes and four voltage sources (voltage cells) connected in series. The main objective of the new topology is to reduce current ripples and torque ripples that are associated with hard switching of the traditional chopper circuit. When the voltage profile of this converter is applied on a DC motor, it positively affects the performance of the DC motor armature current and the generated dynamic torque. The output voltage of the proposed topology shows an adequate performance for tracking of reference voltage with small ripples that are normally reflected into smaller EMI noise. Moreover, it has been shown that the operation of the DC motor with the newly proposed chopper topology greatly decreases the motor armature current ripples and torque ripples by a factor equal to the number of the connected voltage cells.

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CHAPTER 1

INTRODUCTION

Nowadays, Direct Current (DC) motors are the main horse power of the most of the industrial process operations. These motors find a wide area of applications such as robotic motions, automatic manipulations, electric and hybrid vehicles, traction system, servo systems, rolling mills, and similar applications that require adequate process. The DC motors and their associate control and drive system are classified as the first choice compared to the available Alternating Current (AC) motors and their drive systems. The DC motor acquires this popularity due to many merits such as simplicity of its control and drive system compared to AC counterpart, linear variation of the torque and speed against applied armature voltage, wide controlled speed and wide controlled torque ranges, compact of size with high power efficiency for Permanent Magnet DC (PMDC) motors, and finally the overall low cost.

To control the DC motor rotor position, rotor speed, or the developed torque, the motor field current or the armature voltage is controlled to achieve the control goal. The armature terminal voltage through power electronic circuits is mostly used in the motor control system especially for the relatively high-power machines.

The application of pulse width modulation (PWM) with a large DC link voltage to the motor windings with hard switching strategy (as the case of traditional chopper circuit) causes an unsatisfactory dynamic behavior. The abrupt variations in the voltage and the associated change in the armature current corresponding to the PWM switching initiate a wide range of voltage and current harmonics, which lead to torque ripples and the associated mechanical vibrations and acoustic noise.

The mechanical vibration and noise in electric motors have become one of the most important factors for motor selection to do a certain task. The sound of the noise and the vibration in the motor are aroused mainly due to improper electromagnetic exciting forces that are continuously changed in time and space corresponding to the switching operation. This resultant variable-exciting force causes deformation in the mechanical structure and triggers the motor to vibrate

In a modern industrial situation, DC motor is widely used which is due to the low initial cost, excellent drive performance, low maintenance and the noise limit. As the electronic technology develops rapidly, its provide a wide scope of applications of high performance DC motor drives in areas such as rolling mills, electric vehicle tractions, electric trains, electric bicycles, guided vehicles, robotic manipulators, and home electrical appliances. DC motors have some control capabilities, which means that speed, torque and even direction of rotation can be changed at anytime to meet new condition. DC motors also can provide a high starting torque at low speed and it is possible to obtain speed control over a wide range.

So, the study of controlling DC motor is more practical significance. Control theory is an interdisciplinary branch of engineering and mathematics that deals with the behaviour of dynamical systems. For controlling a motor in any system, a controller is needed which is to give input to gate driver. For motor actuation, the microcontroller does not directly actuate the DC motor. It will have a device that known as gate driver which is function to drive the motor. For this system, it use motor driver as PWM amplifier to provide variable output voltage for controlling the speed of the motor and positive or negative voltage to control the direction of motor rotations. In real world, motor applications not only use the maximum speed of motor.

It maybe uses only 50% of its speed. So, the speed of the motor must be control. For some applications, motor is using not only one direction but with alternate direction to control a machine. In industrial field, some machine or robots cannot get in touch according to safety and the location of those things. The new method, which extensively used in motor controller, is pulse width modulation (PWM). PWM switching technique is a best method to control the speed of DC motor compare to another method. The duty cycle can be varied to get the variable output voltage. The concept of this system is same like DC-DC converter which is the output voltage depends on their duty cycle. Digital-to-analog conversion is not necessary because PWM itself is a signal that remains digital all the way from processor to control the overall system. By keeping the signal digital, noise effects are minimized unless there is a change from logic 1 to logic 0, which will make noise affect the digital signal. The Pulse-Width-Modulation (PWM) in microcontroller is used to control duty cycle of DC motor drive. PWM is an entirely different approach to controlling the speed of a DC motor. Power is supplied to the motor in square wave of constant voltage but varying pulse-width or duty cycle. Duty cycle refers to the percentage of one cycle during which duty cycle of a continuous train of pulses .

Since the frequency is held constant while the on-off time is varied, the duty cycle of PWM is determined by the pulse width. Thus the power increases duty cycle in PWM. A direct current (DC) motor converts DC electrical energy into mechanical energy. It produces a mechanical rotary action at the motor shaft where the shaft is physically coupled to a machine or other mechanical device to perform some type of work. DC motors are well suited for many industrial applications. For example, DC motors are used where accurate control of speed or position of the load is required and can be accelerate or decelerate quickly and smoothly. Plus, the direction easily reversed

CHAPTER 2

SPEED CONTROL OF DC MOTOR

DC MOTOR

There are two types of DC motors based on the construction such as self-excited, and separately excited. Similarly, self-excited motors classified into three types namely DC series motor, DC shunt motor, and DC compound motor. This article discusses an overview of the series motor, and the main function of this motor is to convert electrical energy to mechanical energy. The working principle of this motor mainly depends on electromagnetic law, which states that whenever a magnetic field is formed in the region of current carrying conductor & cooperates with an outside field, then the rotating motion can be generated. Once the series motor is started, then it will give utmost speed as well as torque slowly with high speed.

What is DC Series Motor?

The DC Series Motor is similar to any other motor because the main function of this motor is to convert electrical energy to mechanical energy. The operation of this motor mainly depends on the electromagnetic principle. Whenever the magnetic field is formed approximately, a current carrying conductor cooperates with an exterior magnetic field, and then a rotating motion can be generated.

Fig.2.1 DC Series Motor

Components used in DC Series Motor

The components of this motor mainly include the rotor (the armature), Commutator, stator, axle, field windings, and brushes. The fixed component of the motor is the stator, and it is built with two otherwise more electromagnet pole parts. The rotor includes the armature and the windings on the core allied to the Commutator. The power source can be connected toward the armature windings throughout a brush array allied to the Commutator.

The rotor includes a central axle for rotating, and the field winding must be able to hold high current due to the larger quantity of current throughout the winding, the larger will be the torque produced with the motor.

Therefore the motor winding can be fabricated with solid gauge wire. This wire does not permit a huge number of twists. The winding can be fabricated with solid copper bars because it assists in simple as well as efficient heat dissipation generated accordingly by a large amount of current flow during winding.

DC Series Motor Circuit Diagram

In this motor, field, as well as stator windings, are coupled in series by each other. Accordingly the armature and field current are equivalent.

Huge current supply straightly from the supply toward the field windings. The huge current can be carried by field windings because these windings have few turns as well as very thick. Generally, copper bars form stator windings. These thick copper bars dissipate heat generated by the heavy flow of current very effectively. Note that the stator field windings S1-S2 are in series with the rotating armature A1-A2.

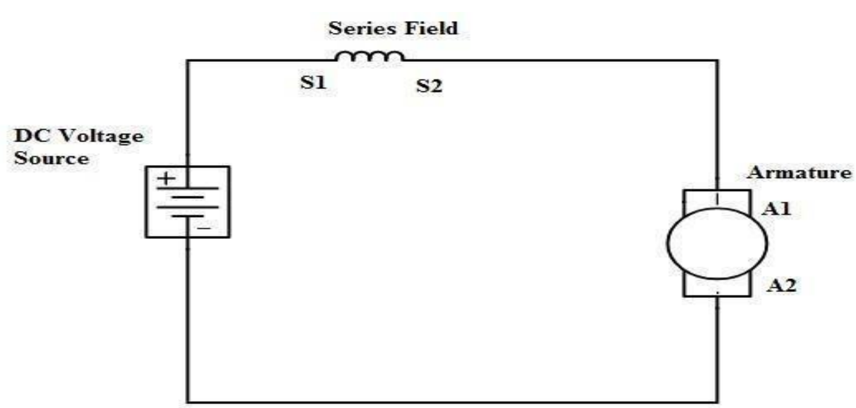


Fig.2.2 DC Series Motor Circuit Diagram

The strength of these magnetic fields provides the armature shafts with the greatest amount of torque possible. The large torque causes the armature to begin to spin with the maximum amount of power and the armature starts to rotate.

Electromagnetic motors

A coil of wire with a current running through it generates an electromagnetic field aligned with the center of the coil. The direction and magnitude of the magnetic field produced by the coil can be changed with the direction and magnitude of the current flowing through it.

A simple DC motor has a stationary set of magnets in the stator and an armature with one or more windings of insulated wire wrapped around a soft iron core that concentrates the magnetic field. The windings usually have multiple turns around the core, and in large motors there can be several parallel current paths. The ends of the wire winding are connected to a Commutator. The Commutator allows each armature coil to be energized in turn and connects the rotating coils with the external power supply through brushes. (Brushless DC motors have electronics that switch the DC current to each coil on and off and have no brushes.)

The total amount of current sent to the coil, the coil's size and what it's wrapped around dictate the strength of the electromagnetic field created.

The sequence of turning a particular coil on or off dictates what direction the effective electromagnetic fields are pointed. By turning on and off coils in sequence a rotating magnetic field can be created. These rotating magnetic fields interact with the magnetic fields of the magnets (permanent or electromagnets) in the stationary part of the motor (stator) to create a torque on the armature which causes it to rotate. In some DC motor designs the stator fields use electromagnets to create their magnetic fields which allow greater control over the motor.

At high power levels, DC motors are almost always cooled using forced air.

Different number of stator and armature fields as well as how they are connected provide different inherent speed/torque regulation characteristics. The speed of a DC motor can be controlled by changing the voltage applied to the armature. The introduction of variable resistance in the armature circuit or field circuit allowed speed control. Modern DC motors are often controlled by power electronics systems which adjust the voltage by "chopping" the DC current into on and off cycles which have an effective lower voltage.

Since the series-wound DC motor develops its highest torque at low speed, it is often used in traction applications such as electric locomotives, and trams. The DC motor was the mainstay of electric traction drives on both electric and diesel-electric locomotives, street-cars/trams and diesel electric drilling rigs for many years. The introduction of DC motors and an electrical grid system to run machinery starting in the 1870s started a new second Industrial Revolution. DC motors can operate directly from rechargeable batteries, providing the motive power for the first electric vehicles and today's hybrid cars and electric cars as well as driving a host of cordless tools. Today DC motors are still found in applications as small as toys and disk drives, or in large sizes to operate steel rolling mills and paper machines. Large DC motors with separately excited fields were generally used with winder drives for mine hoists, for high torque as well as smooth speed control using thyristor drives. These are now replaced with large AC motors with variable frequency drives.

If external mechanical power is applied to a DC motor it acts as a DC generator, a dynamo. This feature is used to slow down and recharge batteries on hybrid and electric cars or to return electricity back to the electric grid used on a street car or electric powered train line when they slow down. This process is called regenerative braking on hybrid and electric cars. In diesel electric locomotives they also use their DC motors as generators to slow down but dissipate the energy in resistor stacks. Newer designs are adding large battery packs to recapture some of this energy.

Speed control of DC series Motor

The speed of this type of motor is controlled by the following methods

- Armature resistance control
- Field control
- Tapped Field control

The most frequently used method is armature-resistance control method. Because in this method, the flux generated by this motor can be changed. The difference of flux can be attained by using the three methods like field diverters, armature diverter, and tapped field control.

Armature-resistance Control:

In the armature resistance control method, a changeable resistance can directly be connected in series through the supply. This can reduce the voltage which is accessible across the armature &

the speed drop. By altering the variable resistance value, any speed under the regular speed can be attained. This is the most general method used to control the DC series motor speed.

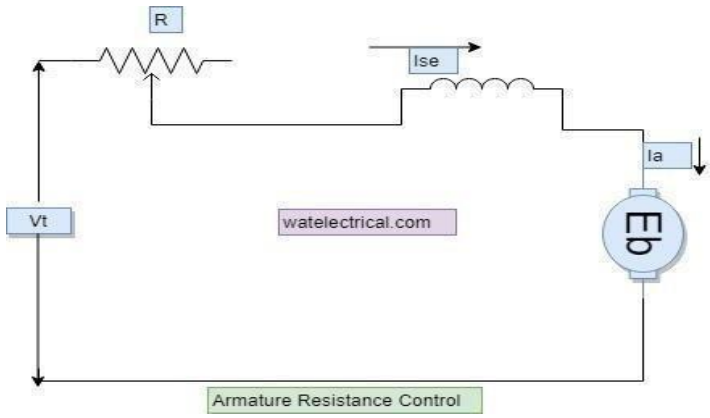


Fig.2.3

From the diagram, it is clear that as and when the resistance is adjusted the speed is varied. We know that in a series motor the field winding is in series and line and field current are the same. Due to this, the current flow depends upon the value of resistance. If more resistance is put in series with the armature, then the current flow will be less and vice-versa if less resistance is put in series.

The relationship between the speed and the back emf is given by $\mathbf{N\ E_b/\phi}$

Field Control Method

The circuit diagram that explains the field control method is shown in the figure below.

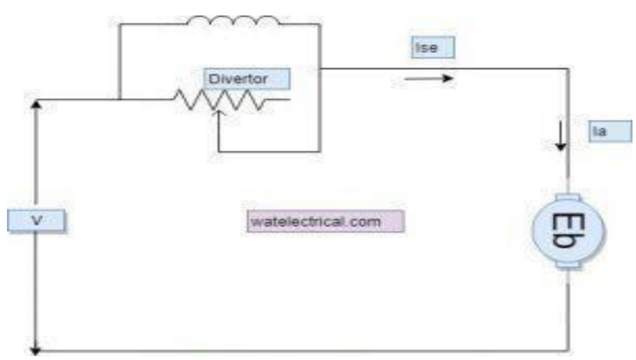


Fig no.2.4

Tapped diverter method

From the diagram, we can observe that a field diverter is connected across the field winding which is in series with the armature. The use of this diverter is to bypass the amount of flow armature current through the machine. As and when the armature current is varied we can able to vary the speed of the motor just like in armature resistance control. But the difference is, here we bypass the armature current by allowing some amount of current through the field winding as required. This is achieved by varying the resistance connected across field winding. If the diverter has maximum resistance, the current flows through the field winding and vice-versa if less resistance is connected.

Tapped Field Control Method

The circuit diagram that explains the Tapped field control method is shown in the figure below.

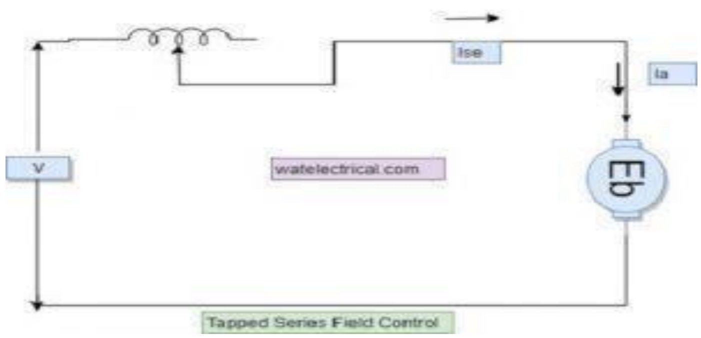


Fig.2.5

From the diagram, we can observe that a tapped series field resistance is connected in series with the armature. Just like the armature resistance control method, the series field is tapped at different points to vary the speed.

Speed Torque Characteristics of DC Series Motor

In general, for this motor, there are 3-characteristic curves are considered significant like Torque Vs. armature current, Speed Vs. armature current, & Speed Vs. torque. These three characteristics are determined by using the following two relations.

T_a aϕ.I_a

N aE_b/ϕ

The above two equations can be calculated at the equations of emf as well as torque. For this motor, the back emf's magnitude can be given with the similar DC generator e.m.f equation like

E_b= Pϕ NZ / 60A. For a mechanism, A, P, and Z are stable, thus, N aE_b/ϕ.

The **DC series motor torque equation** is,

Torque= Flux* Armature current

T = If * Ia

Here If= Ia, then the equation will become

T= Ia^2

Wound stators

The DC series motor torque (T) can be proportional to the Ia^2 (square of the armature current). In load test on dc series motor, the motor should be activated on load condition because if the motor can be activated on no load, then it will achieve an extremely high speed.

There are three types of electrical connections between the stator and rotor possible for DC electric motors: series, shunt/parallel and compound (various blends of series and shunt/parallel) and each has unique speed/torque characteristics appropriate for different loading torque profiles/signatures.

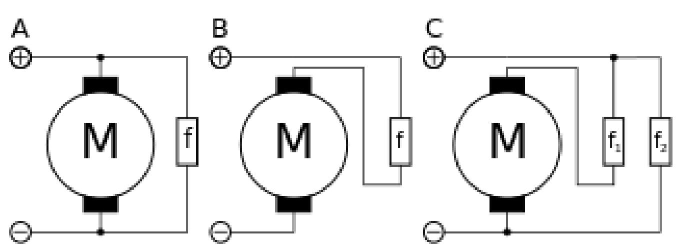


Fig .2.6

A field coil may be connected in shunt, in series, or in compound with the armature of a DC machine (motor or generator)

Series connection

A series DC motor connects the armature and field windings in series with a common D.C. power source. The motor speed varies as a non-linear function of load torque and armature current; current is common to both the stator and rotor yielding current squared (I^2) behavior. A series motor has very high starting torque and is commonly used for starting high inertia loads, such as trains, elevators or hoists. This speed/torque characteristic is useful in applications such as dragline excavators, where the digging tool moves rapidly when unloaded but slowly when carrying a heavy load.

A series motor should never be started at no load. With no mechanical load on the series motor, the current is low, the counter-Electro motive force produced by the field winding is weak, and so the armature must turn faster to produce sufficient counter-EMF to balance the supply voltage. The motor can be damaged by over speed. This is called a runaway condition.

Series motors called universal motors can be used on alternating current. Since the armature voltage and the field direction reverse at the same time, torque continues to be produced in the same direction. However they run at a lower speed with lower torque on AC supply when compared to DC due to reactance voltage drop in AC which is not present in DC. Since the speed is not related to the line frequency, universal motors can develop higher-than-synchronous speeds, making them lighter than induction motors of the same rated mechanical output. This is a valuable characteristic for hand-held power tools. Universal motors for commercial utility are usually of small capacity, not more than about 1 kW output. However, much larger universal motors were used for electric locomotives, fed by special low-frequency traction power networks to avoid problems with commutation under heavy and varying loads.

Shunt connection

A shunt DC motor connects the armature and field windings in parallel or shunt with a common D.C. power source. This type of motor has good speed regulation even as the load varies, but does not have the starting torque of a series DC motor. It is typically used for industrial, adjustable speed applications, such as machine tools, winding/unwinding machines and tensioners.

Compound connection

A compound DC motor connects the armature and fields windings in a shunt and a series combination to give it characteristics of both a shunt and a series DC motor. This motor is used when both a high starting torque and good speed regulation is needed. The motor can be connected in two arrangements: cumulatively or differentially. Cumulative compound motors connect the series field to aid the shunt field, which provides higher starting torque but less speed regulation. Differential compound DC motors have good speed regulation and are typically operated at constant speed.

DC Series Motor Advantages

The **advantages of the DC series motor** include the following.

- Vast starting torque
- Easy assembly and simple design
- Protection is easy
- Cost-effective

DC Series Motor Disadvantages

The disadvantages of DC series motor include the following.

- The motor speed regulation is fairly poor. When the load speed increases then the machine speed will decrease
- When the speed is increased, then the DC series motor's torque will be decreased sharply.
- This motor always needs the load before running the motor. So these motors are not suitable for where the motor's load is totally removed.

CHAPTER 3

PROPOSED CONVERTERS AND CONTROLLER CONFIGURATION

PROPOSED CONVERTER

The proposed block diagram of the multilevel chopper circuit (MLCC) for a DC motor drive system is shown in Fig. 1. This suggested system consists of the proposed MLCC block, H-bridge block in order to control the direction of the motor rotation, PMDC motor, in addition to many control blocks that arrange and synchronize the operation of the whole system. In this research work, the suggested multilevel chopper circuit (MLCC) is a 5-level power converter as illustrated in Fig. 2, it is composed of four controllable power switches

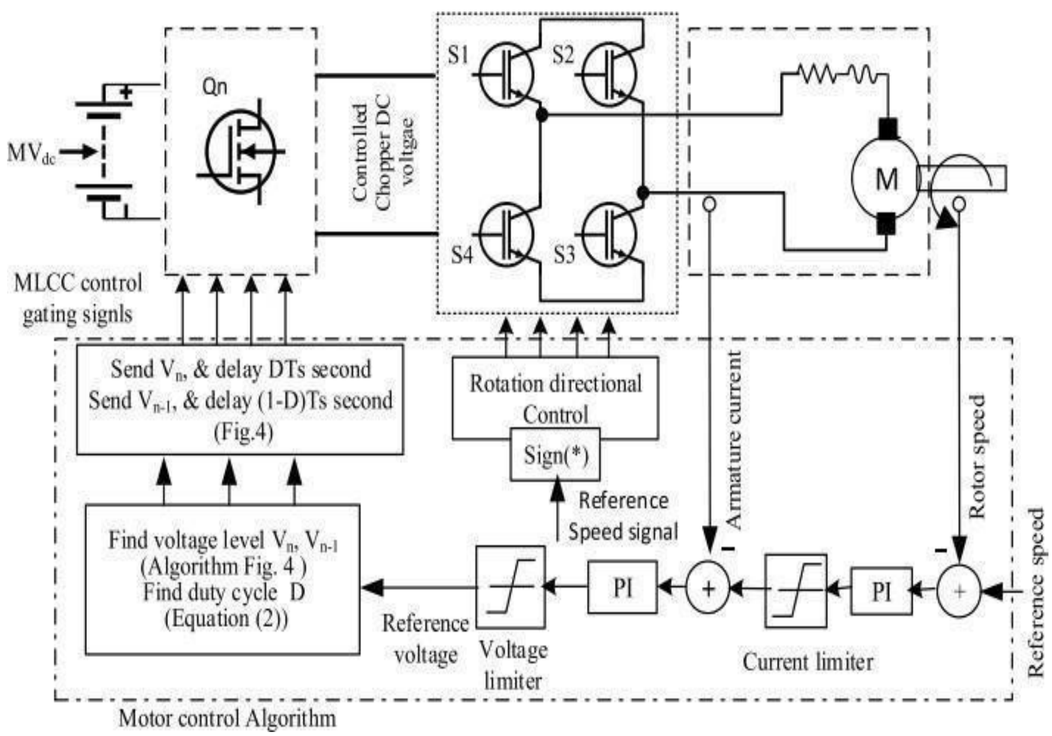


Fig.3.1

such as power MOSFET. The MLCC consists of three clamped diodes, (D1, D2 D3), preferably Schottky diodes and freewheeling diode DF: These diodes together with the power switches actualize the correct operation of the multilevel chopper circuit. The voltage of the sources VDC1, VDC2, VDC3 and VDC4 are of equal or different voltage values. These independent DC voltage sources could be cell storage batteries, solar cell units or any equivalent DC voltage sources.

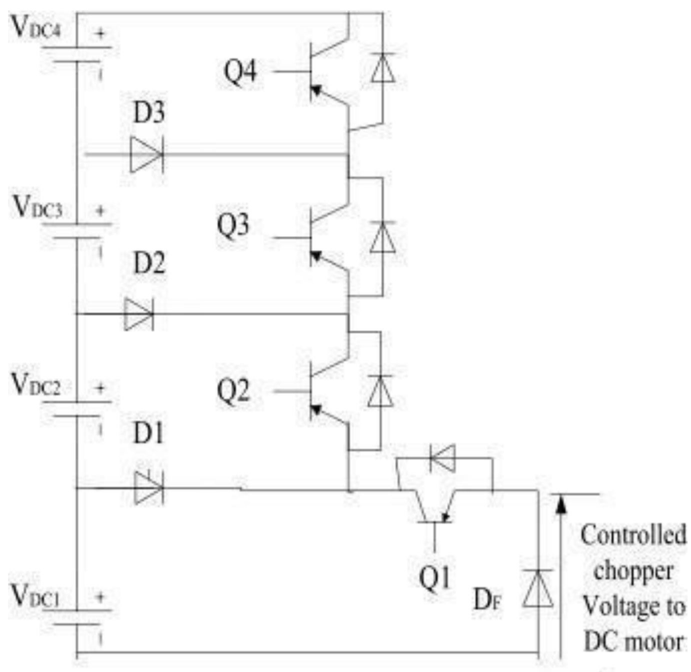


Fig.3.2

Controller design for any system needs knowledge about system behavior. Usually this involves a mathematical description of the relation among inputs to the process, state variables, and output. This description in the form of mathematical equations which describe behavior of the system (process) is called model of the system. This paper describes an efficient method to learn, analyze and simulation of power electronic converters, using system level nonlinear, and switched state- space models. The MATLAB/SIMULINK software package can be advantageously used to simulate power converters. This study aims at development of the models for all basic converters and studying its open loop response, so these models can be used in case of design of any close loop scheme. Also as a complete exercise a closed scheme case has been studied using cascaded control for a boost converter.

System modeling is probably the most important phase in any form of system control design work. The choice of a circuit model depends upon the objectives of the simulation. If the goal is to predict the behavior of a circuit before it is built. A good system model provides a designer with valuable information about the system dynamics. Due to the difficulty involved in solving general nonlinear equations, all the governing equations will be put together in block diagram form and then simulated using Matlab's Simulink program. Simulink will solve these nonlinear equations numerically, and provide a simulated response of the system dynamics.

To obtain a nonlinear model for power electronic circuits, one needs to apply Kirchhoff's circuit laws. To avoid the use of complex mathematics, the electrical and semiconductor devices must be represented as ideal components (zero ON voltages, zero OFF currents, zero switching times). Therefore, auxiliary binary variables can be used to determine the state of the switches. It must be ensure that the equations obtained by the use of Kirchhoff's laws should include all the permissible states due to power semiconductor devices being ON or OFF.

The steps to obtain a system-level modeling and simulation of power electronic converters are listed below.

1) Determine the state variables of the power circuit in order to write its switched state-space model, e.g., inductor current and capacitor voltage.

2) Assign integer variables to the power semiconductor (or to each switching cell) ON and OFF states.

3) Determine the conditions governing the states of the power semiconductors or the switching cell.

4) Assume the main operating modes of the converter (continuous or discontinuous conduction or both) or the modes needed to describe all the possible circuit operational modes. Then, apply Kirchhoff's laws and combine all the required stages into a switched state-space model, which is the desired system-level model.

5) Write this model in the integral form, or transform the differential form to include the semiconductors logical variables in the control vector: the converter will be represented by a set of nonlinear differential equations.

6) Implement the derived equations with "SIMULINK" blocks (open loop system simulation is then possible to check the obtained model).

7) Use the obtained switched space-state model to design linear or nonlinear controllers for the power converter.

8) Perform closed-loop simulations and evaluate converter performance.

9) The algorithm for solving the differential equations and the step size should be chosen before running any simulation. The two last steps are to obtain closed-loop simulations.

Each of the power electronic models represents subsystems within the simulation environment. These blocks have been developed so they can be interconnected in a consistent and simple manner for the construction of complex systems. The subsystems are masked, meaning that the user interface displays only the complete subsystem, and user prompts gather parameters for the entire subsystem. Relevant parameters can be set by double-clicking a mouse or pointer on each subsystem block, then entering the appropriate values in the resulting dialogue window.

To facilitate the subsequent simulation analysis and feedback controller verification, the pulse-width-modulation signal to control the ideal switch can also be built into the masked subsystem Fig. 9(a) and Fig. 9(b). For each converter to verity it's working in open loop configuration trigger pulses have been derived using a repeating sequence generator and duty cycle block. Function block compares the duty cycle and saw tooth from repeating sequence- derived trigger pulses are connected as an input to the switch control. Hence inputs for the masked subsystem are duty ratio and input voltage, and the outputs are chosen to be inductor current, capacitor voltage, and output voltage. When double-clicking the pointer on the masked subsystem, one enters parameter values of the switching converter circuit in a dialogue window. The intuitive signal flow interface in SIMULINK makes this mathematical model and its corresponding masked subsystem very easy to create.

PI Controller

A variation of Proportional Integral Derivative (PID) control is to use only the proportional and integral terms as PI control. The PI controller is the most popular variation, even more than full PID controllers. The value of the controller output u(t)u(t) is fed into the system as the manipulated variable input.

$$e(t) = SP - PV$$

$$u(t) = u_{bias} + K_c\, e(t) + \frac{K_c}{\tau_I} \int_0^t e(t)dt$$

The u_{bias} term is a constant that is typically set to the value of u(t)u(t) when the controller is first switched from manual to automatic mode. This gives "bump less" transfer if the error is zero when the controller is turned on. The two tuning values for a PI controller are the controller gain, KcKc and the integral time constant τI τI. The value of Kc Kc is a multiplier on the proportional error and integral term and a higher value makes the controller more aggressive at responding to errors away from the set point. The set point (*SP*) is the target value and process variable (*PV*) is the measured value that may deviate from the desired value. The error from the set point is the difference between the *SP* and *PV* and is defined as e(t)= SP−PVe(t) =SP-PV.

Digital controllers are implemented with discrete sampling periods and a discrete form of the PI equation is needed to approximate the integral of the error. This modification replaces the continuous form of the integral with a summation of the error and uses Δt as the time between sampling instances and ntnt as the number of sampling instances.

$$u(t) = u_{bias} + K_c\, e(t) + \frac{K_c}{\tau_I} \sum_{i=1}^{n_t} e_i(t)\Delta t$$

A P.I Controller is a feedback control loop that calculates an error signal by taking the difference between the output of a system, which in this case is the power being drawn from the battery, and the set point. The set point is the level at which we'd like to have our system running, ideally we'd like our system to be running near max power (990W) without causing the limiter to engage.

It is important to point out that due the the complexity of the electronic components within the circuit path(i.e ESC, power limiter, and motor) I was not able to accurately create model (transfer function) for the system. Having a transfer function would have allowed me to simulate the system in a software package such as MATLAB/Simulink and assist me in finding the right proportional and integral constant parameters for the controller. Unfortunately, due to the lack of a model, the parameters were obtained via a trial and error format. The figure above shows a software level block diagram of the P.I control algorithm. The controller receives a current and voltage measurement which it then uses to calculate the power being drained from the battery. Once the power is measured the error signal is calculated by taking the difference between the set point and the power measured. The error signal then goes into the P.I control loop where it gets multiplied by the proportional and integral constant. The output of the P.I control is a power value and in order to convert it to a quantity that is comparable to that of the control signal, it goes through a power to PWM signal converter. The adjusted PWM signal (output of PWM converter) then gets compared with the throttle signal, which is also a PWM signal, that is being sent by pilot,the least of the two gets sent to the controlled system. The controlled system block encompasses the battery, motor, speed controller, and limiter.

PI control is needed for non-integrating processes, meaning any process that eventually returns to the same output given the same set of inputs and disturbances. A P-only controller is best suited to integrating processes. Integral action is used to remove offset and can be thought of as an adjustable ubiasubias.

Common tuning correlations for PI control are the ITAE (Integral of Time-weighted Absolute Error) method and IMC (Internal Model Control). IMC is an extension of *lambda* tuning by accounting for time delay. The parameters KcKc, τpτp, and θpθp are obtained by fitting dynamic input and output data to a first-order plus dead-time (FOPDT) model.

An important feature of a controller with an integral term is to consider the case where the controller output u(t)u(t) saturates at an upper or lower bound for an extended period of time. This causes the integral term to accumulate to a large summation that causes the controller to stay at the saturation limit until the integral summation is reduced. Anti-reset windup is that the integral term does not accumulate if the controller output is saturated at an upper or lower limit.

Suppose that a driver of a vehicle set the desired speed set point to a value higher than the maximum speed. The automatic controller would saturate at full throttle and stay there until the driver lowered the set point. Suppose that the driver kept the speed set point higher than the maximum velocity of the vehicle for an hour. The discrepancy between the set point and the current speed would create a large integral term. If the driver then set the speed set point to zero, the controller would wait to lower the throttle until the negative error cancels out the positive error from the hour of driving. The automobile would not slow down but continue at full throttle for an extended period of time. This undesirable behavior is fixed by implementing anti-reset windup.

P-only Control

Simulate the behavior for using a P-only controller with Kc=2Kc=2 and Kc=0.5Kc=0.5. Implement a set point change from 0 to 10 and back in automatic mode (closed-loop). Include a plot of the error between the set point (*SP*) and process variable (*PV*). What happens with increased KcKc in terms of offset and oscillation?

PI Control

Configure the controller to add an integral term in addition to the proportional control with Kc=2Kc=2. Simulate the PI controller response with integral reset times τI=200,100,10τI=200,100,10. Include a plot of the integral of the error between the set point (*SP*) and process variable (*PV*) with anti-reset windup. Explain what happens and why.

Open Loop Response with Dead Time

Add dead time θp=100θp=100 as an input delay. Simulate the behavior for making a step change in manual mode from 0 to 10 (and back). Explain what happens in terms of oscillations.

P-only Control with Dead Time

With the dead time, simulate the response of a P-only controller with Kc=2Kc=2 and Kc=0.5Kc=0.5. Implement a set point change from 0 to 10 and back in automatic mode (closed-loop). Include a plot of the error between the set point (*SP*) and process variable (*PV*). What happens with increased KcKc in terms of offset and oscillation?

PI Control with Dead Time

Simulate the response of a PI controller with τI=200τI=200. Include a plot of the integral of the error between the set point (*SP*) and process variable (*PV*) with anti-reset windup. Explain what happens and why. Explain the results.

WHY PULSE WIDTH MODULATION

1. Cheap to make.
2. Little heat whilst working.
3. Low power consumption.
4. Can utilize very high frequencies (40-100 Khz is not uncommon.)
5. Very energy-efficient when used to convert voltages or to dim light bulbs.

6. High power handling capability
7. Efficiency up to 90%

a modulation technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photovoltaic solar battery chargers,[1] the other being MPPT.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. Typically switching has to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

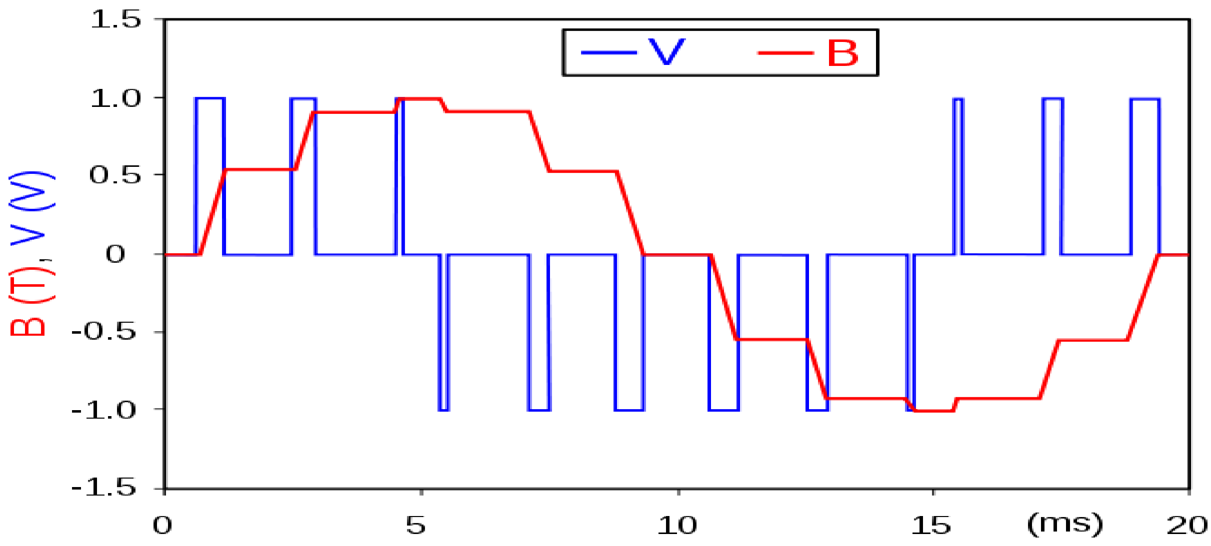


Fig 3.3 wave for combined positive and negative pulse

An example of PWM in an idealized inductor driven by a voltage source: the voltage source (blue) is modulated as a series of pulses that results in a sine-like current/flux (red) in the inductor. The blue rectangular pulses nonetheless result in a smoother and smoother red sine wave as the switching frequency increases. Note that the red waveform is the (definite) integral of the blue waveform.

Principle

Pulse-width modulation uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform. If we consider a pulse waveform $f(t)$, with period T, low value y_{min} , a high value $y_{max}$and a duty cycle D (see figure 1), the average value of the waveform is given by:

$$\bar{y} = \frac{1}{T}\int_0^T f(t)\,dt.$$

As $f(t)$is a pulse wave, its value is y_{max} for $0 < t < D \cdot T$ and y_{min} for $D \cdot T < t < T$. The above expression then becomes:

$$\bar{y} = \frac{1}{T}\left(\int_0^{DT} y_{max}\,dt + \int_{DT}^{T} y_{min}\,dt\right)$$
$$= \frac{D \cdot T \cdot y_{max} + T\,(1-D)\,y_{min}}{T}$$
$$= D \cdot y_{max} + (1-D)\,y_{min}.$$

This latter expression can be fairly simplified in many cases where $y_{min} = 0$ as $\bar{y} = D \cdot y_{max}$. From this, it is obvious that the average value of the signal ($\bar{y}$) is directly dependent on the duty cycle D.

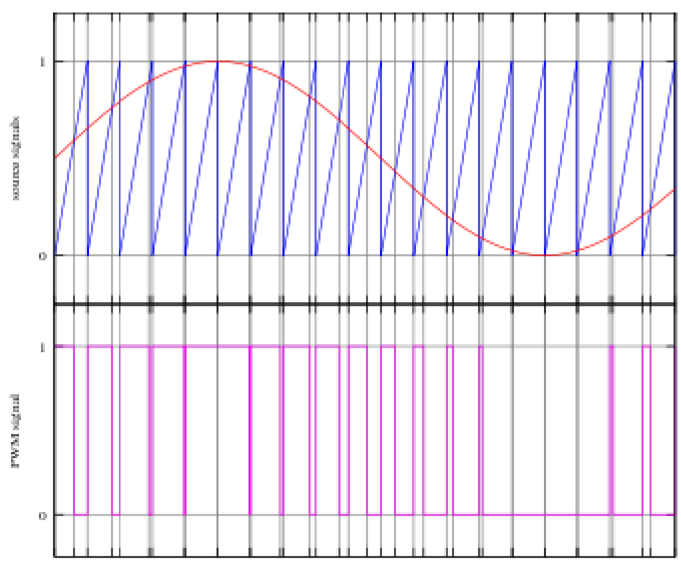


Fig. 3.4

Fig. 3.4 A simple method to generate the PWM pulse train corresponding to a given signal is the intersective PWM: the signal (here the red sine wave) is compared with a saw tooth waveform (blue). When the latter is less than the former, the PWM signal (magenta) is in high state (1). Otherwise it is in the low state (0).

The simplest way to generate a PWM signal is the intersective method, which requires only a sawtooth or a triangle waveform (easily generated using a simple oscillator) and a comparator. When the value of the reference signal (the red sine wave in figure 2) is more than the modulation waveform (blue), the PWM signal (magenta) is in the high state, otherwise it is in the low state.

The **PWM** is a technique which is used to drive the inertial loads since a very long time.The simple example of an inertial load is a motor. Apply the power to a motor for a very short period of time and then turn off the power: it can be observed that the motor is still running even after the power has been cut off from it. This is due to the inertia of the motor and the significance of this factor is that the continuous power is not required for that kind of devices to operate. A burst power can save the total power supplied to the load while achieving the same performance from the device as it runs on continuous power.

The **PWM technique** is use in devices like DC motors, Loudspeakers, Class -D Amplifiers, SMPS etc. They are also used in communication field as-well. The modulation techniques like AM, FM are widely used RF communication whereas the PWM is modulation technique is mostly used in Optical Fiber Communication (OFC).

As in the case of the inertial loads mentioned previously, the PWM in a communication link greatly saves the transmitter power. The immunity of the PWM transmission against the inter-symbol interference is another advantage. This article discusses the technique of generating a PWM wave corresponding to a modulating sine wave.

CHAPTER 4

PROPOSED CIRCUIT SIMULATION RESULTS

INTRODUCTION

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.

Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor. The model depicts the time-dependent mathematical relationships among the system's inputs, states, and outputs. Then, we use Simulink to simulate the behavior of the system over a specified time span. Simulink uses information that you entered into the model to perform the simulation.

BLOCK DIAGRAM

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block). The lines represent connections of block inputs to block outputs. Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time. A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate. A block comprises one or more of the following:

1) A set of inputs,
2) A set of states, and
3) A set of outputs.

A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance. Continuous Versus discrete Blocks Simulink's standard block set includes continuous blocks and discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only at integral multiples of a fixed interval called the block's sample time. Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, depending on whether they are driven by continuous or discrete blocks. A block that can be either discrete or continuous is said to have an implicit sample rate. The implicit sample time is continuous if any of the block's inputs are continuous. The implicit sample time is equal to the shortest input sample time if all the input sample times are integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times.

Simulink can optionally color code a block diagram to indicate the sample times of the blocks it contains, e.g., black (continuous), magenta (constant), yellow (hybrid), red (fastest discrete), and so on. The block contains block name, icon, and block library that contain the block, the purpose of the block

SIMULINK BLOCK LIBRARIES

Simulink organizes its blocks into block libraries according to their behavior.

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-time components.
4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.
6) The Functions & Tables library contains blocks that describe general functions and table look-up operations.
7) The Nonlinear library contains blocks that describe nonlinear functions.
8) The Signal & Systems library contains blocks that allow multiplexing and demultiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types of subsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

SUB SYSTEMS

Simulink allows to model a complex system as a set of interconnected subsystems each of which is represented by a block diagram. We create a subsystem using Simulink's Subsystem block and the Simulink model editor. We can embed subsystems with subsystems to any depth to create hierarchical models. We can create conditionally executed subsystems that are executed only when a transition occurs on a triggering or enabling input.

SOLVERS

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model. The process of computing the successive states of a system from its model is known as solving the model. No single method of solving a model suffices for all systems. Accordingly, Simulink provides a set of programs, known as solvers, that each embody a particular approach to solving a model. The Simulation Parameters dialog box allows us to choose the solver most suitable for our model.

Fixed-Step and Variable-Step Solvers

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size. Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly and increasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time, required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

Continuous and Discrete Solvers

Continuous solvers use numerical integration to compute a model's continuous states at the current time step from the states at previous time steps and the state derivatives. Continuous solvers rely on the model's blocks to compute the values of the model's discrete states at each time step. Mathematicians have developed a wide variety of numerical integration techniques for solving the ordinary differential equations (ODEs) that represent the continuous states of dynamic systems. Simulink provides an extensive set of fixed-step and variable-step continuous solvers, each implementing a specific ODE solution method. Some continuous solvers subdivide the simulation time span into major and minor steps, where a minor time step represents a subdivision of the major time step. The solver produces a result at each major time step. It use results at the minor time steps to improve the accuracy of the result at the major time step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time-step for a model and nothing else. They do not compute continuous states and they rely on the model's blocks to update the model's discrete states. We can use a continuous solver, but not a discrete solver, to solve a model that contains both continuous and discrete states. This is because a discrete solver does not handle continuous states. If you select a discrete solver for a continuous model, Simulink disregards your selection and uses a continuous solver instead when solving the model.

Simulink provides two discrete solvers, a fixed-step discrete solver and a variable-step discrete solver. The fixed-step solver by default chooses a step size and hence simulation rate fast enough to track state changes in the fastest block in our model. The variable-step solver adjusts the simulation step size to keep pace with the actual rate of discrete state changes in our model. This can avoid unnecessary steps and hence shorten simulation time for multirate models.

MODEL EXECUTION PHASE

In the simulation model execution phase, Simulink successively computes the states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps. The length of time between steps is called the step size. The step size depends on the type of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states have discontinuities (Zero Crossing Detection). At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated. At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

1) Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and states to the output function as it may require these arguments to compute the block's output. Simulink updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.
2) Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's

continuous states by numerically integrating the time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.

3) Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.
4) Computes the time for the next time step.

Simulink repeats steps 1 through 4 until the simulation stop time is reached.

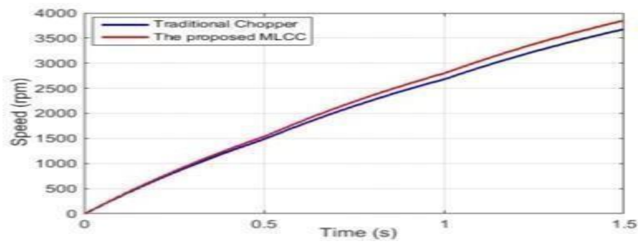
Block Sorting Rules

Simulink uses the following basic update rules to sort the blocks:

1) Each block must be updated before any of the direct-feed through blocks that it drives. This rule ensures that the inputs to direct-feed through blocks will be valid when they are updated.
2) Non direct-feed through blocks can be updated in any order as long as they are updated before any direct-feed through blocks that they drive. This rule can be met by putting all non direct-feed through blocks at the head of the update list in any order. It thus allows Simulink to ignore non direct-feed through blocks during the sorting process.

The result of applying these rules is an update list in which non direct-feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct-feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output. However, an algebraic loop can represent a set of simultaneous algebraic equations (hence the name) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step. Accordingly, Simulink assumes that loops involving direct-feed through blocks do, in fact, represent a solvable set of algebraic equations and attempts to solve them each time the block is updated during a simulation.

Parameter	Value
Rated power	3.02 kW
Rated torque	4.35 Nm
Rated speed	6724 rpm
Rated voltage	48 V
Rated current	75A
Ra	0.48 Ohm
La	1.4 mH
J	0.0117
B	0
Km	0.0631 Nm/A
Kg	1/138 V/rpm



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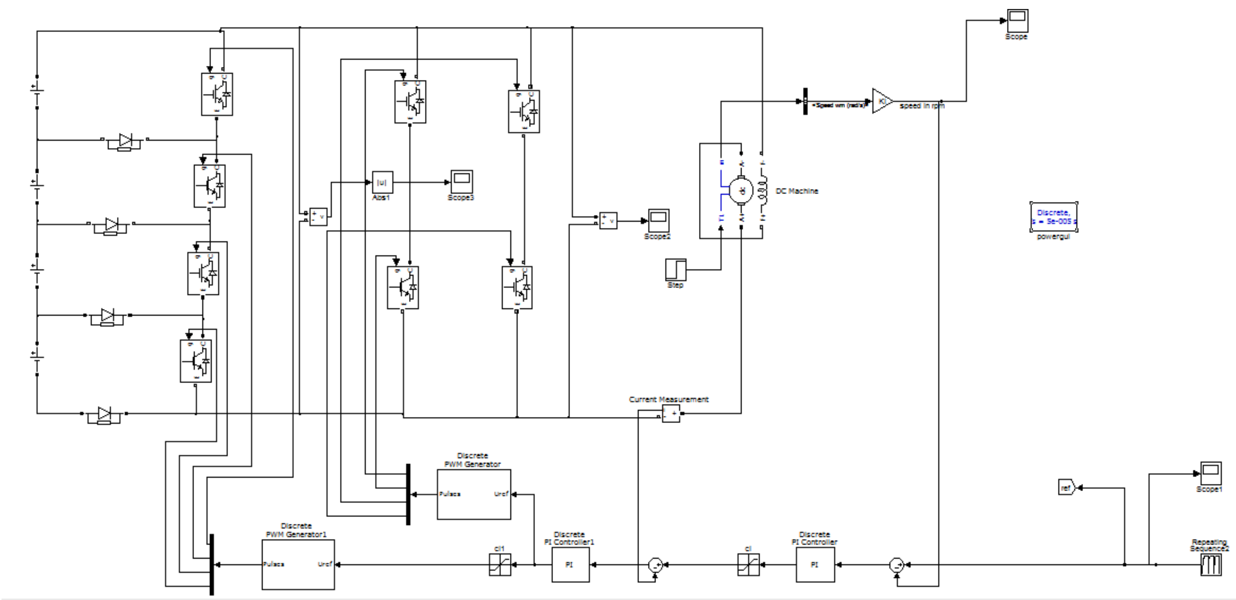

Fig 4.1 Proposed circuit configuration

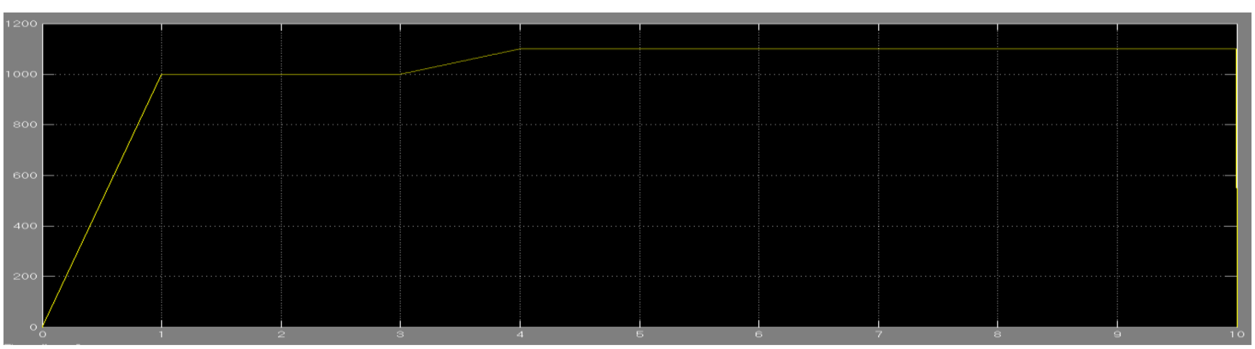

Fig 4.2 Reference speed

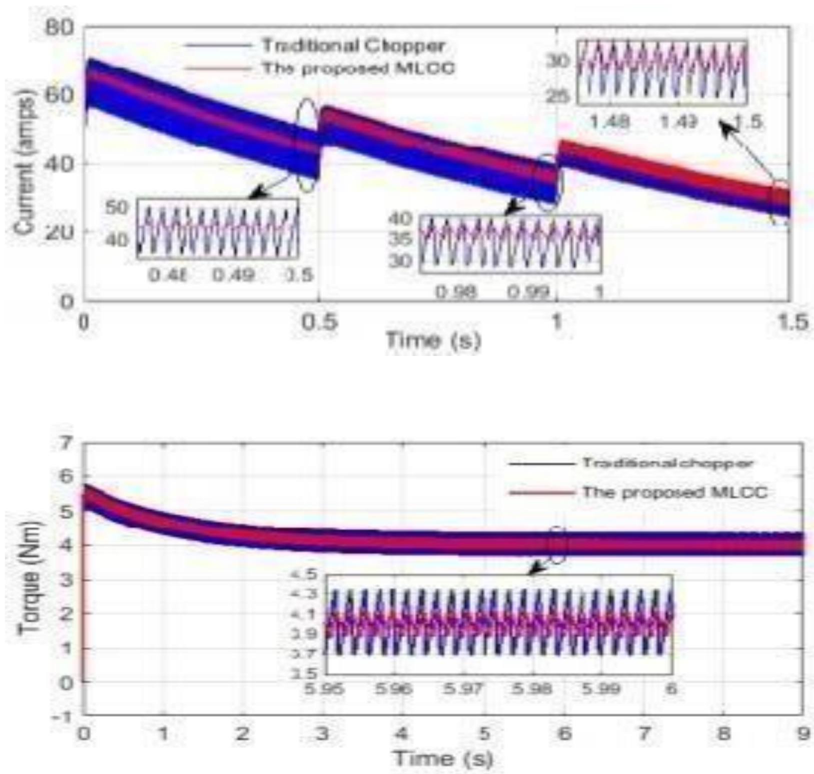

Fig.4.3 Comparison b/w traditional chopper and proposed MLCC

To evaluate the performance of the proposed multilevel chopper circuit, two Simulink models are built. One model is given for the proposed MLCC with the structure given in section II and the other one is given for the traditional chopper circuit with one fixed DC voltage source and one controllable switching element. The traditional chopper circuit works in a step-down mode to achieve the required reference voltage. The results of the output voltage performance is shown where the reference voltage (red) is changed from 40V to 20V then to 30V and thereafter to 6V for a duration of 0.05 s for each voltage level. It is clear from the comparison of these two figures that the proposed system works properly to provide the required level voltage to the load. The system keeps switching only between two consecutive voltage levels, While the tradition system of Fig must follow hard switching across the ultimate voltage range (0-48V) to provide the required reference voltage. The torque ripple in the steady-state performance is shown in the magnified part of Fig for the both drive systems.

The peak to peak torque ripple is approximately 0.7 Nm for the traditional chopper drive circuit and around 0.2 Nm for the proposed MLCC. It can be roughly concluded that with the proposed MLCC, the torque ripple is decreased by a factor of n (equal to the number of the DC voltage source cells). This reduction in the torque ripples eventually reflects on less noise and reduced mechanical vibration. In addition, the armature current in Fig which is like the developed torque performance, shows smaller current ripples for the proposed MLCC. These smaller ripples lead to less ohmic losses, and less harmonics and low EMI noise. The corresponding

speed problem in Fig.4.1 shows that for the same applied average voltage, the proposed MLCC gives a relatively higher speed level. In addition, the magnified part of the Fig.13 shows that the speed pulsation is higher in the case of the traditional chopper.

To accurately evaluate the proposed topology, the MLCC is simulated in closed loop control mode. The simulated circuit is arranged as given in Fig.1. The tuned parameters of the current loop controller are (Ki D 0:2 and Kp D 2, and high voltage limits of 48V), and that of the speed controller are (Ki D 16 and Kp D 1:6, and current limit of 90 amps). The speed reference is changed from initial value of 100 rad/s to 120 rad /s or (in rpm as 100_60/2_to 120_60/2_) at time tD 3 second. The load torque is changed from an initial value of 4 Nm to a intial value of 2 Nm at time t D 6 second. The detailed speed and torque performances are shown in Fig respectively. The controlled speed performance for the both methods (the proposed in red and the traditional in blue) shows almost the same general performance at starting and at steady state. However, the magnified parts of the traditional chopper show that the proposed MLCC has smallerspeed ripples and relatively smaller overshoot during the load change at time D 6 second. On the other hand, the corresponding torque profile shows an outstanding performance of the proposed MLCC as can be seen in the magnified parts. Although the average dynamic timeresponse is almost the same, the torque overshoot at load torque change point is higher than theproposed MLCC, in addition the torque ripples of the traditional chopper circuit are extremelyhigh.

CHAPTER 5

CONCLUSION

This project presents simulation results and experimental validation of a new topology of the multilevel chopper DC/DC converter for a DC motor system. The main objective of the propounded topology is to reduce current ripples and torque ripples that are associated with hard switching of the traditional chopper circuit. The proposed configuration provides constant -ve values of standard cell voltage and has the ability to generate the required nonstandard voltage within the cell voltage ranges. The generated voltage pattern of this topology has relatively smaller switching ripples compared to the traditional step-down DC/DC power converters. It has been shown that the operation of the DC motor with the new proposed chopper topology can efficiently decrease the motor armature current ripples and torque ripples by a factor equal to the number of the connected voltage cells. As compared with the operation of the motor with traditional chopper circuit.

CHAPTER 6

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APPENDIX

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

(a) Development Environment

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

(b) The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

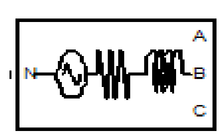
(e) The MATLAB Application Program Interface (API)

This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

(f) MATLAB Documentation

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

(1) Three phase source block

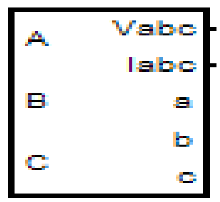


Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

(2) VI measurement block

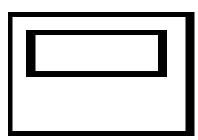
The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents



Three Phase V-I Measurement

(3) Scope

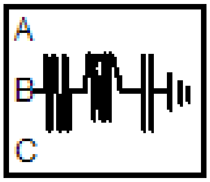
Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes. The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation



Scope

(4) Three-Phase Series RLC Load

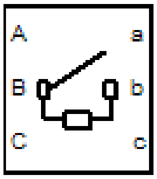
The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.



Three-Phase Series RLC Load

(5) Three-Phase Breaker block

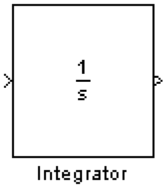
The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.



Three-Phase Breaker Block

(6) Integrator

Library: Continuous

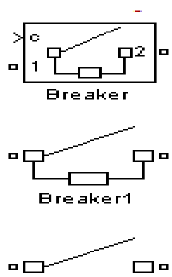


Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

(7) Breaker : Implement circuit breaker opening at current zero crossing.

Library: Elements



Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it).

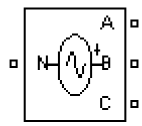
When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

(8) Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources



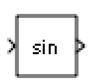
Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

(9) Trigonometric Function

Specified trigonometric function on input

Library: Math Operations



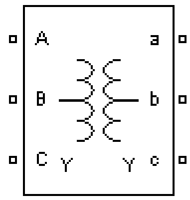
Trigonometric Function

Purpose: The Trigonometric Function block performs common trigonometric functions

(10) Three-Phase Transformer (Two Windings)

Implement three-phase transformer with configurable winding connections

Library: **Elements**



Three Phase Transformer

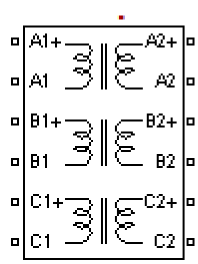
Purpose:

The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

(11) Three-Phase Transformer 12 Terminals

Implement three single-phase, two-winding transformers where all terminals are accessible

Library: Elements



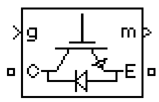
Two winding Transformer

Purpose: The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

(12) IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: **Power Electronics**



IGBT

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

A

PROJECT REPORT

On

FAST DC-TYPE ELECTRIC VEHICLE BASED ON A QUASI-DIRECT BOOST-BUCK RECTIFIER

Submitted by

1)Ms. K. Meghana (17K81A0223) **2) Ms. T. Manideepa (17K81A0239)**

3) Mr. B. Vinay Santosh (17K81A0205) **4) Mr. B. Soma Shekar (17K81A0209)**

in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS

Under The Guidance of

Mr.CH.Srinivas(Ph.D.)

ASSOCIATE PROFESSOR

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled **Fast Dc-Type Electric vehicle based on a Quasi-DirectBoost-Buck Rectifier**, is being submitted by **1. Ms. K. Meghana (17K81A0223), 2. Ms. T. Manideepa(17K81A0239) 3. Mr. Vinay Santosh (17K81A0205) 4. Mr. B. Soma Shekar (17K81A0209)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN** Electrical and Electronics is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

	Head of the Department
Mr. CH. Srinivas	Dr. N. Ramachandra
Department of Electrical and Electronics Engineering	Department of Electrical and Electronics Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of Electrical and Electronics', session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled is **Fast Dc-Type Electric vehicle based on a Quasi-Direct Boost-Buck Rectifier** the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

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1. K. Meghana
2. T. Manideepa
3. B. Vinay Santosh
4. B. Soma Shekar

ABSTRACT

The electric vehicle (EV) charging market is very dynamic. Companies and institutes involved in the research and development of this area are devoted to considerably reduce the EV charging times to be close to the ones spent by users in gas-stations filling the fuel of the internal combustion engines vehicles. Today most EVs can be charged at 50 kW and 400 V following the fast-charging standards “CCS - up to 80kW However new EVs are designed to withstand higher charging power. Therefore, output power scalability will be a key feature of the EV charging system by usage of power electronics building blocks, i.e., the total power can be scalable by paralleling circuits. This leads to manufacturing advantages because a single circuit building block design can satisfy a plurality of business and many charging standards. one can identify a well-known two-stage power conversion system, i.e., a three-phase AC-DC converter, a DC-DC circuit. The back-end circuit works as a three-channel PWM interleaved DC-DC buck-type converter. This features enhanced loss distribution among semiconductors or better current shared between the parallel circuits than hard paralleling of semiconductors. This results in improvements in the achievable total conduction and switching losses. Additionally, the symmetric PWM interleaved operation will cancel out the high frequency harmonics proportional to the number of employed parallel circuits in both voltages and currents This work presents a DC-type fast electric vehicle battery charger featuring low switching losses. Herein, a conventional three-phase two-level voltage source rectifier with low capacitive energy storage operates with a discontinuous PWM modulation where each phase-legs stops switching for 240o of the grid fundamental period, i.e. only a single phase-leg switch every 60o . In this case, this AC-DC converter loses voltage controllability of the DC-link and thus a buck-type DC-DC converter is cascaded in order to provide the necessary voltage regulation and current limitation for the charging process of the electric vehicle. The presented circuit is benchmarked against other solutions for a designed 50 kW power capability battery charger when considering the charging of a 30 kWh.

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1. INTRODUCTION

1.0 OVERVIEW OF THE PROJECT

- These days Electric vehicle charging market is very high.
- Most of the companies involved in research and development of thisareas and work to reduce the charging time of EV's.
- Today most of the EV's can be charged at 50KW and 400Vfollowing the fast-charging standards and are designed to with stand higher charging power.
- So, the output power characteristics are key features of EV'scharging system by using power electronics building block (PEBB).
- Connecting EV charger to medium level voltage (MV) AC grid.
- Bidirectional PEBB is connected to MV grid through 50/60 Hz transformer.
- Advantage of this is that the battery charger can be fully assemblewith half-bridge power modules.
- It is a two-stage power conversion system.
- Converts three phase AC to DC pulse DC to DC.
- The front-end circuit consist of three phase two level voltage sourcerectifier which has low complexity, low cost and proper voltage conversion rate.

- The back-end circuit has three channel pulse width modulators with DC-DC buck type converter. This feature improves the current shared between parallel circuits and results in the improvement in total conduction and switching losses

- PWM will cancels out the high frequency harmonics in both voltageand current.

- The front-end back-end circuits are connected through a DC linkemploying capacitor with low energy storage capability thismakes the operation of both circuits highly coupled to each other.

- Therefore, high power factor operation can only be achieved ifthe back-end circuit converter ensures constant power operation.

1.1. OBJECTIVES OF THE STUDY

- The Objective of the project is to reduce the charging time ofelectric vehicle and are designed to withstand higher charging power.
- To analyze the Pulse width modulator with 240 degrees stopswitching interval in the two-level voltage source rectifier.

1.2. SCOPE OF THE STUDY

- The scope of the paper is to present the initial steps in the implementation of a fast DC-type electric vehicle charger, based onQuasi-direct boost- buck rectifier.
- It is to endorse the demand and sales of electric vehicles by providing affordable and easily accessible charging infrastructure.
- Based on fact, the average charge time by EV batteries is nearly 5- 8 hours. Thus, this creates a need for an adequate number ofcharging ports and further raise the demand for fast chargingpoints.

  DC fast stations which consist of these fast chargers, convert AC power to DC within the station, delivering DC power directly to sources such as batteries and also enabling amuch faster charge inavery less time.

1.3. ORGANIZATION OF CHAPTERS

1.3.0 INTRODUCTION

The electric vehicle (EV) charging market is very dynamic. Companies and institutes involved in the research and development of this area are devoted to considerably reduce the EV charging times to be close to the ones spent by users in gas-stations filling the fuel of the internal combustion engines vehicles (ICEVs). Today most EVs can be charged at 50 kW and 400 V following the fast-charging standards "CCS - up to 80kW" and "CHAdeMO – approx. 50kW".However new EVs are designed to withstand higher charging power. Therefore, output power scalability will be a key feature of the EV charging system by usage of power electronics building blocks (PEBB), i.e. the total power can be scalable by paralleling circuits. This leads to manufacturing advantages because a single circuit building block design can satisfy a plurality of business and many charging standards. Connections to medium-voltage (MV) level AC grid becomes economically sensible for EV chargers with power capabilities of several 100 kW than today's most used 380 V .. 480 V grid. In places where the high power charger is installed, local energy storage systems, like battery banks, might become more and more often used in order to mitigate power fluctuations and power quality issues of the AC grid. Local renewable energy generation systems may also be used to buffer the power demand and reduce energy consumption from the grid. In fact, there is a great potential for the use of photovoltaic (PV) energy generation as available surfaces in the roofs of the EV charging station and the nearby buildings can be greater than 1000 m2 . Both batteries and PV systems can also be integrated into the charger itself as proposed.

A suitable bidirectional PEBB circuit is shown for a high power DC- type EV charger with connection to a MV grid through a 50/60 Hz transformer. Advantageously, the battery charger can be fully assembled with half-bridge power modules, which has a large number of manufacturers with several current ratings and blocking voltage available.

By close inspection of the circuit depicted in Fig. 1, one can identify a well-known two-stage power conversion system, i.e. a three-phase AC-DC converter + a DC-DC circuit. The back-end circuit works as a three-channel PWM interleaved DC-DC buck-type converter. This features enhanced loss distribution among semiconductors or better current shared between the parallel circuits than hard paralleling of semiconductors. This results in improvements in the achievable total conduction and switching losses. Additionally, the symmetric PWM interleaved operation will cancel out the high frequency harmonics proportional to the number of employed parallel circuits in both voltages and currents, lowering the rms current across the DC capacitors Cf and Co. This feature can be used to enlarge the current ripple across each phase-leg of the back-endcircuit in order to achieve Zero-Voltage-Switching turn-on of the active switches and low reverse-recovery losses of the antiparallel diodes. The front-end converter comprises a three phase three-wire two-level six-switch voltage source rectifier (2L-VSR), which inherent features low complexity and low cost.Note that with proper voltage conversion rate between the AC grid and EV battery the current stress across the front- and back-end circuits can be similar, which will bring a manufacturing advantage.

In this paper, the front- and back-end circuits are intentionally connected through a DC-link employing capacitors with low energy storage capability, e.g., electrolytic capacitor-less DC-link. This makes the operation of both circuits highly coupled to each other. The DC-link or voltage across the terminals p and n (or upn) in Fig. 1 will follow the rectified envelop of the AC capacitors line-to-line voltages, similarly to what is achieved by a basic three-phase diode-bridge rectifier.

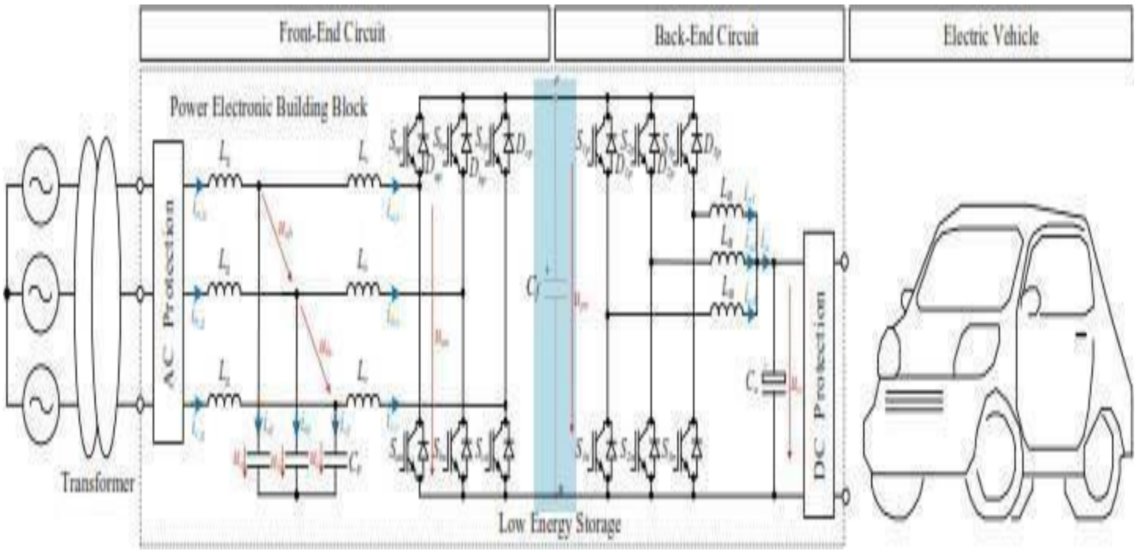

Fig 1.3.1 EV charger concept with back-end power conversion based on the PWM interleaved Buck- converter and front-end circuit based on the two-level bidirectional six-switch voltage source rectifier. Note that the systems are connected to each other through a low energy storage DC-link.

This allows that the rectifier phase-legs operate with a unique discontinuous PWM modulation (DPWM) where they can stop switching during two-thirds of the grid period or 240o, while the AC currents are at their highest values, i.e. only one phase-leg switch during every60o .

Table I : Main modulation functions for EV charger

Sector	k_y	k_x / m_{buck}	m_a	m_b	m_c
I: 0°-60°	u_{bc}^* / u_{ac}^*	u_o^* / u_{ac}^*	1 or 0	k_y	0
II: 60°-120°	u_{ac}^* / u_{bc}^*	u_o^* / u_{bc}^*	k_y	1 or 0	0
III: 120°-180°	u_{ca}^* / u_{ba}^*	u_o^* / u_{ba}^*	0	1 or 0	k_y
IV: 180°-240°	u_{ba}^* / u_{ca}^*	u_o^* / u_{ca}^*	0	k_y	1 or 0
V: 240°-300°	u_{ab}^* / u_{cb}^*	u_o^* / u_{cb}^*	k_y	0	1 or 0
VI: 300°-360°	u_{cb}^* / u_{ab}^*	u_o^* / u_{ab}^*	1 or 0	0	k_y

This operation was previously reported and it yield to the best switching loss reduction in any known DPWM strategy, e.g., the ones described, but at the cost of losing voltage controllability of upn. The back-end circuit becomes necessary for voltage regulation and current limitation for the charging process of the EV batteries. Additionally, high power factor operation can only be achieved if the back-end converter ensures constant power operation. VIENNA-type and a DELTA-SWITCH-type front-end circuit with similar operation have been proposed. The goal of this paper is to analyze the benefits of implementing the DPWN with 240o stop switching interval in the widely used 2L-VSR considering the application of a fast EV battery charger. This paper is organized as follows. The explanation of the structural characteristicsof the presented DC-type EV charger, suitable modulation strategy featuring low switching losses and feedback control method, guaranteeing high-power- factor operation, are presented in Section II and III.

In Section IV, the analytical equations for calculating the power semiconductors and passives stresses with dependency on the AC or DC current amplitudes and the voltage transfer ratio of the converter are given. In Section V, the circuit in Fig. 1 is benchmarked against other suitable solutions for a 50 kW PEBB systemregarding the achievable efficiency when considering the fast charging of a 30kWh Nissan Leaf vehicle from state-of-charging (SoC) 0 % to 90 %.

1.3.1 HISTORY OF POWER ELECTRONICS

Power electronics is the application of solid-state electronics for the control and conversion of electric power. It also refers to a subject of research in electronic and electrical engineering which deals with design, control, computation and integration of nonlinear, time varying energy processing electronic systems with fast dynamics.

The first high power electronic devices were mercury-arc valves. In modern systems the conversion is performed with semiconductor switching devices such as diodes, thyristors and transistors, pioneered by R. D. Middlebrook and others beginning in the 1950s. In contrast to electronic systems concerned with transmission and processing of signals and data, in power electronics substantial amounts of electrical energy are processed.

An AC/DC converter (rectifier) is the most typical power electronics device found in many consumer electronic devices, e.g. television sets, personal computers, battery chargers, etc.

The power range is typically from tens of watts to several hundred watts. In industry a common application is the variable speed drive (VSD) that is used to control an induction motor. The power range of VSDsstart from a few hundred watts and end at tens of megawatts. The power conversion systems can be classified according to the type of the input and output power AC to DC (rectifier), DC to AC (inverter), DC to DC (DC-to- DC converter), AC to AC (AC-to-AC converter)

History

Power electronics started with the development of the mercury arc rectifier. Invented by Peter Cooper Hewitt in 1902, it was used to convert alternating current (AC) into direct current (DC).

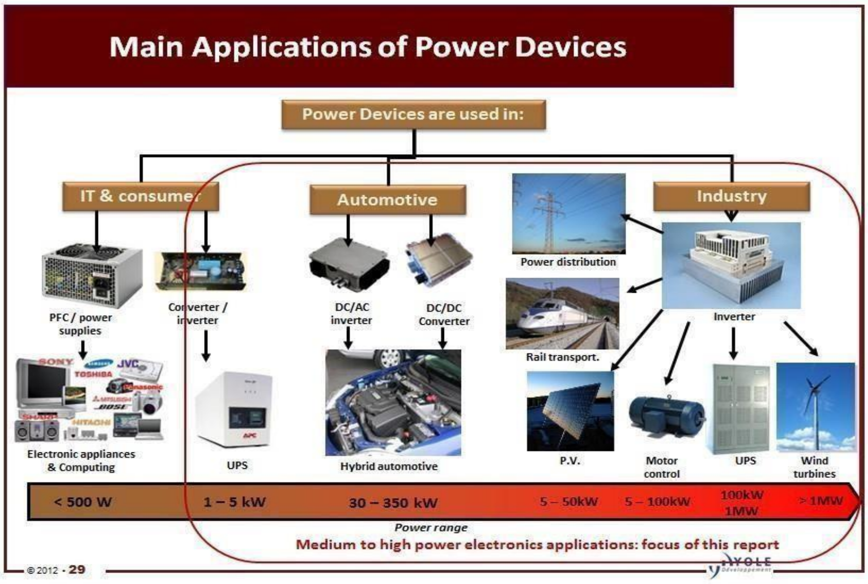

Fig:1.3.2: Applications of Power devices

From the 1920s on, research continued on applying thyratrons and grid-controlled mercury arc valves to power transmission. Uno Lamm developed a valve with grading electrodes making mercury valves usable for high voltage direct current transmission. In 1933 selenium rectifiers were invented.

In 1957 the bipolar point-contact transistor was invented by Walter H. Brattain and John Bardeen under the direction of William Shockley at Bell Telephone Laboratory. In 1958 Shockley's invention of the bipolar junction transistor improved the stability and performance of transistors, and reduced costs. By the 1950s, semiconductor power diodes became available and started replacing vacuum tubes. In 1956 the Silicon Controlled Rectifier (SCR) was introduced by General Electric, greatly increasing the range of power electronic application.

In the 1960s the switching speed of bipolar junction transistors allowed for high frequency DC/DC converters. In 1976 power MOSFET became commercially available. In
1982 the Insulated Gate Bipolar Transistor (IGBT) was introduced.

The capabilities and economy of power electronics system are determined by the active devices that are available. Their characteristics and limitations are a key element in the design of power electronics systems. Formerly, the mercury arc valve, the high-vacuum and gas-filled diode thermionic rectifiers, and triggered devices such as the thyratron and ignitron were widely used in power electronics. As the ratings of solid-state devices improved in both voltage and current-handling capacity, vacuum devices have been nearly entirely replaced by solid-state devices.

Power electronic devices may be used as switches, or as amplifiers. An ideal switch is either open or closed and so dissipates no power; it withstands an applied voltage and passes no current, or passes any amount of current with no voltage drop. Semiconductor devices used as switches can approximate this ideal property and so most power electronic applications rely on switching devices on and off, which makes systems very efficient as very little power is wasted in the switch. By contrast, in the case of the amplifier, the current through the device varies continuously according to a controlled input. The voltage and current at the device terminals follow a load line, and the power dissipation inside the device is large compared with the power delivered to the load.

Several attributes dictate how devices are used. Devices such as diodes conduct when a forward voltage is applied and have no external control of the start of conduction. Power devices such as silicon controlled rectifiers and thyristors (as well as the mercury valve and thyratron) allow control of the start of conduction, but rely on periodic reversal of current flow to turn them off. Devices such as gate turn-off thyristors, BJT and MOSFET transistors provide full switching control and can be turned on or off without regard to the current flow through them. Transistor devices also allow proportional amplification, but this is rarely used for systems rated more than a few hundred watts. The control input characteristics of a device also greatly affect design; sometimes the control input is at a very high voltage with respect to ground and must be driven by an isolated source.

As efficiency is at a premium in a power electronic converter, the losses that a power electronic device generates should be as low as possible. Devices vary in switching speed. Some diodes and thyristors are suited for relatively slow speed and are useful for power frequency switching and control; certain thyristors are useful at a few kilohertz. Devices such as MOSFETS and BJTs can switch at tens of kilohertz up to a few megahertz in power applications, but with decreasing power levels. Vacuum tube devices dominate high power (hundreds of kilowatts) at very high frequency (hundreds or thousands of megahertz) applications. Faster switching devices minimize energy lost in the transitions from on to off and back, but may create problems with radiated electromagnetic interference. Gate drive (or equivalent) circuits must be designed to supply sufficient drive current to achieve the full switching speed possible with a device. A device without sufficient drive to switch rapidly may be destroyed by excess heating.

Practical devices have non-zero voltage drop and dissipate power when on, and take some time to pass through an active region until they reach the "on" or "off" state. These losses are a significant part of the total lost power in a converter.

Power handling and dissipation of devices is also a critical factor in design. Power electronic devices may have to dissipate tens or hundreds of watts of waste heat, even switching as efficiently as possible between conducting and non-conducting states. In the switching mode, the power controlled is much larger than the power dissipated in the switch. The forward voltage drop in the conducting state translates into heat that must be dissipated. High power semiconductors require specialized heat sinks or active cooling systems to manage their junction temperature; exotic semiconductors such as silicon carbide have an advantage over straight silicon in this respect, and germanium, once the main-stay of solid-state electronics is now little used due to its unfavorable high temperature properties.

Semiconductor devices exist with ratings up to a few kilovolts in a single device. Where every high voltage must be controlled, multiple devices must be used in series, with networks to equalize voltage across all devices. Again, switching speed is a critical factor since the slowest -switching device will have to withstand a disproportionate share of the overall voltage. Mercury valves were once available with ratings to 100 kV in a single unit, simplifying their application in HVDC systems.

The current rating of a semiconductor device is limited by the heat generated within the dies and the heat developed in the resistance of the interconnecting leads. Semiconductor devices must be designed so that current is evenly distributed within the device across its internal junctions (or channels); once a "hot spot" develops, breakdown effects can rapidly destroy the device. Certain SCRs are available with current ratings to 3000 amperes in a single unit.

DC to AC converters produce an AC output waveform from a DC source. Applications include adjustable speed drives (ASD), uninterruptable power supplies (UPS), active filters, Flexible AC transmission systems (FACTS), voltage compensators, and photovoltaic generators. Topologies for these converters can be separated into two distinct categories: voltage source inverters and current source inverters. Voltage source inverters (VSIs) are named so because the independently controlled output is a voltage waveform. Similarly, current source

inverters (CSIs) are distinct in that the controlled AC output is a current waveform.

Being static power converters, the DC to AC power conversion is the result of power switching devices, which are commonly fully controllable semiconductor power switches. The output waveforms are therefore made up of discrete values, producing fast transitions rather than smooth ones. The ability to produce near sinusoidal waveforms around the fundamental frequency is dictated by the modulation technique controlling when, and for how long, the power valves are on and off. Common modulation techniquesinclude the carrier-based technique, or pulse width modulation, space- vector technique, and the selective-harmonic technique.

Voltage source inverters have practical uses in both single-phase and three-phase applications. Single-phase VSIs utilize half-bridge and full- bridge configurations, and are widely used for power supplies, single-phase UPSs, and elaborate high-power topologies when used in multicell configurations. Three-phase VSIs are used in applications that require sinusoidal voltage waveforms, such as ASDs, UPSs, and some types of FACTS devices such as the STATCOM. They are also used in applications where arbitrary voltages are required as in the case of active filters and voltage compensators.

Current source inverters are used to produce an AC output current from a DC current supply. This type of inverter is practical for three-phase applications in which high-quality voltage waveforms are required.

A relatively new class of inverters, called multilevel inverters, has gained widespread interest. Normal operation of CSIs and VSIs can be classified as two-level inverters, due to the fact that power switches connect to either the positive or to the negative DC bus. If more than two voltage levels were available to the inverter output terminals, the AC output could better approximate a sine wave. It is for this reason that multilevel inverters,although more complex and costly, offer higher performance.

Each inverter type differs in the DC links used, and in whether or not they require freewheeling diodes. Either can be made to operate in square- wave or pulse-width modulation (PWM) mode, depending on its intended usage. Square-wave mode offers simplicity, while PWM can be implemented several different ways and produces higher quality waveforms.

Voltage Source Inverters (VSI) feed the output inverter section from an approximately constant-voltage source.

The desired quality of the current output waveform determines which modulation technique needs to be selected for a given application. The output of a VSI is composed of discrete values. In order to obtain a smooth current waveform, the loads need to be inductive at the select harmonic frequencies. Without some sort of inductive filtering between the source and load, a capacitive load will cause the load to receive a choppy current waveform, with large and frequent current spikes.

The single-phase voltage source half-bridge inverters, are meant for lower voltage applications and are commonly used in power supplies.

Low-order current harmonics get injected back to the source voltage by the operation of the inverter. This means that two large capacitors are needed for filtering purposes in this design. As Figure 2 illustrates, only one switch can be on at time in each leg of the inverter. If both switches in aleg were on at the same time, the DC source will be shorted out.

Inverters can use several modulation techniques to control their switching schemes. The carrier-based PWM technique compares the AC output waveform, v_c, to a carrier voltage signal, v_Δ. When v_c is greater than v_Δ, S+ is on, and when v_c is less than v_Δ, S- is on. When the AC output is at frequency fc with its amplitude at v_c, and the triangular carrier signal is at frequency f_Δ with its amplitude at v_Δ, the PWM becomes a special sinusoidal case of the carrier based PWM. This case is dubbed sinusoidal pulse-width modulation (SPWM).For this, the modulation index, or amplitude-modulation ratio, is defined as $\mathbf{m_a = v_c / v_\Delta}$.

The normalized carrier frequency, or frequency-modulation ratio, is calculated using the equation $\mathbf{m_f = f_\Delta / f_c}$.

If the over-modulation region, ma, exceeds one, a higher fundamental AC output voltage will be observed, but at the cost of saturation. For SPWM, the harmonics of the output waveform are at well-defined frequencies and amplitudes. This simplifies the design of the filtering components needed for the low-order current harmonic injection from the operation of the inverter. The maximum output amplitude in this mode of operation is half of the source voltage. If the maximum output amplitude, m_a, exceeds 3.25, the output waveform of the inverter becomes a square wave.

As was true for PWM, both switches in a leg for square wave modulation cannot be turned on at the same time, as this would cause a short across the voltage source. The switching scheme requires that both S+ and S- be on for a half cycle of the AC output period. The fundamental AC output amplitude is equal to $\mathbf{v_{o1} = v_{aN}}$.

Therefore, the AC output voltage is not controlled by the inverter, but rather by the magnitude of the DC input voltage of the inverter.

Using selective harmonic elimination (SHE) as a modulationtechnique allows the switching of the inverter to selectively eliminate intrinsic harmonics. The fundamental component of the AC output voltage can also be adjusted within a desirable range. Since the AC output voltage obtained from this modulation technique has odd half and odd quarter wave symmetry, even harmonics do not exist. Any undesirable odd (N-1) intrinsic harmonics from the output waveform can be eliminated.

DC Link Converters, also referred to as AC/DC/AC converters, convert an AC input to an AC output with the use of a DC link in the middle. Meaning that the power in the converter is converted to DC from AC with the use of a rectifier, and then it is converted back to AC from DC with the use of an inverter. The end result is an output with a lower voltage and variable (higher or lower) frequency. Due to their wide area of application, the AC/DC/AC converters are the most common contemporary solution. Other advantages to AC/DC/AC converters is that they are stable inoverload and no-load conditions, as well as they can be disengaged from aload without damage.

Hybrid matrix converters are relatively new for AC/AC converters. These converters combine the AC/DC/AC design with the matrix converter design. Multiple types of hybrid converters have been developed in this new category, an example being a converter that uses uni-directional switches and two converter stages without the dc-link; without the capacitors or inductors needed for a dc-link, the weight and size of the converter is reduced. Two sub- categories exist from the hybrid converters, named hybrid direct matrix converter (HDMC) and hybrid indirect matrix converter (HIMC). HDMC convert the voltage and current in one stage, while the HIMC utilizes separate stages, like the AC/DC/AC converter, but without the use of an intermediate storage element.

AC Voltage Controller: Lighting Control; Domestic and Industrial Heating; Speed Control of Fan, Pump or Hoist Drives, Soft Starting of Induction Motors, Static AC Switches (Temperature Control, Transformer Tap Changing, etc.)

Cycloconverter: High-Power Low-Speed Reversible AC Motor Drives; Constant Frequency Power Supply with Variable Input Frequency; Controllable VAR Generators for Power Factor Correction; AC System Interties Linking Two Independent Power Systems.

Matrix Converter: Currently the application of matrix converters are limited due to non- availability of bilateral monolithic switches capable of operating at high frequency, complex control law implementation, commutation and other reasons. With these developments, matrix converters could replace cycloconverters in many areas. DC Link: Can be used for individual or multiple load applications of machine building and construction.

Simulations of power electronic systems

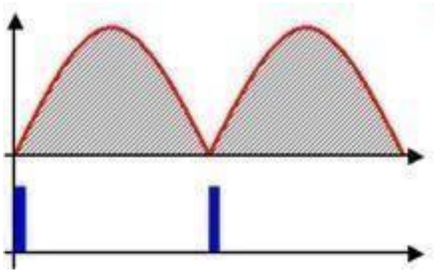

Fig:1.3.1: Output voltage of a full-wave rectifier with controlled thyristors.

Power electronic circuits are simulated using computersimulation programs such as PSIM and MATLAB/ Simulink. Circuits are simulated before they are produced to test how the circuits respond under certain conditions. Also, creating a simulation is both cheaper and faster than creating a prototype to use for testing.

Applications of power electronics range in size from a switched mode power supply in an AC adapter, battery chargers, fluorescent lamp ballasts, through variable frequency drives and DC motor drives used to operate pumps, fans, and manufacturing machinery, up to gigawatt-scale high voltage direct current power transmission systems used to interconnect electrical grids. Power electronic systems are found in virtually every electronic device.

For example:

DC/DC converters are used in most mobile devices (mobile phones, PDA etc.) to maintain the voltage at a fixed value whatever the voltage level of the battery is. These converters are also used for electronic isolation and power factor correction.AC/DC converters (rectifiers) are used every time an electronic device is connected to the mains (computer, television etc.). These may simply change AC to DC or can also change the voltage level aspart of their operation.

AC/AC converters are used to change either the voltage level or the frequency(international power adapters, light dimmer). In power distribution networks AC/AC converters may be used to exchange power between utility frequency 50 Hz and 60 Hz power grid.

DC/AC converters (inverters) are used primarily in UPS or renewable energy systems or emergency lighting systems. Mains power charges the DC battery. If the mains fail, an inverter produces AC electricity at mains voltage from the DC battery.

Motor drives are found in pumps, blowers, and mill drives for textile, paper, cement and other such facilities. Drives may be used for power conversion and for motion control.[19] For AC motors, applications includevariable-frequency drives, motor soft starters and excitation systems.[20] In hybrid electric vehicles (HEVs), power electronics are used in two formats: series hybrid and parallel hybrid. The difference between a serieshybrid and a parallel hybrid is the relationship of the electric motor to the internal combustion engine (ICE). Devices used in electric vehicles consist mostly of dc/dc converters for battery charging and dc/ac converters to power the propulsion motor. Electric trains use power electronic devices to obtain power, as well as for vector control using pulse width modulation (PWM) rectifiers. The trains obtain their power from powerlines. Another new usage for power electronics is in elevator systems.

These systems may use thyristors, inverters, permanent magnet motors, or various hybrid systems that incorporate PWM systems and standard motors.

In general, inverters are utilized in applications requiring direct conversion of electrical energy from DC to AC or indirect conversion from AC to AC. Dc to AC conversion is useful for many fields, including power conditioning, harmonic compensation, motor drives, and renewable energy grid-integration.

In power systems it is often desired to eliminate harmonic content found in line currents. VSIs can be used as active power filters to provide this compensation. Based on measured line currents and voltages, a control system determines reference current signals for each phase.

This is fed back through an outer loop and subtracted from actual current signals to create current signals for an inner loop to the inverter. These signals then cause the inverter to generate output currents that compensate for the harmonic content. This configuration requires no real power consumption, as it is fully fed by the line; the DC link is simply a capacitor that is kept at a constant voltage by the control system. In this configuration, output currents are in phase with line voltages to produce a unity power factor. Conversely, VAR compensation is possible in a similar configuration where output currents lead line voltages to improve the overall power are utilized. In a standby system, an inverter is brought online when the normally supplying grid is interrupted. Power is instantaneously drawn from onsite batteries and converted into usable AC voltage by the VSI, until grid power is restored, or until backup generators are brought online. In an online UPS system, a rectifier-DC-link-inverter is used to protect the load from transients and harmonic content. A battery in parallel with the DC-link is kept fully charged by the output in case the grid power is interrupted, while the output of the inverter is fed through a low pass filter to the load. High power quality and independence from disturbances is achieved.

Various AC motor drives have been developed for speed, torque, and position control of AC motors. These drives can be categorized as low- performance or as high-performance, based on whether they are scalar- controlled or vector-controlled, respectively. In scalar-controlled drives, fundamental stator current, or voltage frequency and amplitude, are the only controllable quantities. Therefore, these drives are employed in applicationswhere high-quality control is not required, such as fans and compressors. On the other hand, vector-controlled drives allow for instantaneous current and voltage values to be controlled continuously. This high performance is necessary for applications such as elevators and electric cars.

Inverters are also vital to many renewable energy applications. In photovoltaic purposes, the inverter, which is usually a PWM VSI, gets fed by the DC electrical energy output of a photovoltaic module or array. The inverter then converts this into an AC voltage to be interfaced with either a load or the utility grid. Inverters may also be employed in other renewable systems, such as wind turbines.

In these applications, the turbine speed usually varies causing changes in voltage frequency and sometimes in the magnitude. In this case, the generated voltage can be rectified and then inverted to stabilize frequency and magnitude.

A smart grid is a modernized electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. Electric power generated by wind turbines and hydroelectric turbines by using induction generators can cause variances in the frequency at which power is generated. Power electronic devices are utilized in these systems to convert the generated ac voltages into high -voltage direct current (HVDC). The HVDC power can be more easily converted into three phase power that is coherent with the power associated to the existing power grid. Through these devices, the power systems optimum torque is obtained either through a gearbox or direct drive technologies that can reduce the size of the power electronics device. Electric power can be generated through photovoltaic cells by using power electronic devices. The produced power is usually then transformed by inverters. Inverters are divided into three different types: central, module- integrated and string. Central converters can be connected either in parallel or in series on the DC side of the system. converters are connected in series on either the DC or AC side. Normally several modules are used within a photovoltaic system, since the system requires these converters on both DC and AC terminals. A string converter is used in a system that utilizes photovoltaic cells that are facing different directions. It is used to convert the power generated to each string, or line, in which the photovoltaic cells are interacting. Power electronics can be used to help utilities adapt to the rapid increase in distributed residential/commercial solar power generation. Germany and parts of Hawaii, California and New Jersey require costly studies to be conducted before approving new solar installations. Relatively small-scale ground- or pole- mounted devices create the potential for a distributed control infrastructure to monitor and manage the flow of power. Traditional electromechanical systems, such as capacitor banks or voltage regulators at substations, can take minutes to adjust voltage and can be distant from the solar installations where the problems originate. If voltage on a neighborhood circuit goes too high, it can endanger utility crews and cause damage to both utility and customer equipment. Further, spiking demand for grid power. Smart grid- based regulators are more controllable than far more numerous consumer devices.

1.3.2 PROPOSED VOLTAGE SOURCE INVERTER

Because thyristors can only be turned on (not off) by control action, and rely on the external AC system to effect the turn-off process, the control system only has one degree of freedom – when to turn on the thyristor. This limits the usefulness of HVDC in some circumstances because it means that the AC system to which the HVDC converter is connected must always contain synchronous machines in order to provide the commutating voltage

– the HVDC converter cannot feed power into a passive system. With some other types of semiconductor device such as the insulated-gate bipolar transistor (IGBT), both turn-on and turn-off can be controlled, giving a second degree of freedom. As a result, IGBTs can be used to make self- commutated converters. In such converters, the polarity of DC voltage is usually fixed and the DC voltage, being smoothed by a large capacitance, can be considered constant. For this reason, an HVDC converter using IGBTs is usually referred to as a voltage-source converter (or voltage- sourced converter). The additional controllability gives many advantages, notably the ability to switch the IGBTs on and off many times per cycle in order to improve the harmonic performance, and the fact that (being self- commutated) the converter no longer relieson synchronous machines in the AC system for its operation. A voltage-sourced converter can therefore feed power to an AC network consisting only of passive loads, something which is impossible with LCC HVDC. Voltage-source converters are also considerably more compact than line-commutated converters (mainly because much less harmonic filtering is needed) and are preferable to line- commutated converters in locations where space is at a premium, for example on offshore platforms.

In contrast to line-commutated HVDC converters, voltage-source converters maintain a constant polarity of DC voltage and power reversal is achieved instead by reversing the direction of current. This makes voltage-source converters much easier to connect into a Multi- terminal HVDC system or “DC Grid”. HVDC systems based on voltage-source converters normally use the six-pulse connection because the converter produces much less harmonic distortion than a comparable LCC and the twelve-pulse connection is unnecessary. This simplifies the construction of the converter transformer. However, there are several different configurations of voltage- source converter and research is continuing to take place into new alternatives.

Two-level converter

From the very first VSC-HVDC scheme installed (the Hellsjön experimental link commissioned in Sweden in 1997[7]) until 2012, most of the VSC HVDC systems built were based on the two level converter. The two-level converter is the simplest type of three-phase voltage-source converter and can be thought of asa six pulse bridge in which the thyristors have been replaced by IGBTs with inverse- parallel diodes, and the DC smoothing reactors have beenreplaced by DC smoothing capacitors. Such converters derive their name from the fact that the voltage at the AC output of each phase is switched between two discrete voltage levels, corresponding to the electrical potentials of the positive and negative DCterminals. When the upper of the two valves in a phase is turned on, the AC output terminal is connected to the positive DC terminal, resulting inan output voltage of +½ U_d with respect to the midpoint potential of the converter.

Conversely when the lower valve in a phase is turned on, the ACoutput terminalis connected to the negative DC terminal, resulting in an outputvoltage of -

½U_d. The two valves corresponding to one phase must never be turned on simultaneously, as thiswould result in an uncontrolled discharge of theDC capacitor, risking severe damage to the converter equipment.

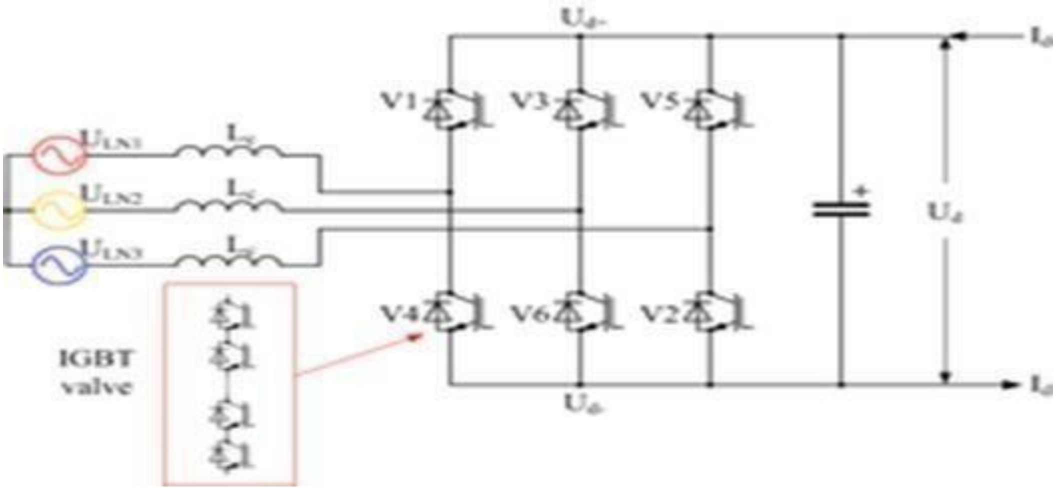

Fig 1.3.3: Three-phase, two-level Voltage-source converter

The simplest (and also, the highest-amplitude) waveform that can be produced by a two-level converter is a square wave; however this would produce unacceptable levels of harmonic distortion, so some form of Pulse- width modulation (PWM) is always used to improve the harmonic distortion of the converter. As a result of the PWM, the IGBTs are switched on and off many times (typically 20) in each mains cycle. This results in high switching losses in the IGBTs and reduces the overall transmission efficiency. Several different PWM strategies are possible for HVDC but in all cases the efficiency of the two-level converter is significantly poorer than that of a LCC because of the higher switching losses. A typical LCC HVDC converter station has power losses of around 0.7% at full load (per end, excluding the HVDC lineor cable) while with 2-level voltage-source converters the equivalent figure is 2-3% per end. Another disadvantage of the two-level converter is that, in order to achieve the very high operating voltages required for an HVDC scheme, several hundred IGBTs have to be connected in series and switched simultaneously in each valve. This requires specialized types of IGBT with sophisticated gate drive circuits, and can lead to very high levels of electromagnetic interference. In an attempt to improve on the poor harmonic performance of the two-level converter, some HVDC systems have been built with three level converters.

Three-level converters can synthesize three (instead of only two) discrete voltage levels at the AC terminalof each phase: +½ U_d, 0 and -½ U_d. A common type of three-level converter is the diode- clamped (or neutral-point- clamped) converter, where each phase contains four IGBT valves, each rated at half of the DC line to line voltage, along with two clamping diode valves. The DC capacitor is split into two series-connected branches, with the clamping diode valves connected between the capacitor midpoint and the one-quarter and three-quarter points on each phase.

To obtain a positive output voltage (+½ U_d) the top two IGBT valves are turned on, to obtain a negative output voltage (-½ U_d) the bottom two IGBT valvesare turned on and to obtain zero output voltage the middle two IGBT valves areturned on. In this latter state, the two clamping diode valves complete the current path through the phase.

In a refinement of the diode-clamped converter, the so-called active neutral- point clamped converter, the clamping diode valves are replaced by IGBT valves, giving additional controllability. Such converters were used on the Murraylink project in Australia and the Cross Sound Cable link in the United States. However, the modest improvement in harmonic performance came at a considerable price in terms of increased complexity, and the design proved to be difficult to scale up to DC voltages higher than the ±150 kV used on those two projects.

Another type of three-level converter, used in some adjustable-speed drives but never in HVDC, replaces the clamping diode valves by a separate, isolated, flying capacitor connected between the one-quarter and three-quarter points.

The operating principle is similar to that of the diode-clamped converter. Both the diode-clamped and flying capacitor variants of three-level converter can be extended to higher numbers of output levels (for example, five), but the complexity of the circuit increases disproportionately and such circuits have not been considered practical for HVDC applications.

Like the two-level converter and the six-pulse line-commutated converter, a MMC consists of six valves, each connecting one AC terminal to one DC terminal. However, where each valve of the two-level converter is effectively a high-voltage controlled switch consisting of a large number of IGBTs connected in series, each valve of a MMC is a separate controllable voltage source in its own right. Each MMC valve consists of anumber of independent converter submodules,

each containing its own storage capacitor. In the most common form of the circuit, the half-bridge variant, each submodule contains two IGBTs connected in series across the capacitor, with the midpoint connection and one of the two capacitor terminals brought out as external connections.

Depending on which of the two IGBTs in each submodule is turned on, the capacitor is either bypassed or connected into the circuit. Each submodule therefore acts as an independent two-level converter generating a voltage of either 0 or U_{sm} (where U_{sm} is the submodule capacitor voltage). With a suitable number of submodules connected in series, the valve can synthesize a stepped voltage waveform that approximates very closely to a sine -wave and contains very low levels of harmonic distortion.

The MMC differs from other types of converters in that current flows continuously in all six valves of the converter throughout the mains- frequency cycle. As a result, concepts such as "on- state" and "off-state" have no meaning in the MMC. The direct current splits equally into the three phases and the alternating current splits equally into the upper and lower valve of each phase. The current in each valve is therefore related to the direct current I_d and alternating current I_{ac} as follows:

Upper valve: $$I_{\mathrm{v}} = \frac{I_{\mathrm{d}}}{3} + \frac{I_{\mathrm{ac}}}{2}$$

Lower valve: $$I_{\mathrm{v}} = \frac{I_{\mathrm{d}}}{3} - \frac{I_{\mathrm{ac}}}{2}$$

A typical MMC for an HVDC application contains around 300 submodules connected in series in each valve and is therefore equivalent to a 301-level converter. Consequently, the harmonic performance is excellent and usuallyno filters are needed. A further advantage of the MMC is that PWM is not necessary, with the result that the power losses are much lower than those of the 2-level converter, ataround 1% per end.[36] Finally, because direct series-connection of IGBTs is not necessary, the IGBT gate drives do not need to be as sophisticated as those for a 2-level converter.

The MMC has two principal disadvantages. Firstly, the control is much more complex than that of a 2-level converter. Balancing the voltages of each of the submodule capacitors is a significant challenge and requires considerable computing power and high-speed communications between the central control unitand the valve.

Secondly, the submodule capacitors themselves are large and bulky. A MMC is considerably larger than a comparable-rated 2-level converter, although this may be offset by the saving in space from not requiring filters.

As of 2012 the largest-capacity MMC HVDC system in operation is still the 400 MW Trans Bay Cable scheme but many larger schemes are under construction, including an underground cable interconnection from France to Spain consisting of two 1000 MW links in parallel at a voltage of ±320 kV.

A variant of the MMC, proposed by one manufacturer, involves connecting multiple IGBTs in series in each of the two switches that make up the submodule. This gives an output voltage waveform with fewer, larger, steps than the conventional MMC arrangement. This arrangement is referred to as the Cascaded Two Level (CTL) converter. Functionally it is exactly equivalentto the conventional half-bridge MMC in every respect except for the harmonic performance, which is slightly inferior – although still claimed to be good enough to avoid the need for filtering in most instances. Another alternative replaces the half bridge MMC submodule described above, with a full bridge sub module containing four IGBTs in an H bridge arrangement, instead of two. The full-bridge variant of MMC allows the submodule capacitor to be inserted into the circuit in either polarity. This confers additional flexibility in controlling the converter and allows the converterto block the fault current which arises from a short-circuit between the positive and negative DC terminals (something which is impossible with anyof the preceding types of VSC). Furthermore, it allows the DC voltage to beof either polarity (like a LCC HVDC scheme), giving rise to the possibility of hybrid LCC and VSC HVDC systems. However, the full-bridge arrangement requires twice as many IGBTs and has higher power losses than the equivalent half-bridge arrangement.

2. LITERATURE SURVEY

1. **Dale Hall and Nic Lutsey (2017)** have worked and explained on "Emerging best practices for electric vehicle charging infrastructure". Electric vehicles offer great potential to dramatically reduce local air pollution, greenhouse gas emissions and resulting climate change impacts, and oil use from the transport sector. With electric vehicle costs steadily falling, the transition continues to become more feasible. This potential is enabled and made compelling by the ubiquity of electricity and the growing availability of low-carbon, renewable energy sources. Yet there are unanswered questions about the deployment of electric vehicle charging infrastructure and the associated policy that will need to be addressed to help pave the way for electrification. This report provides a global assessment of charging infrastructure deployment practices, challenges, and emerging best practices in major electric vehicle markets, with an emphasis on public charging facilities. Although most early adopters charge their vehicles at home, public charging is an important part of the electric vehicle ecosystem. We analyze public charging infrastructure in the top electric vehicle markets globally, including a statistical analysis of the relationship between public charging and electricvehicle uptake. Our analysis is at the metropolitan-area level to better discern local infrastructure variation, practices, and circumstances**.**

2. **G. R. Chandra Mouli, M. Kefayati, R. Baldick, and P. Bauer(2018)** have elucidated on "Integrated pv charging of ev fleet based on dynamic prices, v2g and offer of reserves," Workplace charging of electric vehicles(EVs) from photovoltaic (PV) panels installed on an office building can provide several benefits. This includes the local production and use of PV energy for charging the EV and making use of dynamic tariffs from the grid to schedule the energy exchange with the grid. The long parking time at the workplace provides the chance for the EV to support the grid via vehicle-to-grid technology, the use of a single EV charger for charging several EVs by multiplexing and the offer of ancillary services to the grid for up and down regulation. Further, distribution network constraints can be considered to limit the power and prevent the overloading of the grid. A single mixed integer linear programming (MILP) formulation that considers all the above applications has been proposed in this paper for a charging a fleet of EVs from PV. The MILP is implemented as a receding - horizon model predictive energy management system. Numerical simulations based on market and PV data in Austin, TX, USA, have shown 32% to 651% reduction in the net cost of EV charging from PV when compared to immediate and average rate charging policies.

3. **M. Vasiladiotis and A. Rufer(2015)** have worked and explained on "A modular multiport power electronic transformer with integrated split battery energy storage for versatile ultrafast ev charging stations,". In this a power converter architecture for the implementation of an ultrafast charging station for electric vehicles (EVs). The versatile converter topology is based on the concept of the power electronic transformer. For the direct transformerless coupling to the medium-voltage grid, a cascaded H-bridge (CHB) converter is utilized. On the level of each submodule, integrated split battery energy storage elements play the role of power buffers, reducing thus the influence of the charging station on the distribution grid. The power interface between the stationary split storage stage and the EV batteries is performed through the use of parallel- connected dual-half-bridge dc/dc converters, shifting the isolation requirements to the medium-frequency range. By choosing several different submodule configurations for the parallel connection, a multiport output concept is achieved, implying the ability to charge several EVs simultaneously without the use of additional high-power chargers. All possible charging station operating modes among with the designed necessary control functions are analyzed. The state-of-charge self- balancing mode of the delta-connected CHB converter is also introduced. Finally, the development of a downscaled laboratory prototype is described, and preliminary experimental results are provided.

4. **D. Menzi, D. Bortis, and J. W. Kolar(2018)**, have described on "Three- phase two-phaseclamped boost-buck unity power factor rectifier employing novel variable dc link voltage input current control," Proc. of 2nd IEEE International Power Electronics and Application Conference and Exposition (PEAC) Nov. 4-7, 2018. Battery chargers supplied from the three-phase mains are typically realized as two-stage systems consisting ofa three-phase PFC boost-type rectifier with an output DC link capacitor followed by a DC/DC buck converter if boost and buck functionality is required. In this paper, a new modulation scheme for this topology is presented, where always only one out of three rectifier half-bridges is pulse width modulated, while the remaining two phases are clamped and therefore a higher efficiency is achieved. This modulation concept with a minimum number of active half-bridges, denoted as 1/3 rectifier, becomes possible if in contrast to other modulation schemes the intermediate DC link voltage is varied in a six-pulse voltage fashion, while still sinusoidal grid currents in phase with their corresponding phase voltages and a constant battery output voltage are obtained. In this paper, a detailed description of the novel 1/3 rectifier's operating principle and the corresponding control structure are presented and the proper closed loop operation is verified by means of a circuit simulation. Finally, the performance gain of the 1/3 rectifier control scheme compared to conventional modulation schemes is evaluated by means of a virtual prototype system.

5. **T. B. Soeiro, and P. Bauer(2019),** have elucidated on “Three-phase unidirectional quasi-singlestage delta-switch rectifier + dc-dc buck converter,” in Proc. of 39th Ann. Conf. of the Ind.Electr. Soc., (IECON), 2019. his work presents a unidirectional three-phase PFC rectifier well- suited for application targeting high efficiency and/or high power density, such as DC-type electric vehicle chargers. Herein, a quasi-single stage AC- DC converter is proposed where a conventional three-phase DELTA- switch voltage source rectifier is cascaded to a PWM interleaved buck-type DC-DC converter by means of a low energy storage DC-link. The characteristics of the presented power electronics, including the principles of operation, modulation strategy, suitable PWM control scheme, and dimensioning equations are described in this paper. The presented circuit is benchmarked against other solutions for a 50 kW power capability battery charger. The results show a superior power efficiency of theproposed system.

6. **L. K. Ries, T. B. Soeiro, M. S. Ortmann and M. L. Heldwein (2017)** have demonstrated on "Analysis of carrier-based pwm patterns for a three- phase five-level bidirectional buck + boost-type rectifier”, This paper analyzes three different carrier-based modulation patterns applied to a three-phase high-power-factor-corrected (PFC) five-level buck+boost-type converter acting as an interface between dc distribution systems and an ac grid. The modulation is analyzed employing the space vectors theory so that the achievable performance is demonstrated. The main advantage of the analyzed modulation strategy is its simplicity, which makes it suitable for digital signal controller (DSC) implementations. This seems straightforward for voltage source converters, but is a challenge for current-multilevel converters that typically employ field-programmable gate array devices to achieve better harmonic distortion performance. This is due to modern power electronics DSCs being typically designed for other converter topologies. The power converter is constructed with two phase-shift-modulated six-switch buck-type PFC converters, paralleled by interphase transformers, and an inverting circuit. The system features: bidirectional current carrying capability; relatively low parts count; high utilization of the semiconductors; and low current and voltage ripple at its terminals. The principle of operation, detailed description, analysis of the modulation strategy, and dimensioning equations for three different power circuit realizations are described in this paper assuming the analyzed modulation patterns. The feasibility of the presented converter is demonstrated by means of a constructed hardware prototype.

7. **J. C. Spoelstra and J. Helmus(2016),** have elaborated on "Public charging infrastructure use in the Netherlands: a rollout-strategy assessment,". Over recent years numbers of public charging points in the Netherlands have known a strong growth in order to facilitate charging for electric vehicles of which the sales continue to increase as well. These charging points were either installed following a request by electrical drivers with the need for charging infrastructure in the vicinity of their home, the demand-driven rollout, or by local and regional governments with the need to facilitate electric vehicle charging near public facilities and strategic locations, the strategic rollout. With a new roll-out wave coming up in the Netherlands, understanding how these charging infrastructure characteristics influence the use of the infrastructure is essential. This paper provides a detailed analysis of the use of these 'demand-driven' and 'strategic' public charging points and the implications of these rollout-strategies by analysing charging transaction data from 788.336 transactions on 1.913 public charging points between January 2012 and February 2015. Results show that demand-driven charging points show higher energy transfers and longer connection durations, and that strategic charging points generally have a higher number of unique users and have a large share of rarely used charging points. With regard to charging profiles, most demand-driven charging points, and well-used strategic charging points show high peak loads during working days and especially demand-driven charging points show a high share of nighttime chargers. These results provide insights in the use of public EV charging points which could contribute to the development of new rollout-strategies.
8. **A. Kuperman, U. Levy, J. Goren, A. Zafransky and A. Savernin(2013)** have discussed on "Battery charger for electric vehicle traction battery switch station," IEEE Trans. Ind. Electr., 2013. This paper presents the functionality of a commercialized fast charger for a lithium-ion electric vehicle propulsion battery. The device is intended to operate in a battery switch station, allowing an up-to 1-h recharge of a 25-kWh depleted battery, removed from a vehicle. The charger is designed as a dual-stage- controlled ac/dc converter. The input stage consists of a three-phase full- bridge diode rectifier combined with a reduced rating shunt active power filter. The input stage creates an uncontrolled pulsating dc bus while complying with the grid codes by regulating the total harmonic distortion and power factor according to the predetermined permissible limits. The output stage is formed by six interleaved groups of two parallel dc-dc converters, fed by the uncontrolled dc bus and performing the battery charging process. The charger is capable of operating in any of the three typical charging modes: constant current, constant voltage, and constant power. Extended simulation and experimental results are shown to demonstrate the functionality of the device.

9. **A. Kuperman, U. Levy, J. Goren, A. Zafransky and A. Savernin(2013)** have discussed on "Battery charger for electric vehicle traction battery switch station," IEEE Trans. Ind. Electr., 2013. This paper presents the functionality of a commercialized fast charger for a lithium-ion electric vehicle propulsion battery. The device is intended to operate in a battery switch station, allowing an up-to 1-h recharge of a 25-kWh depleted battery, removed from a vehicle. The charger is designed as a dual-stage- controlled ac/dc converter. The input stage consists of a three-phase full- bridge diode rectifier combined with a reduced rating shunt active power filter. The input stage creates an uncontrolled pulsating dc bus while complying with the grid codes by regulating the total harmonic distortion and power factor according to the predetermined permissible limits. The output stage is formed by six interleaved groups of two parallel dc-dc converters, fed by the uncontrolled dc bus and performing the battery charging process. The charger is capable of operating in any of the three typical charging modes: constant current, constant voltage, and constant power. Extended simulation and experimental results are shown to demonstrate the functionality of the device.

10. **T. B. Soeiro, G. J. M. de Sousa, M. S. Ortmann and M. L. Heldwein(2014),** have worked and explained on "Three-phase unidirectional buck-type third harmonic Injection Rectifier Concepts," in Proc. of 29th Ann. IEEE Appl. Power Electron. Conf. and Exp. (APEC), 2014. his work introduces three-phase unidirectional buck-type unity power factor rectifiers. The proposed rectifiers are assembled by incorporating auxiliary circuit branches into standard three-phase buck- type PFC topologies, each comprising an active switch and three diodes. These circuits can operate as active third harmonic current injection PFC systems. The characteristics of the buck-type converters, including their operation principle, appropriate modulation strategy and control structure, are described. The proposed converters are compared to state-of-the-art buck-type rectifiers. According to the results, the proposed rectifiers can achieve the highest efficiency and thus are the topology of choice for a 2.5 kW three-phase buck-type PFC rectifier.

3. PROJECT DESIGN

3.0 OVERVIEW OF THE DESIGN

PEBB circuit is shown for a high power DC-type EV charger with connection to a MV grid through a 50/60 Hz transformer. Advantageously, the battery charger can be fully assembled with half-bridge power modules, which has a large number of manufacturers with several current ratings and blocking voltage available. By close inspection of the circuit depicted in Fig. 1, one can identify a well-known two-stage power conversion system, i.e. a three-phase AC-DC converter + a DC-DC circuit. The back-end circuit works as a three-channel PWM interleaved DC-DC buck-type converter. This features enhanced loss distribution among semiconductors or better current shared between the parallel circuits than hard paralleling of semiconductors. This results in improvements in the achievable total conduction and switching losses. Additionally, the symmetric PWM interleaved operation will cancel out the high frequency harmonics proportional to the number of employed parallel circuits in both voltages and currents, lowering the rms current across the DC capacitors Cf and Co. This feature can be used to enlarge the current ripple across each phase -leg of the back- end circuit in order to achieve Zero-Voltage-Switching turn-on of the active switches and low reverse-recovery losses of the antiparallel diodes. The front-end converter comprises a three phase three-wire two-level six-switch voltage sourcerectifier (2L-VSR), which inherent features low complexity and low cost. Note that with proper voltage conversion rate between the AC grid and EV battery thecurrent stress across the front- and back-end circuits can be similar, which will bring a manufacturing advantage. In this paper, the front- and back- end circuits are intentionally connected through a DC-link employing capacitors with low energy storage capability, e.g. electrolytic capacitor-less DC-link. This makes the operation of both circuits highly coupled to each other. The DC-link or voltage across the terminals p and n (or upn) in Fig. 1 will follow the rectified envelop of the AC capacitors line-to-line voltages, similarly to what is achieved by a basic three-phase diode-bridge rectifier.

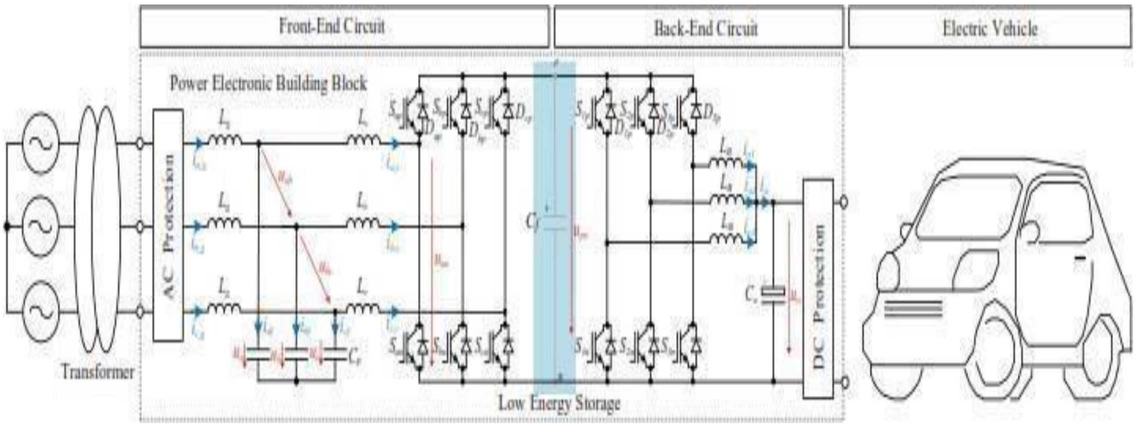

Fig 3.1: EV charger concept with back-end power conversion based on the PWM interleaved Buck-converter and front-end circuit based on the two-level bidirectional six-switch voltage source rectifier.

Note that the systems are connected to each other through a low energy storageDC-link. This allows that the rectifier phase-legs operate with a unique discontinuous PWM modulation (DPWM) where they can stop switching during two-thirds of the grid period or 240o, while the AC currents are at theirhighest values, i.e. only one phase-leg switch during every 60o .

TABLE II. Electric Vehicle Fast DC-type charger specifications.

Sector	k_y	k_x / m_{buck}	m_a	m_b	m_c
I: 0°-60°	u_{bc}^*/u_{ac}^*	u_o^*/u_{ac}^*	1 or 0	k_y	0
II: 60°-120°	u_{ac}^*/u_{bc}^*	u_o^*/u_{bc}^*	k_y	1 or 0	0
III: 120°-180°	u_{ca}^*/u_{ba}^*	u_o^*/u_{ba}^*	0	1 or 0	k_y
IV: 180°-240°	u_{ba}^*/u_{ca}^*	u_o^*/u_{ca}^*	0	k_y	1 or 0
V: 240°-300°	u_{ab}^*/u_{cb}^*	u_o^*/u_{cb}^*	k_y	0	1 or 0
VI: 300°-360°	u_{cb}^*/u_{ab}^*	u_o^*/u_{ab}^*	1 or 0	0	k_y

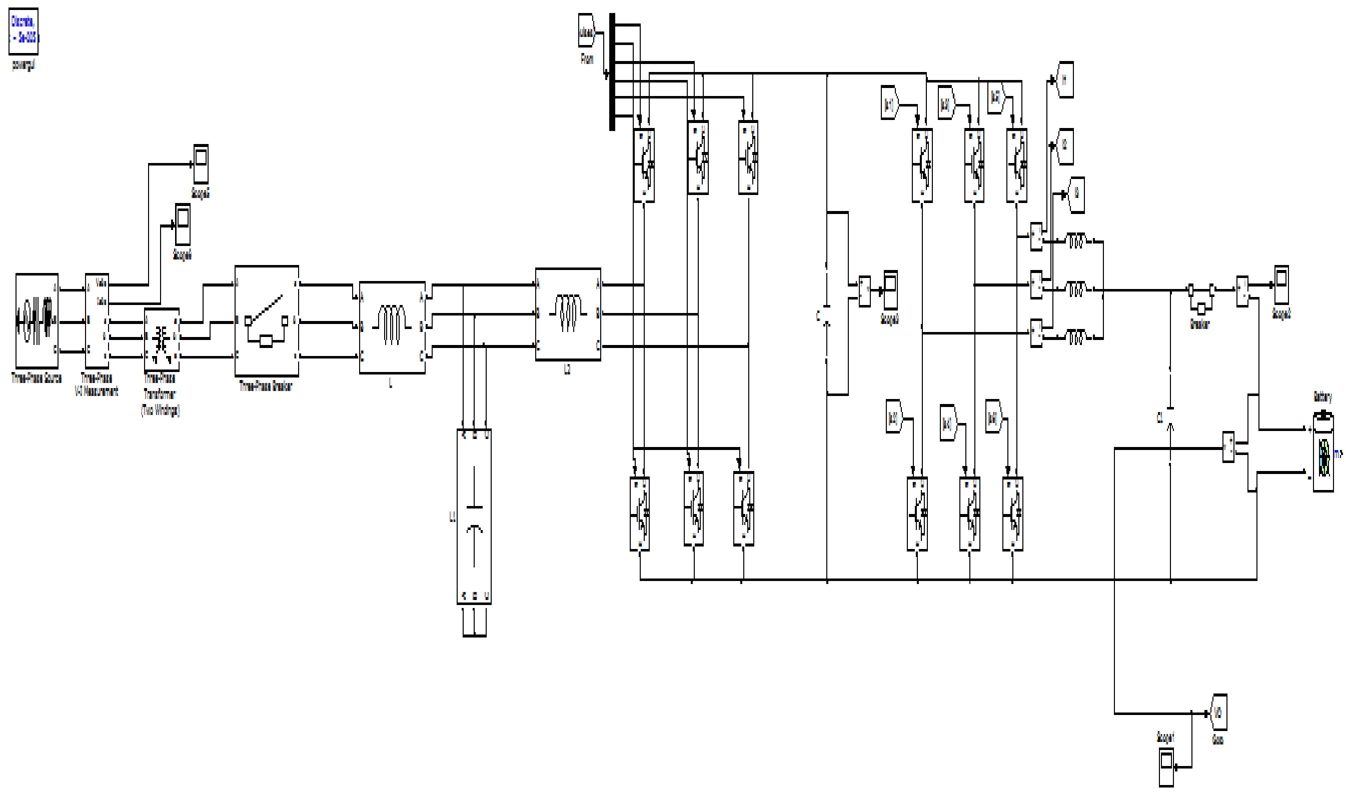

Fig 3.2: Proposed system circuit configuration

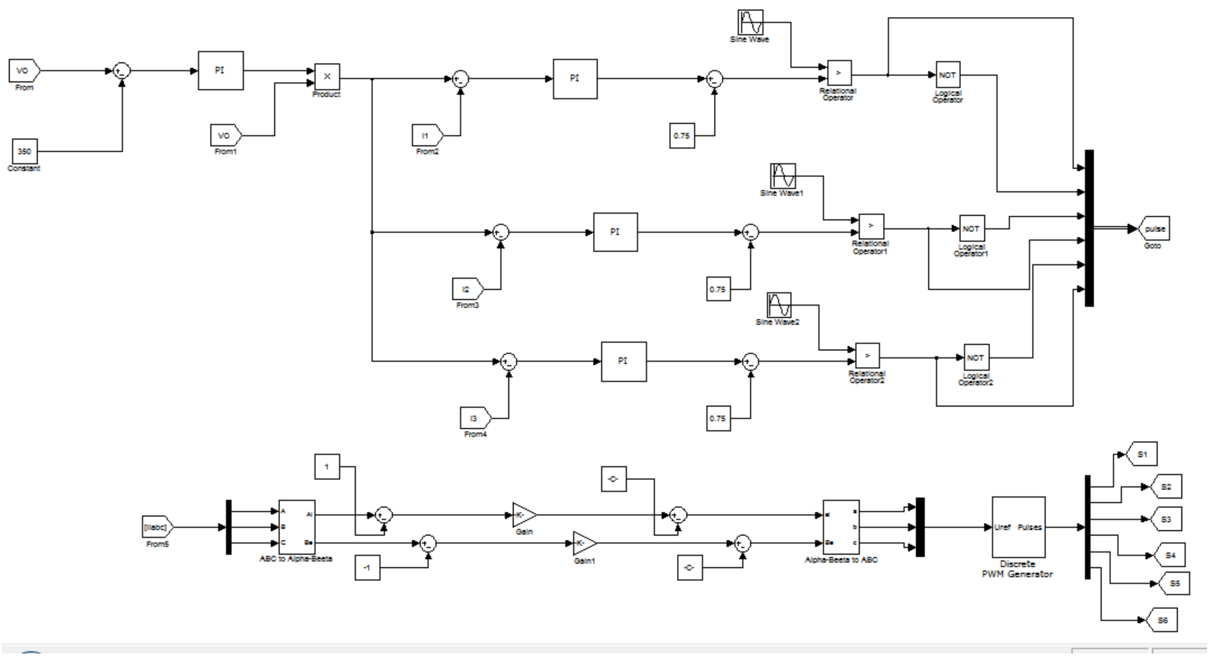

Fig 3.3: Proposed controller

TABLE III: Comparison of active and passive component stresses determined by analytical calculations and digital simulations.

	Analytical Calculations	Simulation	Deviation [%]
$I_{Sabc,avg}$	0.79	0.80	-1.25
$I_{Sabc,rms}$	4.60	4.62	-0.43
$I_{Dabc,avg}$	31.75	31.83	-0.25
$I_{Dabc,rms}$	51.03	51.04	-0.02
$I_{S123p,avg}$	31.04	31.03	+0.03
$I_{S123p,rms}$	35.96	36.00	-0.11
$I_{D123n,avg}$	10.63	10.63	+0.00
$I_{D123n,rms}$	21.05	21.06	-0.05
$\Delta i_{LB,pp,max}$	24.17	24.13	+0.16
$\Delta i_{Lc,pp,max}$	29.343	30.00	-2.2
$\Delta u_{Co,pp,max}$	0.105	0.106	-0.94
$\Delta u_{Cf,pp,max}$	64.34	65.00	-1.01

3.1 EQUIPMENT ANALYSIS

INTRODUCTION

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can buildmodels using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.

Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor. The model depicts the time-dependent mathematical relationships among the system's inputs, states, and outputs. Then, we use Simulink to simulate the behavior of the system over a specified time span. Simulink uses information that you entered into the model to perform the simulation.

BLOCK DIAGRAM

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block). The lines represent connections of block inputs to block outputs. Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time. A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate. A block comprises one or more of the following:

1) A set of inputs,
2) A set of states, and
3) A set of outputs.

A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance. Continuous Versus discrete Blocks Simulink's standard block set includes continuous blocks and discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only at integral multiples of a fixed interval called the block's sample time. Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, depending on whether they are driven by continuous or discrete blocks. A block that can be either discrete or continuous is said to have an implicit sample rate. The implicit sample time is continuous if any of the block's inputs are continuous. The implicit sample time is equal to the shortest input sample time if all the input sample times are integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times.

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Simulink can optionally color code a block diagram to indicate the sample times of the blocks it contains, e.g., black (continuous), magenta (constant), yellow (hybrid), red (fastest discrete), and so on. The block contains block name, icon, and block library that contain the block, the purpose of the block **SIMULINK BLOCK LIBRARIES**

Simulink organizes its blocks into block libraries according to their behavior.

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-timecomponents.

4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.
6) The Functions & Tables library contains blocks that describe general functions and table look-up operations.
7) The Nonlinear library contains blocks that describe nonlinear functions.
8) The Signal & Systems library contains blocks that allow multiplexing and demultiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types ofsubsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

SUB SYSTEMS

Simulink allows to model a complex system as a set of interconnected subsystems each of which is represented by a block diagram. We create a subsystem using Simulink's Subsystem block and the Simulink model editor. We can embed subsystems with subsystems to any depth to create hierarchical models. We can create conditionally executed subsystems that are executed onlywhen a transition occurs on a triggering or enabling input.

SOLVERS

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model.The process of computing the successive states of a system from its model is known as solving the model. No single method of solving a model suffices for all systems. Accordingly, Simulink provides a set of programs, known as solvers, that each embody a particular approach to solving a model. The Simulation Parameters dialog box allows us to choose the solver most suitable for our model.

Fixed-Step and Variable-Step Solvers

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size. Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly andincreasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time,required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

Continuous and Discrete Solvers

Continuous solvers use numerical integration to compute a model's continuous states at the current time step from the states at previous time steps and the state derivatives. Continuous solvers rely on the model's blocks to compute the values of the model's discrete states at each time step.Mathematicians have developed a wide variety of numerical integration techniques for solving the ordinary differential equations (ODEs) that represent the continuous states of dynamic systems. Simulink provides an extensive set of fixed-step and variable-step continuous solvers, each implementing a specific ODE solution method. Some continuous solvers subdivide the simulation time span into major and minor steps, where a minor time step represents a subdivision of the major time step. The solver produces a result at each major time step. It use results at the minor time steps to improve the accuracy of the result at the majortime step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time-step for a model and nothing else. They do not compute continuous states and they rely on the model's blocks to update the model's discrete states. We can use a continuous solver, but not a discrete solver, to solve a model that contains both continuous and discrete states. This is because a discrete solver does not handle continuous states. If you select a discrete solver for a continuous model, Simulink disregards your selection and uses a continuous solver instead when solving the model.

Simulink provides two discrete solvers, a fixed-step discrete solver and avariable-step discrete solver. The fixed-step solver by default chooses a step sizeand hence simulation rate fast enough to track state changes in the fastest block in our model. The variable-step solver adjusts the simulation step size to keep pace with the actual rate of discrete state changes in our model. This can avoid unnecessary steps and hence shorten simulation time for multirate models.

MODEL EXECUTION PHASE

In the simulation model execution phase, Simulink successively computes the states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps. The length of time between steps is called the step size. The step size depends on thetype of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states have discontinuities (Zero Crossing Detection). At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated. At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

1) Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and states to the output function as it may require these arguments to compute the block's output. Simulink updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.
2) Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's continuous states by numerically integrating the time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.
3) Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.
4) Computes the time for the next time step.

Simulink repeats steps 1 through 4 until the simulation stop time is reached.

Block Sorting Rules

Simulink uses the following basic update rules to sort the blocks:

1) Each block must be updated before any of the direct-feed through blocks that it drives. This rule ensures that the inputs to direct-feed through blocks will be valid when they are updated.
2) Non direct-feed through blocks can be updated in any order as long as they are updated before any direct-feed through blocks that they drive. This rule can be met by putting all non direct-feed through blocks at the head of the update list in any order. It thus allows Simulink to ignore non direct-feed through blocks during the sorting process.
3) The result of applying these rules is an update list in which non direct- feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct - feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output. However, an algebraic loop can represent a set of simultaneous algebraic equations (hence the name) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step. Accordingly, Simulink assumes that loops involving direct-feed through blocks do, in fact, represent a solvable set of algebraic equations and attempts to solve them each time the blockis updated during a simulation.

DETERMINING BLOCK UPDATE ORDER

During a simulation, Simulink updates the states and outputs of a model's blocks once per time step. The order in which the blocks are updated is therefore critical to the validity of the results. In particular, if a block's outputs are a function of its inputs at the current time step, the block must be updated after the blocks that drive its inputs. Otherwise, the block's outputs will be invalid. The order in which blocks are stored in a model file is not necessarily the order in which they need to be updated during a simulation. Consequently, Simulink sorts the blocks into the correct order during the model initialization phase.

In order to create a valid update ordering, Simulink categorizes blocks according to the relationship of outputs to inputs. Blocks whose current outputs depend on their current inputs are called direct feed through blocks. All other blocks are called non direct-feed through blocks. Examples of direct-feed through blocks include the Gain, Product, and Sum blocks. Examples of non direct-feed through blocks include the Integrator block (its output is a function purely of its state), the Constant block (it does not have an input), and the Memory block (its output is dependent on its input in the previous time step). Simulink allows you to assign update priorities to blocks. Simulink updates higher priority blocks before lower priority blocks. Simulink honors the priorities only if they are consistent with its block sorting rules.

Some of SIMULINK blocks, which are used in this thesis, are given below.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

3.2 DEFINE THE MODULES

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactivelanguage such as C or FORTRAN.

The MATLAB system consists of six main parts:

(a) Development Environment

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

(b) The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

(e) The MATLAB Application Program Interface (API)

This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for readingand writing MAT-files.

(f) MATLAB Documentation

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

3.3 MODULE FUNTIONALITIES

(1) Three phase source block

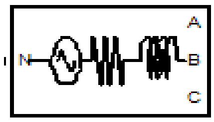


Fig 3.4: Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltagesource with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

(2) VI measurement block

The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and thethree line currents

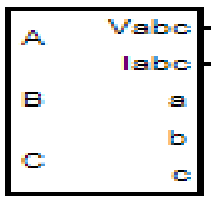


Fig 3.5: Three Phase V-I Measurement

(1) Scope

Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes. TheScope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation

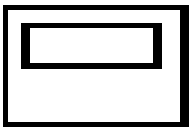


Fig 3.6: Scope

(2) Three-Phase Series RLC Load

The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powersabsorbed by the load are proportional to the square of the applied voltage.

Fig 3.7: Three-Phase Series RLC Load

(3) Three-Phase Breaker block

The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal

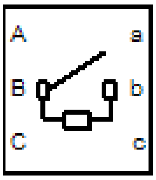


Fig 3.8: Three-Phase Breaker Block

(4) Integrator

Library: Continuous

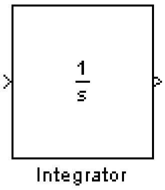


Fig 3.9: Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

(5) Breaker

Implement circuit breaker opening at current zero crossing.

Library: Elements

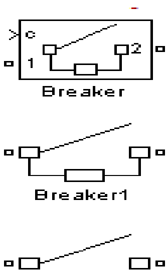


Fig 3.10: Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening andclosing times can be controlled either from an external SIMULINK signal(external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK inputmust be either 0 or 1 (0 to open the breaker, 1 to close it).

When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

(6) Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources

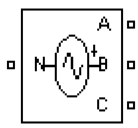


Fig 3.11: Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

(7) Trigonometric Function

Specified trigonometric function on input

Library: Math Operations

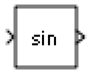


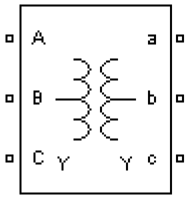
Fig 3.12: Trigonometric Function

Purpose: The Trigonometric Function block performs common trigonometric functions

(8) **Three-Phase Transformer (Two Windings*)***

Implement three-phase transformer with configurable winding connectionsLibrary: **Elements**

Fig 3.13: Three Phase Transformer



Purpose: The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

(9) Three-Phase Transformer 12 Terminals

Implement three single-phase, two-winding transformers where all terminals are accessible

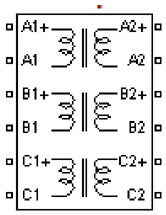


Fig 3.14: Two winding Transformer

Purpose: The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

(10) IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: **Power Electronics**

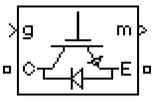


Fig 3.15: IGBT

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

3.4 RELATEDED DESIGNS/GRAPHS

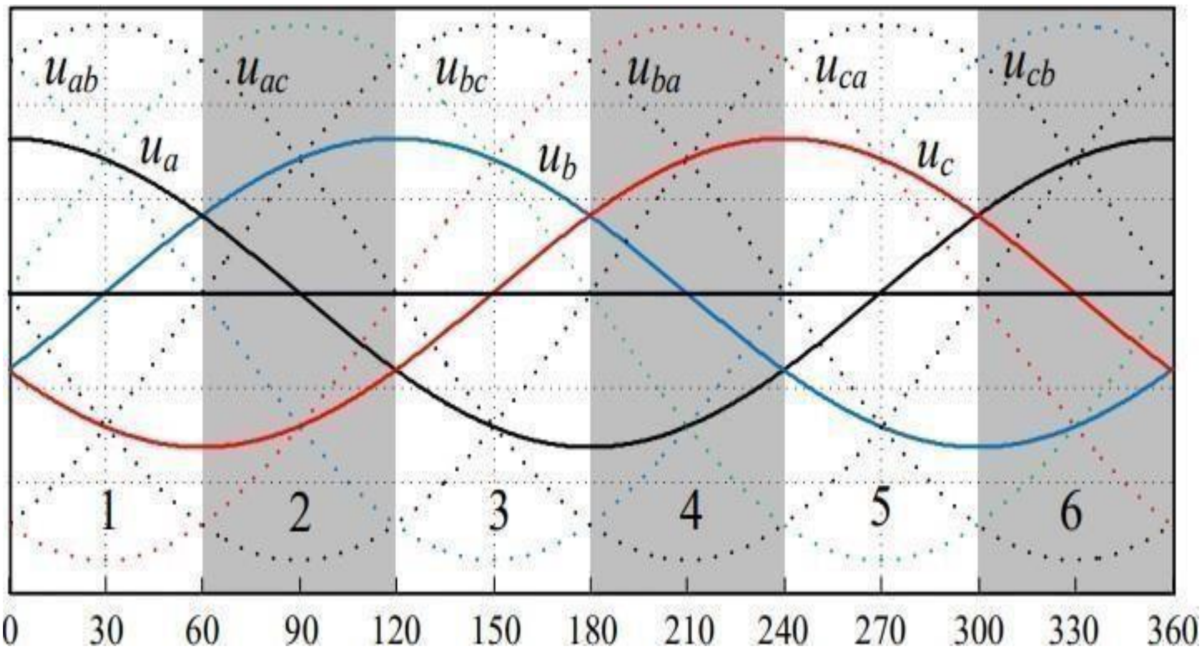


Fig. 3.4.1: Grid sectors defined by the different relations of the instantaneous values of the grid phase voltages ua,b,c.

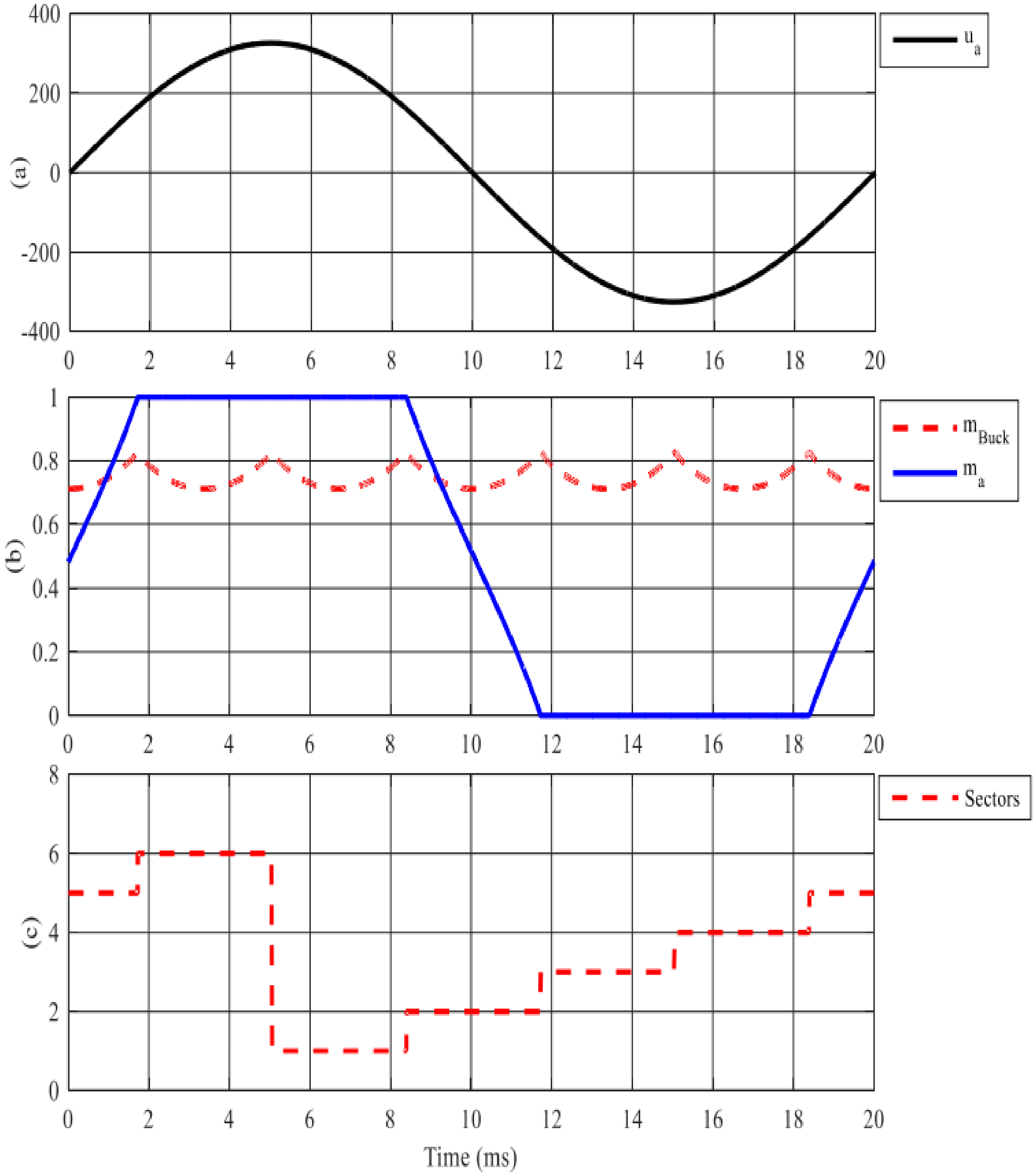


Fig. 3.4.2: DPWM240 modulator main waveforms: a) input voltage ua; b) calculated modulation function for front-end circuit ma and interleaved Buck-converter mBuck; and c) the six reference AC voltage sectors, S1-6.

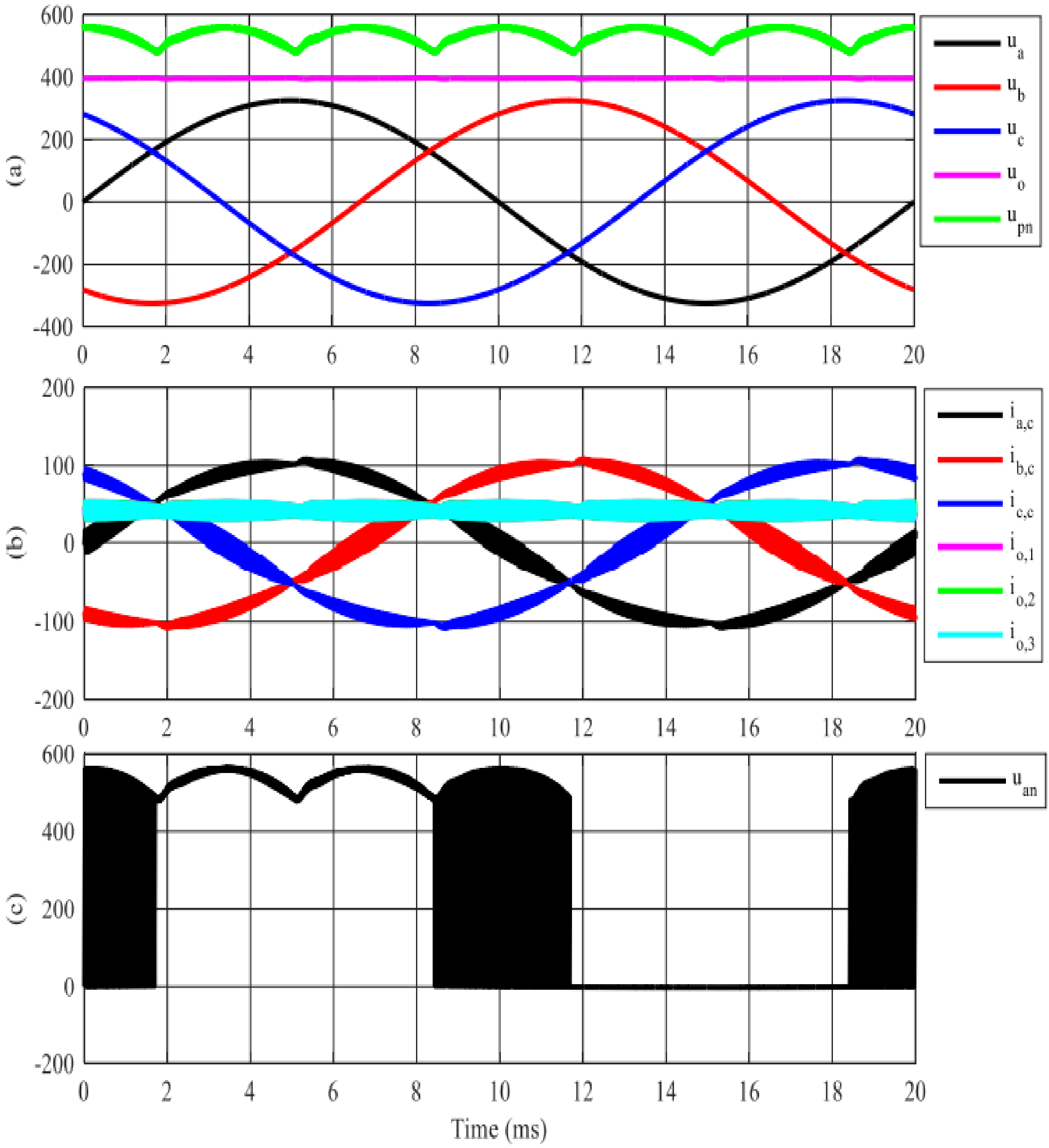


Fig. 3.4.3: Main simulated waveforms: a) AC voltages ua,b,c; DC-link voltage upn and output voltage uo; b) converter side currents ia,c,b,c,c,c; and buckconverter partial currents io1,o2,o3; c) Voltages between phase a and n terminals, uan.

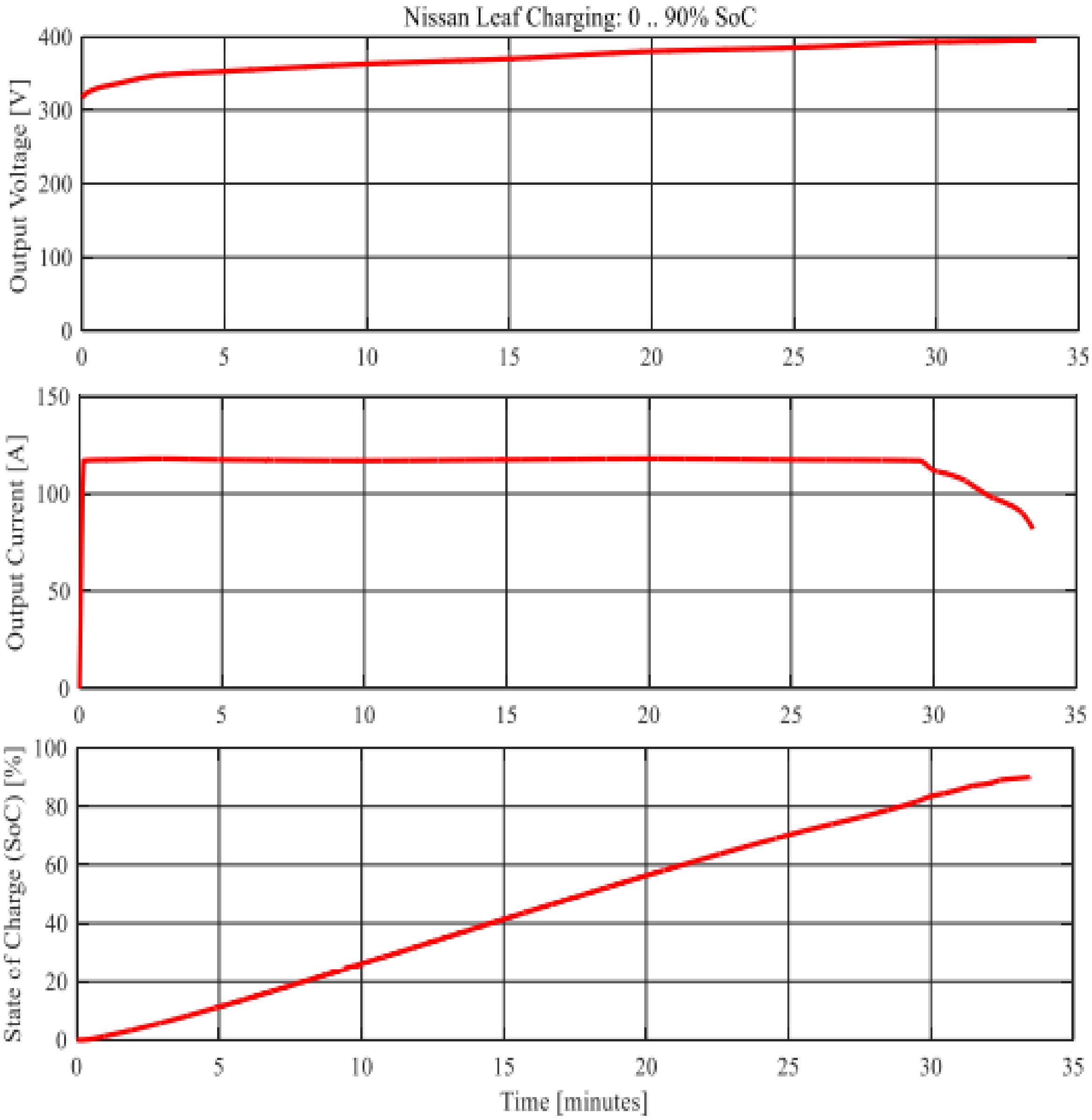


Fig. 3.4.4. Fast charging profile of a 30 kWh Nissan Leaf EV from 0% to 90% of state-of-charging.

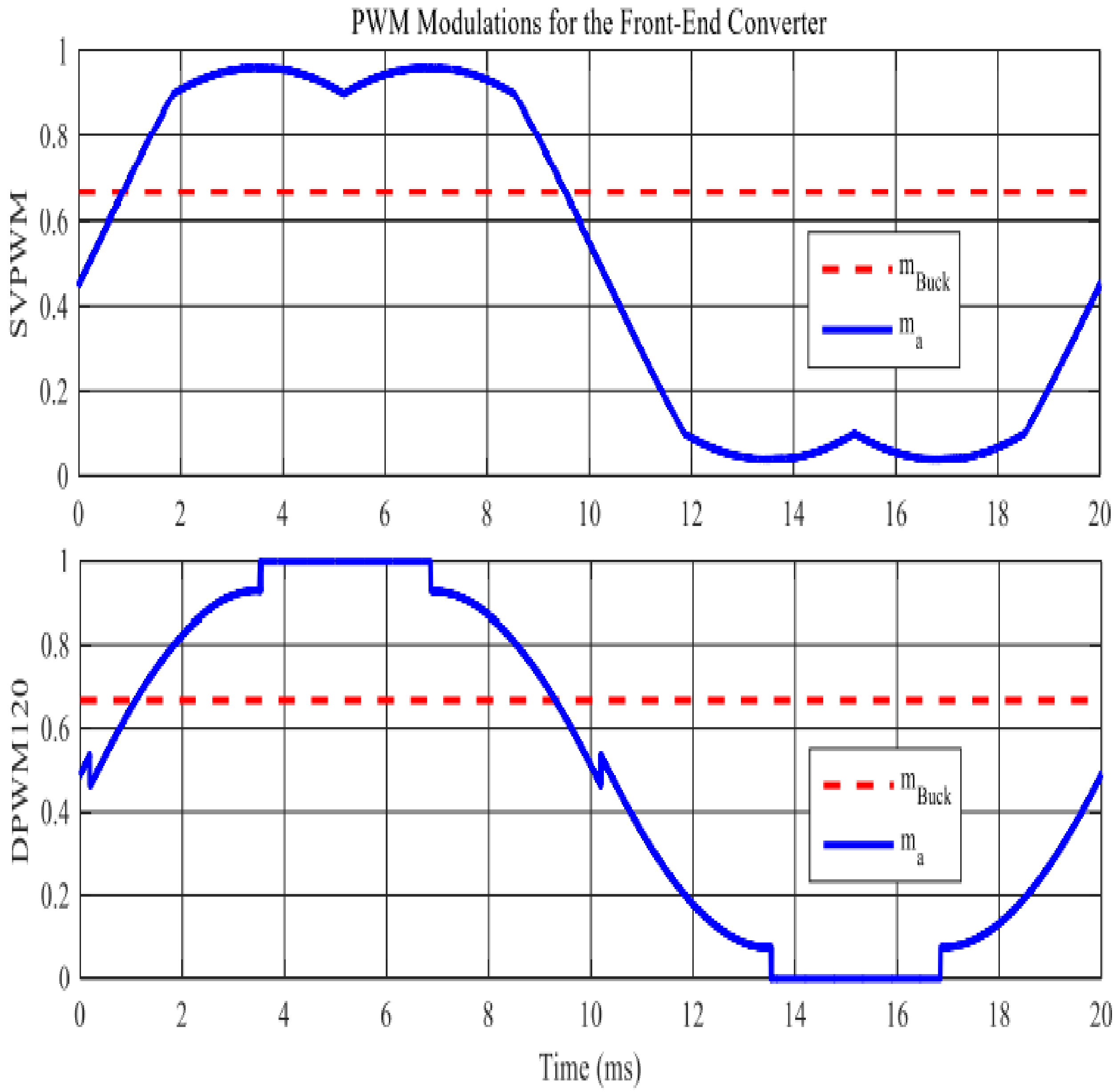


Fig. 3.4.5. Suitable PWM modulation strategies for the grid-connected or frontend power electronics of Fig. 1: a) SVPWM and b) DPWM120.

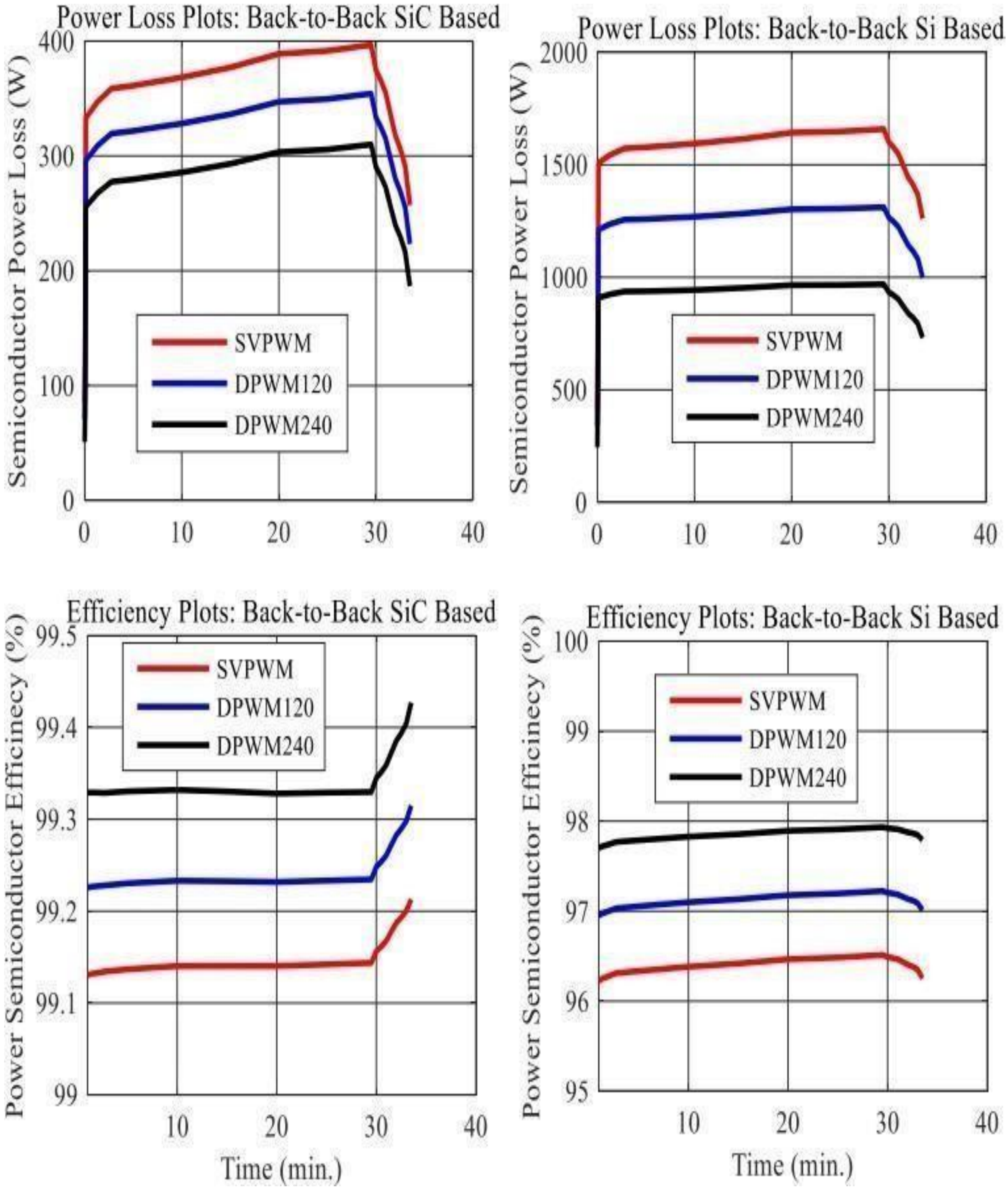


Fig. 3.4.6. Benchmark results of 50 kW fast chargers: Power loss and efficiency results for a 30 kWh Nissan Leaf charging from 0% to 90% SoC for SiC MOSFET- and Si IGBT/Diode-based solutions.

4. PROJECT IMPLEMENTATION

4.0 IMPLEMTATION STAGES

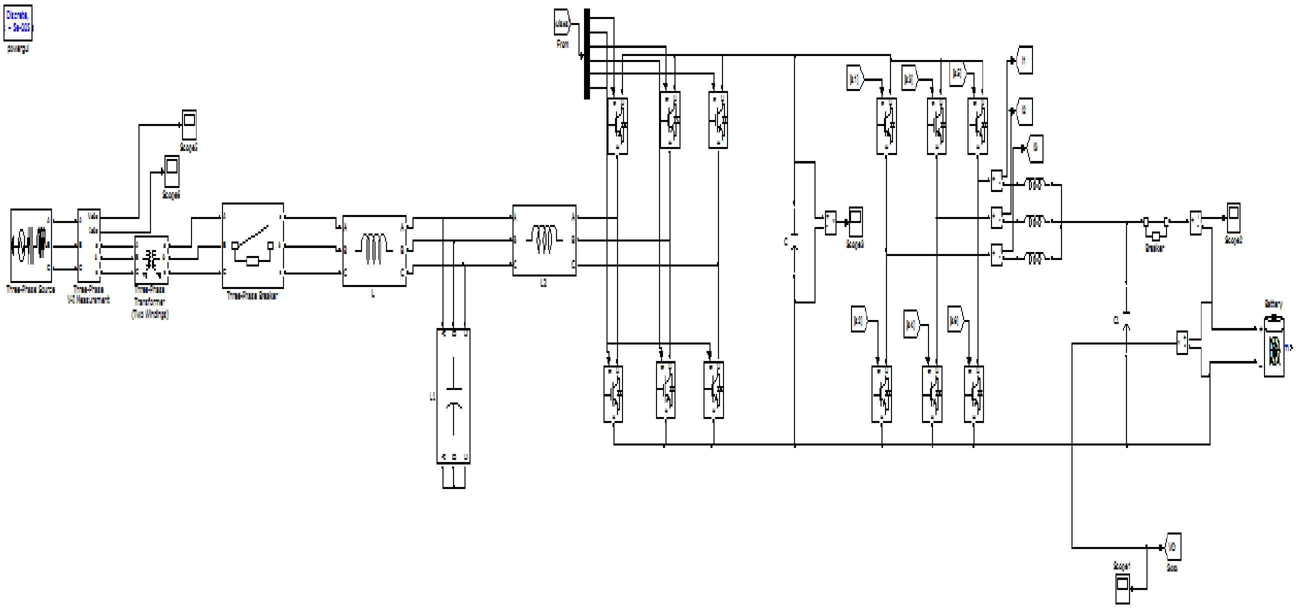


Fig 4.1: Proposed system circuit configuration

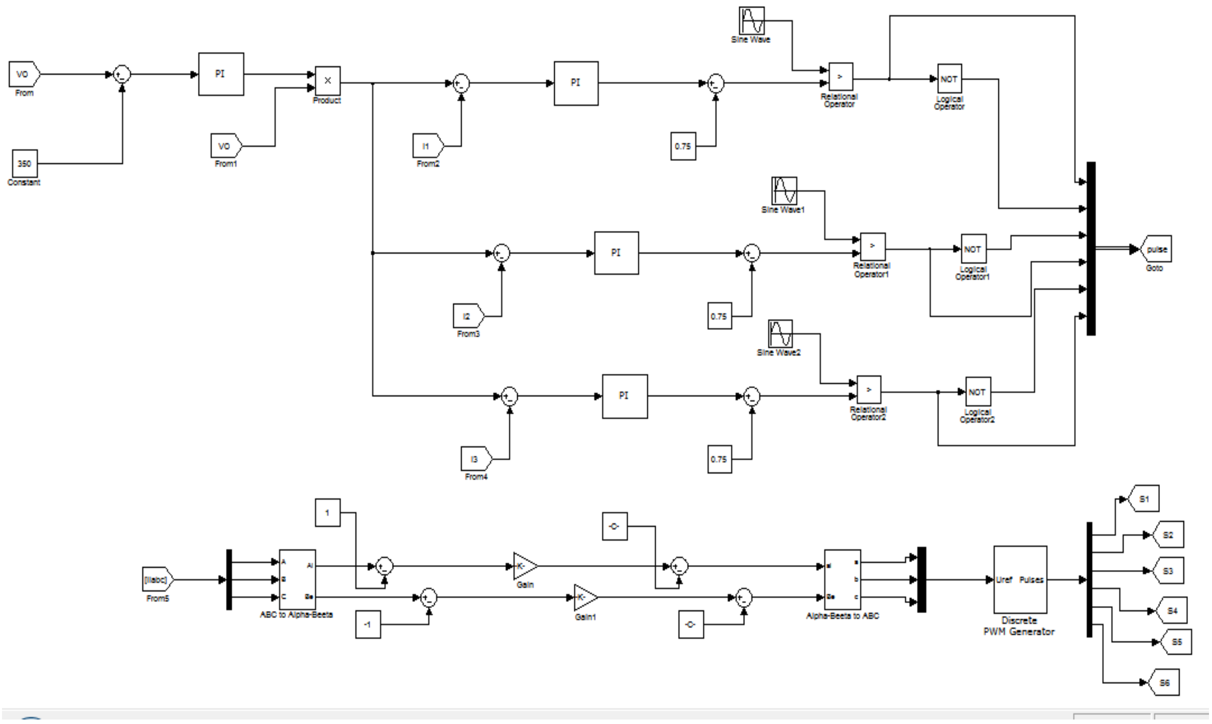


Fig 4.2: Proposed controller

4.1 RESULTS

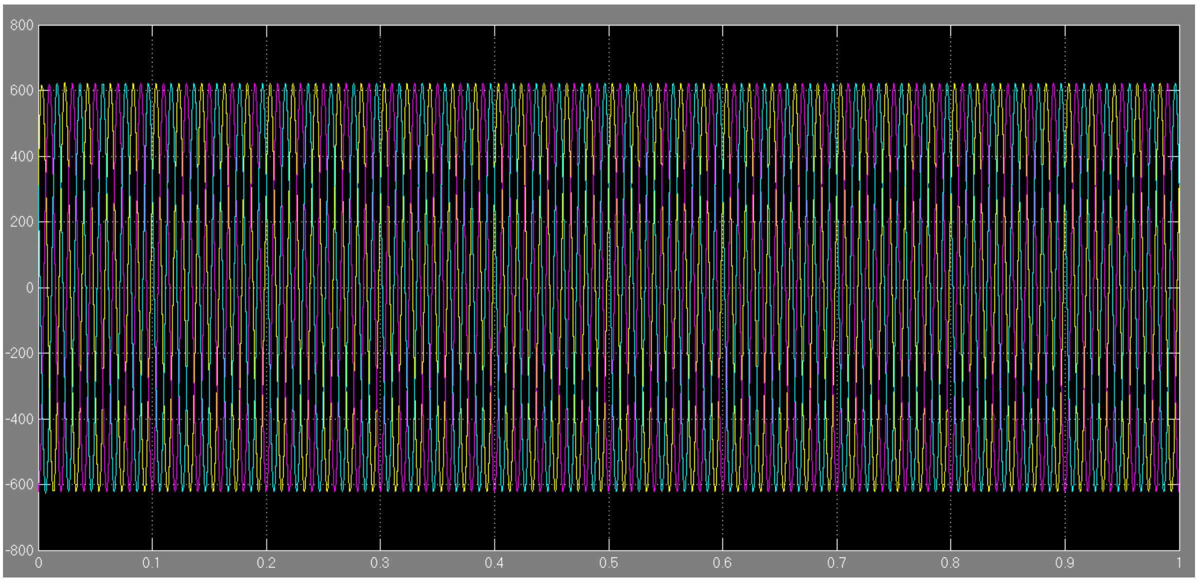


Fig 4.1.1: Input voltage for proposed system

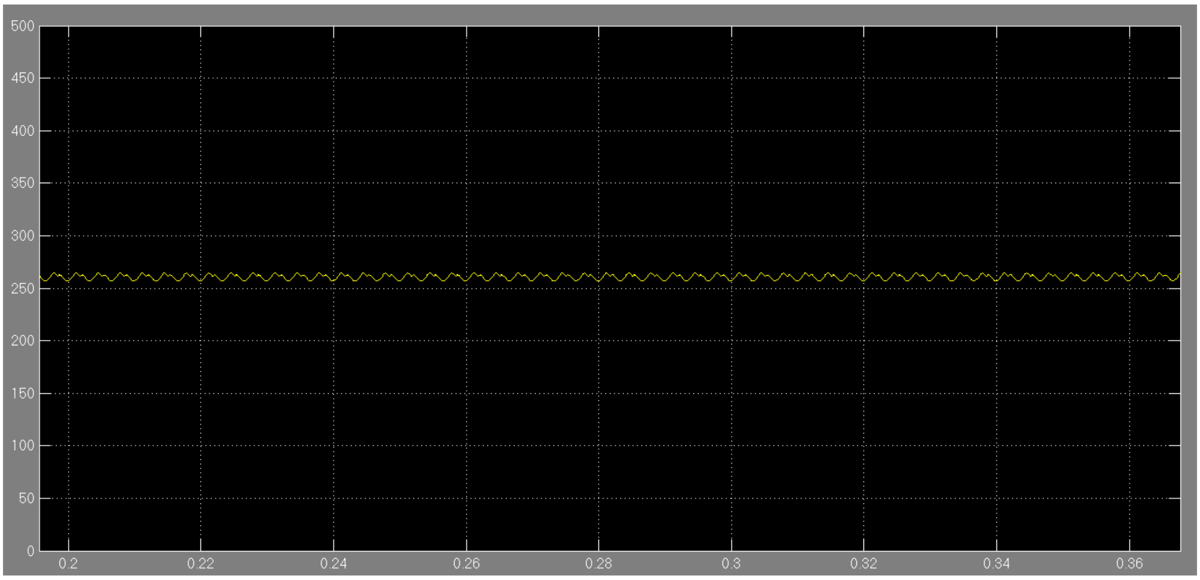


Fig 4.1.2: DC-link voltage for proposed system

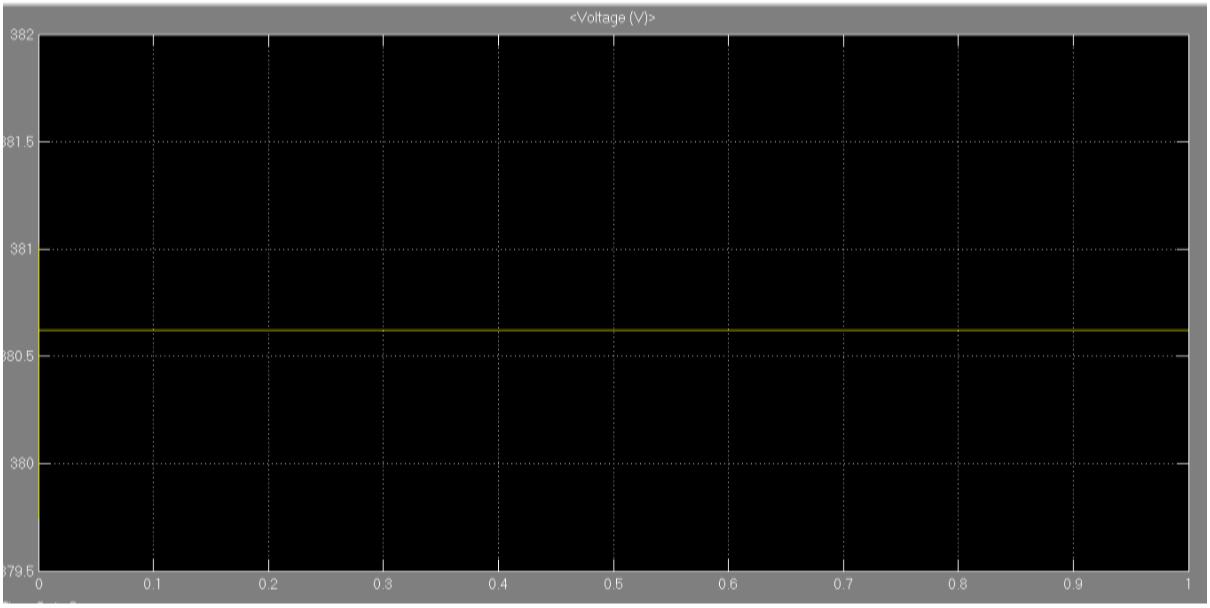


Fig 4.1.3: Battery voltage

5.PROJECT TESTING

5.0 OVERVIEW OF TESTING METHODS

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model. The process of computing the successive states of a system from its model is known as solving the model. No single method of solving a model suffices for all systems. Accordingly, Simulink provides a set of programs, known as solvers, that each embody a particular approach to solving a model. The Simulation Parameters dialog box allows us to choose the solver most suitable for our model.

Fixed-Step and Variable-Step Solvers

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size. Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly and increasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time,required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

Continuous and Discrete Solvers

Continuous solvers use numerical integration to compute a model's continuous states at the current time step from the states at previous time steps and the state derivatives. Continuous solvers rely on the model's blocks to compute the values of the model's discrete states at each time step.

Mathematicians have developed a wide variety of numerical integration techniques for solving the ordinary differential equations (ODEs) that represent the continuous states of dynamic systems. Simulink provides an extensive set of fixed-step and variable-step continuous solvers, each implementing a specific ODE solution method. Some continuous solvers subdivide the simulation time span into major and minor steps, where a minor time step represents a subdivision of the major time step. The solver produces a result at each major time step. It use results at the minor time steps to improve the accuracy of the result at the major time step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time-step for a model and nothing else. They do not compute continuous states and they rely on the model's blocks to update the model's discrete states. We can use a continuous solver, but not a discrete solver, to solve a model that contains both continuous and discrete states. This is because a discrete solver does not handle continuous states. If you select a discrete solver for a continuous model, Simulink disregards your selection and uses a continuous solver instead when solving the model.

Simulink provides two discrete solvers, a fixed-step discrete solver and a variable-step discrete solver. The fixed-step solver by default chooses a step sizeand hence simulation rate fast enough to track state changes in the fastest block in our model. The variable-step solver adjusts the simulation step size to keep pace with the actual rate of discrete state changes in our model. This can avoid unnecessary steps and hence shorten simulation time for multirate models.

MODEL EXECUTION PHASE

In the simulation model execution phase, Simulink successively computes the states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps. The length of time between steps is called the step size. The step size depends on the type of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states havediscontinuities (Zero Crossing Detection).

At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated. At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

5) Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and states to the output function as it may require these arguments to compute the block's output. Simulink updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.
6) Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's continuous states by numerically integrating the time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.
7) Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.
8) Computes the time for the next time step.

Simulink repeats steps 1 through 4 until the simulation stop time is reached.

Block Sorting Rules

Simulink uses the following basic update rules to sort the blocks:

3) Each block must be updated before any of the direct-feed through blocks that it drives. This rule ensures that the inputs to direct-feed through blocks will be valid when they are updated.
4) Non direct-feed through blocks can be updated in any order as long as they are updated before any direct-feed through blocks that they drive. This rule can be met by putting all non direct-feed through blocks at the head of theupdate list in any order. It thus allows Simulink to ignore non direct-feed through blocks during the sorting process.

The result of applying these rules is an update list in which non direct- feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct - feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output. However, an algebraic loop can represent a set of simultaneous algebraic equations (hence thename) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step. Accordingly, Simulink assumes that loops involving direct-feed through blocks do, in fact, represent a solvable set of algebraic equations and attempts to solve them each time the blockis updated during a simulation.

6.CONCLUSION AND FUTURE ENHANCEMENT

The three-phase DC-type electric vehicle battery concept employing a back-end power conversion based on the PWM interleaved Buck-converter and front-end circuit based on the two-level bidirectional six-switch voltage source rectifier has been studied. The implementation of a unique DPWM modulation, was explained. This ensures high power-factor operation while the phase-leg can stop switching during two-thirds of the grid period or 240, reducing considerably the semiconductor switching losses. The principle of operation, the main designing expressions, suitable modulation scheme and PWM control have been described in the project. The three-phase DC-type electric vehicle battery concept consisting a back-end power conversion based on the PWM interleaved Buck- converter and front-end circuit based on the two-level bidirectional six-switch voltage source rectifier has been studied. The implementation of a unique DPWM modulation, was explained. This ensures high power-factor operation. Reducing the semiconductor switching losses. The principle of operation, the main designing expressions, suitable modulation scheme and PWM controller have been described in the project. Based on fact, the average charge time by EV batteries is nearly 5-8 hours. Thus, this creates a need for an adequate number of charging ports and further raise the demand for fast charging points. DC fast stations which consist of these fast chargers, convert AC power to DC within thestation, delivering DC power directly to sources such as batteries This also enables a much faster charge in a very less time.

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APPENDICES

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

(a) Development Environment

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

(b) The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

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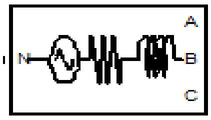
(1) Three phase source block



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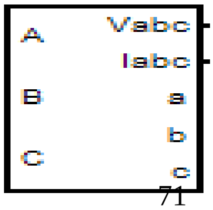
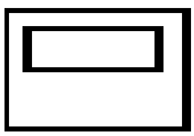


Three Phase V-I Measurement

(3) Scope

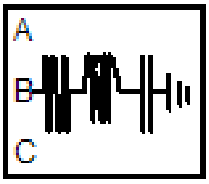
Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes. TheScope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation



Scope

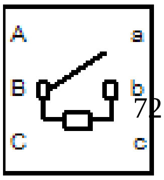
(4) Three-Phase Series RLC Load

The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.



(5) Three-Phase Breaker block

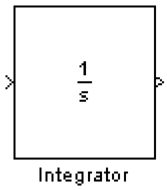
The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.



Three-Phase Breaker Block

(6) Integrator

Library: Continuous



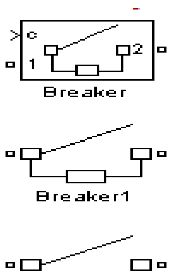
Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

(7) Breaker

Implement circuit breaker opening at current zero crossing.

Library: Elements



Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening andclosing times can be controlled either from an external SIMULINK signal(external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

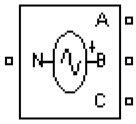
When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK inputmust be either 0 or 1 (0 to open the breaker, 1 to close it).When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

(8) Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources



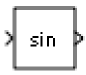
Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

(9) Trigonometric Function

Specified trigonometric function on input

Library: Math Operations

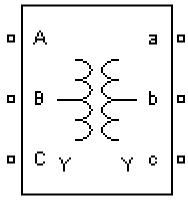


Trigonometric Function

Purpose: The Trigonometric Function block performs common trigonometricfunctions

(10) Three-Phase Transformer (Two Windings)

Implement three-phase transformer with configurable winding connections Library: **Elements**



Three Phase Transformer

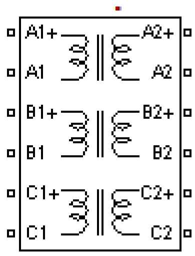
Purpose:

The Three-Phase Transformer (Two Windings) block implements a three- phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

(11) Three-Phase Transformer 12 Terminals

Implement three single-phase, two-winding transformers where all terminals areaccessible

Library: Elements



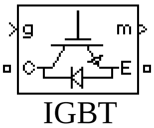
Two winding Transformer

Purpose: The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

(12) IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diodeLibrary: **Power**

Electronics



IGBT

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

A

PROJECT REPORT

On

A Novel Efficient Vehicle Fast Charging System Structure with Low Order Harmonic Current Suppression Capability

Submitted by

1) Ms. K. Kalyani (17K81A0228) **2) Ms. A. Chandana (17K81A0201)**
3) Mr. L. Akhil (17K81A0230) **4) Ms. R. Mahesh (17K81A0236)**

in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

Mrs. S. Trilochana, M.Tech,(PhD)

Asst.Professor,

DEPARTMENT OF Electrical and Electronics Engineering

ST.MARTIN'S ENGINEERING COLLEGE
(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled A Novel Efficient Vehicle Fast Charging System Structure with Low Order Harmonic Current Suppression Capability, is being submitted by **1.Ms. K. Kalyani (17K81A0228) 2. Ms. A. Chandana (17K81A0201) 3. Mr. L. Akhil (17K81A0230) 4. Ms. R. Mahesh (17K81A0236)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN** Electrical and Electronics Engineering department is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Mrs. S. Trilochana
Department of EEE

Head of the Department
Dr. N. Ramchandra
Department of EEE

Internal Examiner

External Examiner

Place: Hyderabad

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of Electrical and Electronics Engineering, session:2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled A Novel Efficient Vehicle Fast Charging System Structure with Low Order Harmonic Current Suppression Capability is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

Ms. K. Kalyani	(17K81A0228)
Ms. A. Chandana	(17K81A0201)
Mr. L. Akhil	(17K81A0230)
Ms. R. Mahesh	(17K81A0236)

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1. Ms. K.Kalyani
2. Ms. A.Chandana
3. Mr. L.Akhil
4. Mr. R.Mahesh

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NOMENCLATURE

EV-	Electric vehicle
V2G -	Vehicle to grid
DC APF -	DC Active Power Filter
ECS -	Electronic Charging Station
EVSE -	Electric vehicle supply equipment
CCS -	Combined charging system
NEMA -	National electrical manufacturers Association
SAE -	Society of Automotive engineering
IEC -	International electrochemical Commission
BSS -	Battery swapping stations
FHWA -	Federal Highway administration
MUTCD -	Manual on uniform traffic control devices
SPARC -	Solar powered automatic Recharging station
THD -	Total harmonic distortion
CSNL -	Current source non-linear loads
VSNL -	Voltage source non-linear loads
PWM -	Pulse width modulation
GUI -	Graphical user interface
TIF -	Telephone interference factor
THFF -	Telephone harmonic form factor
HVDC -	High Voltage direct current

ABSTRACT

Aiming at improving the efficiency of the traditional electric vehicle (EV) fast chargers with two-stage structure, this paper comes up with a novel charger with single-stage structure, where the turn ratio of the transformer is specially designed to obtain a lower input line-to-line voltage (190V) for the single AC/DC converter. Followed by a fair comparison method, the power losses of transformers and converters in both two-stage and single-stage structures are analyzed. The better performances of the single-stage structure, which includes lower costs and higher power conversion efficiency (up to 2%), are approved by the results of calculation and simulation. To suppress the harmonic current getting into the battery packs in the single-stage structure, a small capacity bidirectional half bridge DC/DC converter is designed to function as a DC active power filter (DCAPF) to compensate the harmonics. Finally, both simulation and experimental results are carried out to validate the low order harmonic current compensation effect.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO THE PROJECT:

Efficiency is one of the key parameters to evaluate the performance of electric vehicle (EV) charging system. Among many charging circuit topologies , fast charging systems seem to have a promising future for their shorter charging time for EVs, especially those bidirectional fast chargers which accommodate to the concept "vehicle-to-grid(V2G)". Traditional fast charging system usually consists of two stages, namely an AC/DC converter and a downstream DC/DC converter . Hence the output voltage could be freely adjusted to accommodate the wide battery voltage range (280V-400V) for different EVs. In commercial EV fast chargers, the downstream DC/DC converter is usually designed to be an isolated converter where a high frequency transformer is necessary for isolation.

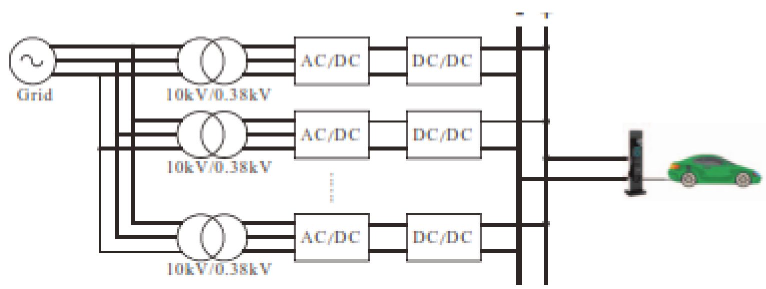


Fig:1.1 Two stage charging system

However the power conversion efficiency is limited a lot compared to non-isolated DC/DC converter. Once the non-isolated DC/DC converter is adopted, there must be a power frequency transformer at the grid side to ensure electrical safety as shown in Fig1.1. No matter which kind of two-stage converters, it seems difficult to improve the system efficiency further with lower cost. In this paper, a single-stage AC/DC structure shown in Fig1.2 is considered to replace two-stage structure with lower cost but higher efficiency. To accommodate the battery voltage range, the turn ratio of power frequency transformer is designed to make the input voltage of the AC/DC converter lower than the grid voltage.

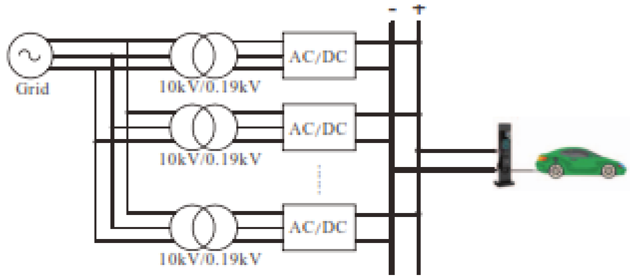


Fig:1.2 proposed single stage charging system

A fair system efficiency comparison is carried out between the proposed structure and the traditional two-stage structure. And the efficiency calculation results are validated by the SEMISEL simulation tool. Through the analysis and calculation, the proposed single-stage structure has nearly more than 2% higher power conversion efficiency compared to traditional two-stage structure with no additional cost. Furthermore based on the proposed structure, there is another problem that the harmonic power from the grid can be directly transmitted to the battery packs to be solved . Hence, a small capacity bidirectional half bridge DC/DC converter shown in Fig1.3 is applied in this paper to work as an DC active power filter (DCAPF) to compensate the harmonic current as shown in Fig1.4. Both the simulation and experimental results indicate that the DCAPF method is effective in battery harmonic current compensation.

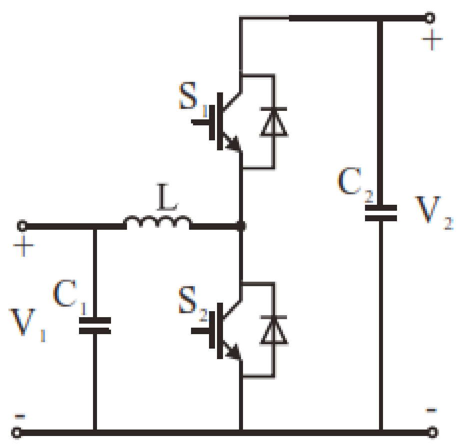


Fig:1.3 Bidirectional half bridge DC/DC Converter.

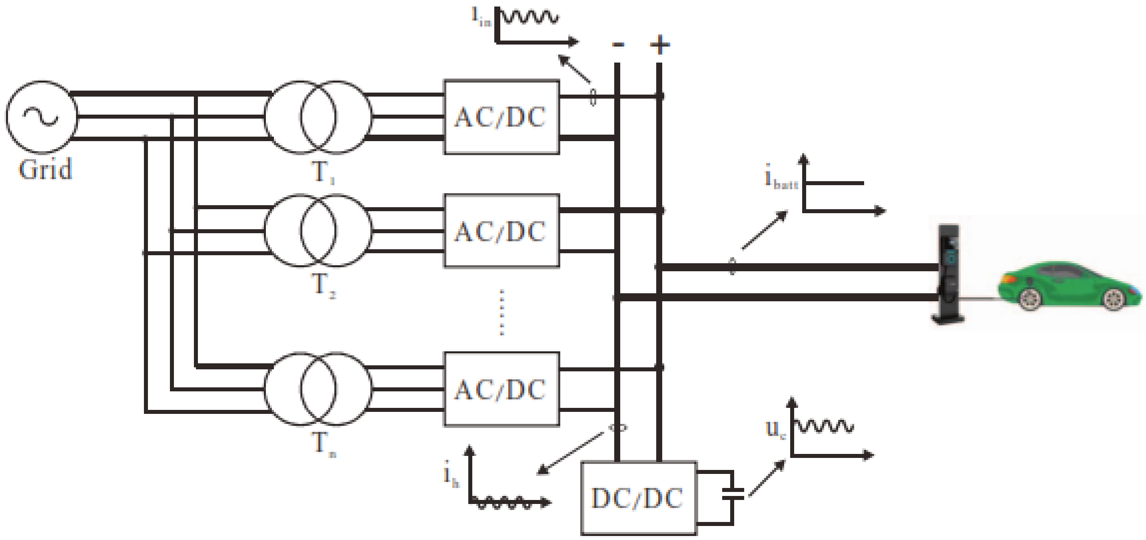


Fig:1.4 single stage charging system with DCAPF

To compare the efficiency of the two kinds of structure fairly, the power losses in both transformers and power converters are considered in the following evaluation model. A. Power Loss Analysis for Transformers Assuming that both transformers of the two structures have the same cost, namely the total transmitted power, copper amount and iron core specifications are the same. Usually a transformer's power loss consists of load loss and no-load loss. For the primary side, the power losses are identical in the two transformers due to their same settings. As for the secondary side, it is difficult to compare their power losses directly. Thus, it is necessary to analyze their load losses and no load losses in detail. No-load loss commonly consists of hysteresis loss and eddy current loss which can be expressed respectively as

$$P_h = C_h f B_m^{\ n} V \qquad (1)$$

$$P_e = C_e \Delta^2 f^2 B_m^{\ 2} V \qquad (2)$$

where Ch and Ce are the loss coefficients severally, Δ is the thickness of the silicon steel sheet, Bm is the flux density, V is the volume of the iron core, and f is the working frequency. Under the prerequisite that the iron core specifications are the same in the two transformers, hysteresis loss and eddy current loss of them are considered to be equal as well. As for the load loss, it consists of copper loss, eddy current loss in the winding, and other stray loss. Due to the fact that stray loss is only a small part, it has been ignored in the evaluation. Normally when ignoring the harmonic current in the transformer windings, the copper loss can be expressed as

$$P_j = R_{dc} \cdot \bar{I}_1^{\,2} \qquad (3)$$

where Rdc is the winding's resistance, 1I is the fundamental current. When the transmitted power is the same in the two transformers, the current of secondary winding at 190V will be twice as high as the secondary winding at 380V. Meanwhile, according to the principle that the copper amount is the same, the cross-sectional area of the secondary winding in (b) is twice as much as in (a), but its length is half of the secondary winding in (a) as shown in Fig.5. Therefore, the dc resistance of secondary winding in (b) is a quarter of that in (a). According to (3), naturally the copper losses are the same When considering the eddy current loss in the winding, it can be calculated through a finite element method as

$$P_i = \frac{1}{24\rho} B_i b \omega^2 R_i S_i \qquad (4)$$

where Bi is the flux density in unit i ,ω is the angular frequency, ρ is the resistivity, b is the wire size, Ri is the distance from the center of gravity of unit i to the center line of the core, i S is the area of conductors in unit i . When the finite units are selected to be the same, parameters b , Ri and i S should be the same for both transformer secondary windings. When the same wire, input source and current density are adopted, parameters ρ , ω and Bi are also the same. Hence, the eddy current losses are the same for two transformers. According to the analysis above, a conclusion can be got that the total power losses of the two transformers are actually identical even under different secondary voltages.

CHAPTER 2

ELECTRIC VEHICLE CHARGING STATION

An electric vehicle charging station, also called EV charging station, electric recharging point, charging point, charge point, electronic charging station (ECS), and electric vehicle supply equipment (EVSE), is an element in an infrastructure that supplies electric energy for the recharging of plug-in electric vehicles—including electric cars, neighborhood electric vehicles and plug-in hybrids.

For charging at home or work, some electric vehicles have converters on board that can plug into a standard electrical outlet or a high-capacity appliance outlet. Others either require or can use a charging station that provides electrical conversion, monitoring, or safety functionality. These stations are also needed when traveling, and many support faster charging at higher voltages and currents than are available from residential EVSEs. Public charging stations are typically on-street facilities provided by electric utility companies or located at retail shopping centers, restaurants and parking places, operated by a range of private companies.

Charging stations provide a range of heavy duty or special connectors that conform to the variety of standards. For common DC rapid charging, multi-standard chargers equipped with two or three of the Combined Charging System (CCS), CHADEMO, and AC fast charging has become the de facto market standard in many regions.

2.1 Charging stations fall into four basic categories:

1. Residential charging stations: An EV owner plugs into a standard receptacle (such as NEMA connector in the US) when he or she returns home, and the car recharges overnight. A home charging station usually has no user authentication, no separate metering, but may require wiring a dedicated circuit to have faster charging. Some portable chargers can also be wall mounted as charging stations.
2. Charging while parked (including public charging stations) – a private or commercial venture for a fee or free, sometimes offered in partnership with the owners of the parking lot. This charging may be slow or high speed and often encourages EV owners to recharge their cars while they take advantage of nearby facilities. It can include parking for an organization's own employees, parking at shopping malls, small centers, and public transit stations. Typically, AC Type1 / Type2 plugs are used.
3. Fast charging at public charging stations >40 kW, capable of delivering over 60-mile (97 km) of range in 10–30 minutes. These chargers may be at rest stops to allow for longer distance trips. They may also be used regularly by commuters in metropolitan areas, and for charging while parked for shorter or longer

periods. Common examples are J1772, Type 2 connector, Combined charging system, CHAdeMO, and Tesla Superchargers.

4. Battery swaps or charges in under 15 minutes. A specified target for CARB credits for a zero-emission vehicle is adding 200 miles (approx. 320 km) to its range in under 15 minutes. In 2014, this was not possible for charging electric vehicles, but it is achievable with EV battery swaps. It intends to match the refueling expectations of regular drivers and give crane mobile support for discharged vehicles where there is no charging station.

Battery capacity and the capability of handling faster charging are both increasing, and methods of charging have needed to change and improve. New options have also been introduced (on a small scale, including mobile charging stations and charging via inductive charging mats). The differing needs and solutions of various manufacturers has slowed the emergence of standard charging methods, and in 2015, there is a strong recognition of the need for standardization.

The charging time depends on the battery capacity and the charging power. In simple terms, the time rate of charge depends on the charging level used, and the charging level depends on the voltage handling of the batteries and charger electronics in the car. The U.S.-based SAE International defines Level 1 (household 120V AC) as the slowest, Level 2 (upgraded household 240 VAC) in the middle and Level 3 (super charging, 480V DC or higher) as the fastest. Level 3 charge time can be as fast as 30 minutes for an 80% charge, although there has been serious industry competition about whose standard should be widely adopted. Charge time can be calculated using the formula: Charging Time [h] = Battery Capacity [kWh] / Charging Power [kW]

The usable battery capacity of a first-generation electric vehicle, such as the original Nissan Leaf, is about 20 kWh, giving it a range of about 100 mi (160 km). Tesla was the first company to introduce longer range mass production electric vehicles, initially releasing their Model S with battery capacities of 40 kWh, 60 kWh and 85 kWh, with the latter having an estimated range of about 480 km (300 mi). Plug-in hybrid vehicles have capacity of roughly 3 to 5 kWh, for an electrical range of 20 to 40 kilometers, but the gasoline engine ensures the full range of a conventional vehicle.

For normal charging (up to 7.4 kW), car manufacturers have built a battery charger into the car. A charging cable is used to connect it to the electrical network to supply 230 volt AC current. For quicker charging (22 kW, even 43 kW and more), manufacturers have chosen two solutions:

- Use the vehicle's built-in charger, designed to charge from 3 to 43 kW at 230 V single-phase or 400 V three-phase.

- Use an external charger, which converts AC current into DC current and charges the vehicle at 50 kW (e.g. Nissan Leaf) or more (e.g. 120-135 kW Tesla Model S).

The user finds charging an electric vehicle as simple as connecting a normal electrical appliance; however to ensure that this operation takes place in complete safety, the charging system must perform several safety functions and dialogue with the vehicle during connection and charging.

Other charging networks are available for non-Tesla vehicles. The Blink network of chargers has both Level 2 and DC Fast Chargers and charges separate rates for members and non members. Their prices range from $0.39 to $0.69 per kWh for members and $0.49 to $0.79 per kWh for non members, depending on location. The ChargePoint network has free chargers and paid chargers that drivers activate with a free membership card. The paid charging stations' prices are based on local rates (similarly to Blink). Other networks use similar payment methods as typical gas stations, in which one pays with cash or a credit card per kWh of electricity.

Although the rechargeable electric vehicles and equipment can be recharged from a domestic wall socket, a charging station is usually accessible to multiple electric vehicles and has additional current or connection sensing mechanisms to disconnect the power when the EV is not charging.

There are two main types of safety sensor:

- Current sensors which monitor the power consumed, and maintain the connection only if the demand is within a predetermined range. Sensor wires react more quickly, have fewer parts to fail and are possibly less expensive to design and implement. Current sensors however can use standard connectors and can readily provide an option for suppliers to monitor or charge for the electricity actually consumed.
- Additional physical "sensor wires" which provide a feedback signal such as specified by the undermentioned SAE J1772 and IEC 62196 schemes that require special (multi-pin) power plug fittings.

Until 2013, there was an issue where Blink chargers were overheating and causing damage to both charger and car. The solution employed by the company was to reduce the maximum current.

The Society of Automotive Engineering (SAE) defines the general physical, electrical, communication and performance requirements for the EV charging systems used in North America, as part of standard SAE J1772. Below are the different charging levels that are practiced in North American market.

2.1.1 Based on the rated power, voltage and current, the charging levels in North America are classified into three categories:

- Level 1: refers to the charging from the regular household 120V outlets with a maximum current of 12 or 15 A, which delivers a maximum power of 1.44KW or 1.92KW. Here the active charging element is inside the car (EV's on-board charger).
- Level 2: can be from the 240V outlet or from a dedicated EV charge pint (EVSE) ; AC voltage at 240 V with a maximum current of 80 A and a maximum power of 19.2KW. In level-2 also uses the EV's on-board charger.
- Level 3: Here, the charger is off-board (meaning the EV's on-board charger is by-passed and the charging station provides DC voltage directly to the battery via a DC connector, with a maximum power of 240 kW.

Charging stations for electric vehicles may not need much new infrastructure in developed countries, less than delivering a new alternative fuel over a new network. The stations can leverage the existing ubiquitous electrical grid and home recharging is an option, since most driving is local over short distances which reduces the need for charging mid-trip. For example, in the United States, 78% of commutes are less than 40 miles (64 km) round-trip. Nevertheless, longer drives between cities and towns require a network of public charging stations or another method to extend the range of electric vehicles beyond the normal daily commute. One challenge in such infrastructure is the level of demand: an isolated station along a busy highway may see hundreds of customers per hour if every passing electric vehicle has to stop there to complete the trip. In the first half of the 20th century, internal combustion vehicles faced a similar infrastructure problem.

Currently charging stations are being installed by public authorities, commercial enterprises and some major employers in order to stimulate the market for vehicles that use alternative fuels to gasoline and diesel fuels. For this reason, most charge stations are currently either provided gratis or accessible to members of certain groups without significant charge (e.g. activated by a free "membership card" or by a digital "day code").

As of December 2012, around 50,000 non-residential charging points were deployed in the U.S., Europe, Japan and China. As of August 2014, there are 3,869 CHAdeMO quick chargers deployed around the world, with 1,978 in Japan, 1,181 in Europe and 686 in the United States, 24 in other countries. As of December 2013, Estonia is the first and only country that had completed the deployment of an EV charging network with nationwide coverage, with 165 fast chargers available along highways at a maximum distance of between 40 to 60 km (25 to 37 mi), and a higher density in urban areas.

As of August 2018, there were 800,000 electric vehicles and 18,000 charging stations in the United States. As of March 2013, 5,678 public charging stations existed across the United States, with 16,256 public charging points, of which 3,990 were located in California, 1,417 in Texas, and 1,141 in Washington. As of November 2012, about 15,000 charging stations had been installed in Europe.

As of March 2013, Norway, which has the highest electric ownership per capita, had 4,029 charging points and 127 quick charging stations. As part of its commitment to environmental sustainability, the Dutch government initiated a plan to establish over 200 fast (DC) charging stations across the country by 2015. The rollout will be undertaken by Switzerland-based power and automation company ABB and Dutch startup Fastned [nl], and will aim to provide at least one station every 50 kilometres (31 miles) for the Netherlands' 16 million residents. In addition to that, the E-laad foundation installed about 3000 public (slow) charge points since 2009.

As of December 2012, Japan had 1,381 public quick-charge stations, the largest deployment of fast chargers in the world, but only around 300 slow chargers. As of December 2012, China had around 800 public slow charging points, and no fast charging stations. As of December 2012, the country with the highest ratio of quick chargers to electric vehicles (EVSE/EV) was Japan, with a ratio of 0.030, and the Netherlands had the largest ratio of slow EVSE/EV, with more than 0.50, while the U.S had a slow EVSE/EV ratio of 0.20.

As of September 2013, the largest public charging networks in Australia exist in the capital cities of Perth and Melbourne, with around 30 stations (7 kW AC) established in both cities – smaller networks exist in other capital cities.

In April 2017, YPF, the state-owned oil company of Argentina, reported that it will install 220 fast-load stations for electric vehicles in 110 of its service stations in national territory.

As of August 2019, in the U.S., there are 2,140 CHAdeMO charge stations (3,010 plugs), 1,888 SAE CCS1 charge stations (3,525 plugs), and 678 Tesla super charger stations (6,340 plugs), according to the U.S. DoE's Alternative Fuels Data Center.

2.2 LOCATIONS:

Charging stations can be found and will be needed where there is on-street parking, at taxi stands, in parking lots (at places of employment, hotels, airports, shopping centers, convenience shops, fast food restaurants, coffeehouses etc.), as well as in the workplaces, in driveways and garages at home. Existing filling stations may also incorporate charging stations. As of 2017, charging stations have been criticized for being inaccessible, hard to find, out of order, and slow; thus reducing EV expansion. At the same time more gas stations add EV charging stations to meet the increasing demand among EV drivers. Worldwide, hotels are adopting a policy of providing their guests with electric car charging.

Vehicle and charging station projects and joint ventures

Fig:2.1 Wireless charging station

Fig:2.2 Detail of the wireless inductive charging device

Electric car manufacturers, charging infrastructure providers, and regional governments have entered into many agreements and ventures to promote and provide electric vehicle networks of public charging stations.

The EV Plug Alliance is an association of 21 European manufacturers which proposes an alternative connecting solution. The project is to impose an IEC norm and to adopt a European standard for the connection solution with sockets and plugs for electric vehicle charging infrastructure. Members (Schneider Electric, Legrand, Scame, Nexans, etc.) argue that the system is safer because they use shutters. General consensus is that the IEC 62196 and IEC 61851-1 already have taken care of safety by making parts non-live when touchable.

A battery swapping (or switching) station is a place at which a vehicle's discharged battery or battery pack can be immediately swapped for a fully charged one, eliminating the delay involved in waiting for the vehicle's battery to charge. Battery swapping is common in warehouses using electric forklift trucks.

2.3 HISTORY:

The concept of an exchangeable battery service was first proposed as early as 1896, in order to overcome the limited operating range of electric cars and trucks. It was first put into practice between 1910 and 1924, by Hartford Electric Light Company, through the GEVECO battery service, and was initially available for electric trucks. The vehicle owner purchased the vehicle, without a battery, from General Vehicle Company (GEVECO), part-owned by General Electric, and the electricity was purchased from Hartford Electric through the use of an exchangeable battery. Both vehicles and batteries were modified to facilitate a fast battery exchange. The owner paid a variable per-mile charge and a monthly service fee to cover maintenance and storage of the truck. During the period of the service, the vehicles covered more than 6 million miles.

Beginning in 1917, a similar successful service was operated in Chicago for owners of Milburn Electric cars, who also could buy the vehicle without the batteries. A rapid battery replacement system was implemented to keep running 50 electric buses at the 2008 Summer Olympics.

In recent years, Better Place, Tesla, and Mitsubishi Heavy Industries have been involved with integrating battery switch technology with their electric vehicles to extend driving range. In a battery switch station, the driver does not need to get out of the car while the battery is swapped. Battery swap requires an electric car designed for the "easy swap" of batteries. However, electric vehicle manufacturers working on battery switch technology have not standardized on battery access, attachment, dimension, location, or type.

In 2013, Tesla announced a proprietary charging station service to support owners of Tesla vehicles. A network of Tesla Supercharger stations was supposed to support both battery pack swaps for the Model S, along with the more-widespread fast charging capability for both the Model S and the Tesla Roadster. However, Tesla has abandoned their battery swap initiatives in favor of rapidly expanding fast-charging stations. This decision has driven Tesla to be a market-leader in fast charging stations, amounting to 1,210 stations worldwide, as of April 2018.

2.4 BENEFITS:

The following benefits are claimed for battery swapping:

- Fast battery swapping under five minutes.
- Unlimited driving range where there are battery switch stations available.
- The driver does not have to get out of the car while the battery is swapped.
- The driver does not own the battery in the car, transferring costs over the battery, battery life, maintenance, capital cost, quality, technology, and warranty to the battery switch station company.

- Contract with battery switch company could subsidize the electric vehicle at a price lower than equivalent petrol cars.
- The spare batteries at swap stations could participate in vehicle to grid storage.

Fig:2.3 A Better Place battery switching station in Israel

2.5 MAIN ARTICLE: Better Place (company)

The Better Place network was the first modern commercial deployment of the battery switching model. The Renault Fluence Z.E. was the first electric car enabled with switchable battery technology available for the Better Place network in operation in Israel and Denmark. Better Place used the same technology to swap batteries that F-16 jet fighter aircraft use to load their bombs. Better Place launched its first battery-swapping station in Israel, in Kiryat Ekron , near Rehovot in March 2011. The battery exchange process took five minutes. As of December 2012, about 600 Fluence Z.E.s had been sold in the country. Sales during the first quarter of 2013 improved, with 297 cars sold, bringing the total fleet in Israel close to 900. As of December 2012, there were 17 battery switch stations fully operational in Denmark, enabling customers to drive anywhere across the country in an electric car. Fluence Z.E. sales totaled 198 units through December 2012.

Better Place filed for bankruptcy in Israel in May 2013. The company's financial difficulties were caused by the high investment required to develop the charging and swapping infrastructure, about US$850 million in private capital, and a market penetration significantly lower than originally predicted by Shai Agassi. Fewer than 1,000 Fluence Z.E. cars had been deployed in Israel and only around 400 units in Denmark. Under Better Place's business model, the company owned the batteries, so the court liquidator had to decide what to do with customers who did not have ownership of the battery and risked being left with a useless car.

2.6 TESLA:

Fig:2.4 Tesla Supercharger rapid charging station in Tejon, California. The rooftop of the carport has a solar collector manufactured by SolarCity feeding energy into the grid.

Tesla designed its Model S to allow fast battery swapping. In June 2013, Tesla announced its goal of deploying a battery swapping station in each of its supercharging stations. At a demonstration event in 2013, Tesla showed that a battery swap operation with the Model S took just over 90 seconds, about half the time it takes to refill a gasoline-powered car used for comparison purposes during the event.

The first stations were planned to be deployed along Interstate 5 in California because, according to Tesla, a large number of Model S sedans make the San Francisco-Los Angeles trip regularly. Those stations were to be followed by ones on the Washington, DC, to Boston corridor. Elon Musk said the service would be offered for the price of about 15 US gallons (57 l; 12 imp gal) of gasoline at the current local rate, around US$60 to US$80 at June 2013 prices. Owners could pick up their battery pack fully charged on the return trip, which was included in the swap fee. Tesla would also offer the option to keep the pack received on the swap and pay the price difference if the battery received was newer, or to receive the original pack back from Tesla for a transport fee. Pricing had not been determined.

In June 2015, Musk indicated that Tesla was likely to abandon its plans to build a network of swap stations. He told his company's shareholders that, despite inviting all Model S owners in the California area to try out the one existing facility, at Harris Ranch, only four or five people had done so. Consequently, it was unlikely that the concept was worth expanding.

Gogoro has announced their intention to launch the Gogoro Energy Network in 2015. The network is built on the idea of distributed Go Stations which will serve as battery swapping locations for Gogoro's Smart scooters.

RAIDO is a company created universal battery and charging station for light electric vehicles, like scooters, bikes. The universal battery can be used in almost any light scooter or bike, accompanied with one of a few RAIDO's designed battery mounts. The company main goal is to build charging infrastructure based on vending machine-style charging stations for scooter and bike sharing networks.

2.7 BATTERY SWAP:

Battery Swap is a new European start-up with battery swap solution. It has a working prototype covered by seed funding received from European angels. Swap station takes only 30 seconds to make a complete swap and is 10x cheaper than Tesla supercharger to build.

Fig:2.5 Battery Swap Station for light commercial vehicles in Slovakia

Voltia (formerly Greenway Operator) designed and runs proprietary battery swapping stations (BSS) in Slovakia for switching the batteries in light commercial vehicles. The stations have been in successful commercial operation since 2012.

Voltia's BSS are drive up/drive in station, with a house for a number of batteries to be charged simultaneously. The structure allows drivers to pull up and, using a hydraulic lift, switch their used battery with a new, fully charged one in under 7 minutes. A computer system notifies drivers where to dock their old battery and which new one to take. It is ideal for companies for whom time is of the essence and time spent recharging is time and money.

Fig:2.6 Loading a Voltia electric LKW battery pack

The batteries come in a variety of sizes (40-90kWh), which offer different useful ranges (160–270 km).

2.8 CRITICISM :

These battery swapping solution have been criticized for being proprietary. By creating a monopoly regarding the ownership of the batteries and the patent protected technologies the companies split up the market and decrease the chances of a wider usage of battery swapping.

2.9 CHARGING STATION MANUFACTURERS :

The principal suppliers and manufacturers of charging stations offer a range of options from simple charging posts for roadside use, charging cabinets for covered parking places to fully automated charging stations integrated with power distribution equipment.

An operator manages charging stations from one or more manufacturers.

2.9.1 Block heater power supplies:

In colder areas such as Finland, some northern US states and Canada there already exists some infrastructure for public power outlets provided primarily for use by block heaters and set with circuit breakers that prevent large current draws for other uses. These can sometimes be used to recharge electric vehicles, albeit slowly. In public lots, some such outlets are turned on only when the temperature falls below −20 °C, further limiting their use.

The US-based SAE International defines Level 1 charging as using a standard 120 volt AC house outlet to charge an electric vehicle. This will take a long time to fully charge the car but if only used to commute or travel short distances, a full charge is not needed or can be done overnight. Level 1 is not used in countries where houses typically have 200-240 V.240 volt AC charging is known as Level 2 charging. In North and South America, 240 V is used for household appliances such as clothes driers but in many countries it is the default for most households. Level 2 chargers range from chargers installed in consumer garages, to relatively slow public chargers. They can charge an electric car battery in 4–10 hours. Level 2 chargers are often placed at destinations so that drivers can charge their car while at work or shopping. Level 2 charge points are standard in many countries outside of North and South America. In North and South America Level 2 home chargers are best for drivers who use their vehicles more often or require more flexibility.

"AC Level 3" charging was defined in early editions of SAE J1772 at up to 400 amps, but has been dropped. Edition 7 of J1772 (2017) states in Appendix M "AC Level 3 charging has never been implemented. The following is historical information for reference only." The term "Level 3" appears to have been adopted colloquially to mean DC "fast" charging, although "Level 3" was never defined to mean that in J1772. Table 17 in Appendix M of J1772 (2017) lists AC Level 2 and AC Level 3 from 208 to 240 VAC, and DC Charging with 208-600 V input and 0–1000 V DC output. A Level 3 charging station may cost $120,000.

DC charging generally supports charging up to 500 volts for passenger cars. Some newer high-end passenger car EVs and many heavy duty EV trucks and buses use DC charging with a nominal DC voltage of 700 V or higher, but below 1000 V peak. The organization CHAdeMO was the world's first standardized fast charging protocol with mass-produced EVs in the market. DC chargers in North America often use a 480 VAC input delivering 62.5 kW (peak power can be as much as 120 kW and is varied across the charge. 208 VAC inputs to the charger are also used, and 400 VAC is standard in Europe. The Tesla Supercharger is the most ubiquitous in the United States. For a Tesla Model S75, a supercharger can add around 275 km (170 miles) of range in about 30 minutes or a full charge in around 75 minutes. As of April 2018, Tesla reports that they have 1,210 supercharging stations and is continuously expanding the network.

Another standards organization, The International Electrotechnical Commission, defines charging in modes (IEC 62196).

- **Mode 1** – slow charging from a regular electrical socket (single- or three-phase)
- **Mode 2** – slow charging from a regular socket but with some EV specific protection arrangement (e.g., the Park & Charge or the PARVE systems)
- **Mode 3** – slow or fast charging using a specific EV multi-pin socket with control and protection functions (e.g., SAE J1772 and IEC 62196)
- **Mode 4** – fast charging using some special charger technology such as CHADEMO

There are three connection cases:

- Case A is any charger connected to the mains (the mains supply cable is usually attached to the charger) usually associated with modes 1 or 2.
- Case B is an on-board vehicle charger with a mains supply cable which can be detached from both the supply and the vehicle – usually mode 3.
- Case C is a dedicated charging station with DC supply to the vehicle. The mains supply cable may be permanently attached to the charge-station such as in mode 4.

There are four plug types:

- **Type 1** – single-phase vehicle coupler – reflecting the SAE J1772/2009 automotive plug specifications
- **Type 2** – single- and three-phase vehicle coupler – reflecting the VDE-AR-E 2623-2-2 plug specifications
- **Type 3** – single- and three-phase vehicle coupler equipped with safety shutters – reflecting the EV Plug Alliance proposal
- **Type 4** – fast charge coupler – for special systems such as CHADEMO

For Combined Charging System (CCS) DC charging which requires PLC (Powerline Communications), two extra connectors are added at the bottom of Type 1 or Type 2 vehicle inlets and charging plugs to connect high voltage DC charging stations to the battery of the vehicle. These are commonly known as Combo 1 or Combo 2 connectors. The choice of Combo 1 or Combo 2 style inlets is normally standardised on a per-country basis, so that public charging providers do not need to fit cables with both variants. Generally, North America uses Combo 1 style vehicle inlets, most of the rest of the world uses Combo 2 style vehicle inlets for CCS.

Reports emerged in late July 2013 of a significant conflict between the companies responsible for the two types of charging plugs. The Japanese-developed CHAdeMO standard is favored by Nissan, Mitsubishi, and Toyota, while the SAE J1772 Combo standard is backed by GM, Ford, Volkswagen, and BMW. Both are direct-current quick-charging systems designed to charge the battery of an electric vehicle to 80 percent in approximately 20 minutes, but the two systems are completely incompatible. In light of an ongoing feud between the two groups, experts in the field warned that the momentum of the electric vehicle market will be severely affected. Richard Martin, editorial director for clean technology marketing and consultant firm Navigant Research, stated:

Fast charging, however and whenever it gets built out, is going to be key for the development of a mainstream market for plug-in electric vehicles. The broader conflict between the CHAdeMO and SAE Combo connectors, we see that as a hindrance to the market over the next several years that needs to be worked out.

EV charging station signs:

Fig:2.7 electric charging station signs

US traffic sign used for EV charging station:

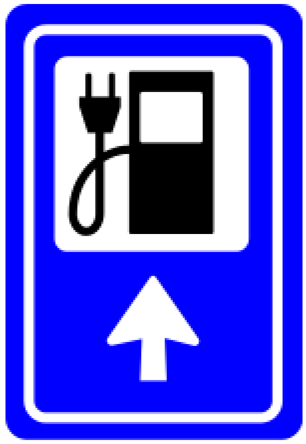


Fig:2.8 Public-domain international charge station sign

In the United States, the standard charging station sign is defined in the Federal Highway Administration's Manual on Uniform Traffic Control Devices (MUTCD) 2009 edition.

In July 2013, FHWA released interim MUTCD approval for charging station signs located on public roads governed by MUTCD standards.

There is an open source, public domain European charge station sign proposed.

Recharging a large battery pack presents a high load on the electrical grid, but this can be scheduled for periods of reduced load or reduced electricity costs. In order to schedule the recharging, either the charging station or the vehicle can communicate with the smart grid. Some plug-in vehicles allow the vehicle operator to control recharging through a web interface or smartphone app. Furthermore, in a vehicle-to-grid scenario the vehicle battery can supply energy to the grid at periods of peak demand. This requires additional communication between the grid, charging station, and vehicle electronics. SAE International is developing a range of standards for energy transfer to and from the grid including SAE J2847/1 "Communication between Plug-in Vehicles and the Utility Grid". ISO and IEC are also developing a similar series of standards known as ISO/IEC 15118: "Road vehicles -- Vehicle to grid communication interface".

2.10 RENEWABLE ELECTRICITY AND RE CHARGING STATIONS:

Charging stations are usually connected to the electrical grid, which often means that their electricity originates from fossil-fuel power stations or nuclear power plants. Solar power is also suitable for electric vehicles. Nidec Industrial Solutions has designed a system that can be powered by either the grid or renewable energy sources like PV (50-320 kW). SolarCity is marketing its solar energy systems along with electric car charging installations. The company has announced a partnership with Rabobank to make electric car charging available for free to owners of Tesla vehicles traveling on Highway 101 between San Francisco and Los Angeles. Other cars that can make use of same charging technology are welcome.

Fig:2.9 Several Chevrolet Volts at a charging station powered with solar panels in Frankfort, Illinois.

2.11 SPARC STATION:

The SPARC (Solar Powered Automotive Recharging Station) uses a single custom fabricated monocrystalline solar panel capable of producing 2.7 kW of peak power to charge pure electric or plug-in hybrid to 80% capacity without drawing electricity from the local grid. Plans for the SPARC include a non-grid tied system as well as redundancy for tying to the grid through a renewable power plan. This supports their claim for net-zero driving of electric vehicles.

CHAPTER:03

CONCEPT OF HARMONICS

3.1 INTRODUCTION

3.1.1 Harmonics:

"A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of fundamental frequency is called as harmonics". Harmonics are multiples of a fundamental frequency. In music, they are called octaves, and are usually desirable. But in a plant's electrical power distribution system, they are unwanted.

Harmonics cause trouble when combined with the fundamental electrical waveform. Since these harmonics are multiples of the 60-Hz fundamental power frequency, harmonic frequencies can be 2-times at 120-Hz, 3-times at 180-Hz, and soon. When harmonics mix with the fundamental, they distort the sine wave (Fig.3.1). Any distorted /truncated waveform can be analyzed by Fourier series to obtain a multitude of frequencies, superimposed upon on another.

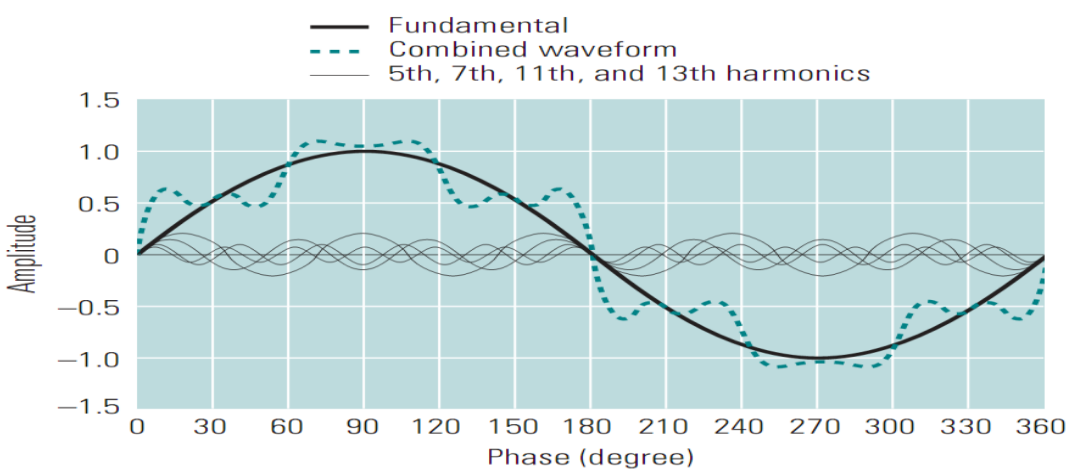


Fig: 3.1 Effect of harmonics on normal voltage or current waveform

3.2 TOTAL HARMONIC DISTORTION(THD):

IEEE (Institute of Electrical and Electronics Engineers) defines harmonic content as "a measure of the presence of harmonics in a voltage or current waveform expressed as a percentage of the amplitude of the fundamental frequency at each harmonic frequency. The total harmonic content is expressed as the square root of the sum of the squares of each of the harmonic amplitudes."

It is defined in the (IEEE) standard 519-1992 as "the ratio of RMS square values of all harmonics to the RMS square values of the fundamental". It is given by the formula.

%THD = (sum of squares of amplitudes of all harmonics)$^{1/2}$ %

(Square of amplitude of fundamental)X 100

$$\%THD = \sqrt{\frac{V_n^2}{V_1^2}} \times 100. \qquad \text{.. (3.1)}$$

Where, n = 2, 3, 4

V_1 = Fundamental Voltage

I_{THD} is called current harmonic distortion

V_{THD} is called voltage harmonic distortion.

3.3 SOURCES OF HARMONICS:

Nonlinear loads are the primary sources of harmonics. These nonlinear loads include, but are not limited to, variable speed drives, solid-state controls for heating and other applications, switched-mode power supplies like those found in virtually every computerized piece of equipment, static Uninterruptible Power supply (UPS) systems, electronic ballasts, electronic test equipment, and electronic office machines. Nonlinear loads draw short bursts of current each waveform cycle, thereby distorting the sinusoidal waveform. Harmonic voltages are the result of harmonic currents interacting with power system impedance.

3.4 TYPES OF NONLINEAR LOADS:

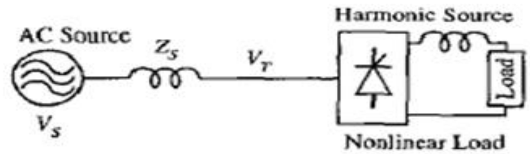
3.4.1 Current-Source Nonlinear Loads (CSNLs):

Thyristor converters are a common and typical source of harmonic currents. Fig: 3.2 Show a thyristor rectifier where a sufficient dc inductance produces a dc current. Fig. 3.2 (a) shows the source voltage and rectifier current waveforms. The current waveform distortion (i.e., the generation of harmonics) results from the switching operation. Because the harmonic current contents and characteristics are less dependent on the ac side, this nonlinear load behaves like a current source. Therefore, it is called a current-source nonlinear load and represented as a current source shown in Fig3.2 Similarly, a diode rectifier with a sufficient dc inductance, a highly inductive load with SCR ac power control, etc., are current-source nonlinear loads.

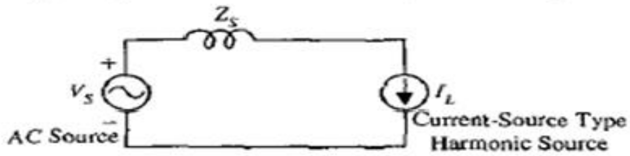
3.4.2 Voltage-Source Nonlinear Loads (VSNLs):

Another common type of harmonic source isa diode rectifier with smoothing dc capacitors, as shown in Fig 3.2(a), Fig 3.2(c)shows typical current and voltage waveforms. Although the currentis highly distorted, its harmonic amplitude is greatly affected by the ac side impedance and source voltage unbalance, whereas the rectifier voltage (i.e., the voltage at the rectifier input terminal, as shown in Fig. 3.2) is characteristic and less dependent on the ac impedance. Therefore, the diode rectifiers behave like a voltage source rather than a current source.

Fig. 3.2 (b) shows the equivalent circuit of the diode rectifier system where the diode rectifier is represented as a harmonic voltage source (or voltage source nonlinear load). It has been shown in that a parallel active filter (PAF) or a parallel passive filter (PPF) is not effective for compensating for such voltage-source nonlinear loads.



(a) Thyristor rectifier for dc drives, heater drives, etc.



(b) Per-phase equivalent circuit of thyristor rectifier.

Fig. Typical current-source nonlinear load.

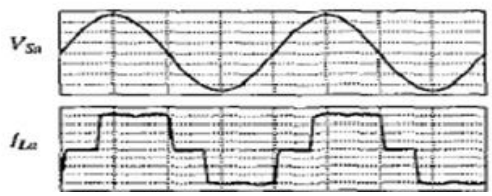


Fig 3.2: Typical voltage and current waveforms of thyristor rectifier, source voltage V_{sa}, and line current I_{la}

3.5 PROBLEMS RESULTING HARMONICS:

The detrimental effects of harmonics include overheating of transformers, power cables, motors, and drives. They cause inadvertent thermal tripping of relays and protective devices. Harmonics can even cause logic faults in digital devices and incorrect voltage and current meter measurements. Any of these damaging results can cause downtime in your plant. The potential for harmonic distortion problems is dependent on two important factors:

- The level of harmonic generation which can be associated with loads in the plant. Harmonic currents are generated by loads which have nonlinear voltage-current characteristics. The number and sizes of these devices at a given bus determines the level of harmonic current generation.

- The system frequency response characteristics at a given bus are dominated by the application of capacitors at that bus. Series reactors for transient control or harmonic control significantly change the frequency response. Problems occur when the system response exhibits a parallel resonance near one of the harmonic components generated by the loads on the system (usually the 5th or 7th harmonic). Resistive load provides damping near these resonant frequencies

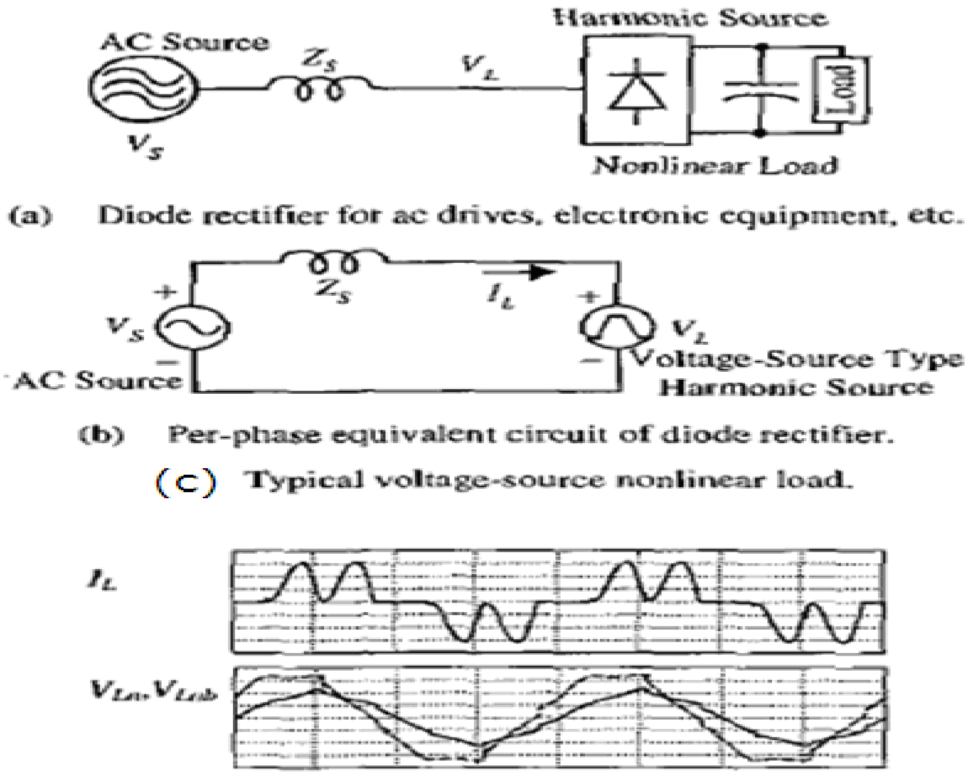


Fig 3.3 Typical current and voltage waveforms of diode rectifier, line current I_{la}, line to neutral voltage V_{la}, line to line voltage V_{lab} at rectifier input.

Harmonic currents increase heating in motors, transformers, and power cables. According to the specification, harmonics can cause electrical losses in transformer cores and motor rotors resulting from hysteretic and eddy currents, making them overheat. Motors experience torque reduction. High harmonics cause electronic equipment to operate erratically.

Harmonics affect different equipment differently. Some of the detrimental effects caused by harmonics are:

- **Capacitors:** Capacitors operate as sinks to increased harmonics and harmonic frequencies. Supply system inductance can resonate with capacitors at some harmonic frequencies, causing large currents and voltages to develop at these frequencies. Increased currents and voltages cause breakdown of dielectric material within capacitors, which, in turn, causes the capacitors to heat.

  As capacitor dielectrics dry out, they are less capable of dissipating heat, and become even more susceptible to damage from harmonics. As this deterioration continues, short circuits or capacitor explosions can occur.

- **Transformers:** Harmonic voltages cause higher transformer voltage and insulation stress, resulting in transformer heating, reduced life, increased copper and iron losses through hysteretic and eddy currents, and insulation stress.

- **Motors** : Harmonic voltages produce magnetic fields that rotate at speeds corresponding to the harmonic frequencies, resulting in increased losses, motor heating, mechanical vibrations and noise, pulsating torques, increased eddy current and hysteretic losses in stator and rotor windings, reduced efficiency, reduced life, and voltage stress on motor winding insulation.

- **CBs and Fuses:** If the distortion results in a higher level of di/dt at zero crossing, load interruption can be made difficult than for a sinusoidal waveform. Fuses mal-operate under the influence of harmonics. These must be derated.

- **Meters** : Modern rms responding voltmeters and ammeters are relatively, immune to the influence of waveform distortion .Normally harmonic affect induction disc drive meters peripherally and in both directions.

- **Watt-hour meters:** Induction disks are calibrated for accurate operation on the fundamental frequency only. Harmonics generate additional torque on these disks, causing improper operation and incorrect readings.

- **Rotating Machines:** Harmonics increase dielectric losses in insulation, raise its hot spot temperature, cause premature failure, increase iron and copper losses and reduce the overall operational efficiencies. Fields produced by some harmonics, in the air gap, rotate in a reverse direction. This can cause cogging, crawling or even shaft vibrations

- **Telephones :**The most common interference mechanism between power system harmonics and the telephone circuit is induction coupling by the power line magnetic field and the loop formed by the telephone conductor and ground.

- **Conductors:** Skin effect and proximity effect both proportional to the square of frequency and hence increase with increasing harmonics. Hence cables have to be derated.

- **Electronic and computer-controlled equipment:** Some electronic equipment depends on zero-crossing or voltage peaks for proper operation. Harmonics can alter these parameters, causing erratic operation and premature equipment failure.

The IEEE specification requires that harmonic distortion of the current waveform be limited to 5%. However, some engineers feel that operating a plant with harmonic distortion this high can cause significant energy losses and shortened equipment life, and recommend that total harmonic distortion should not exceed 1.5% under normal conditions.

3.5.1 Benefits of treating harmonics:

1. Reduction in energy losses.
2. Less equipment repair and replacement
3. Increased life of measuring instruments, cables and equipment's.
4. Increased available capacity
5. Less work interruption
6. Lower maintenance costs

3.6METHODS TO REDUCE HARMONICS:

A power quality site survey can help you determine what, if any, power quality problems your plant has on both sides of the power meter. Most surveys require the installation of power quality monitoring equipment or software. Not only does the survey help determine the presence and the extent of harmonics, but it also reveals other power quality problems such as voltage sags, power interruption, flicker, voltage unbalance, transients, poor wiring, and poor or inadequate grounding.

Harmonics can be minimized and to some extent prevented by:

1. Designing electrical equipment and systems to prevent harmonics from causing equipment or system damage
2. Analyzing harmonic symptoms to determine their causes and devise solutions
3. Identifying and reducing or eliminating the medium that is transmitting harmonics
4. Using power conditioning equipment to mitigate harmonics and other power quality problems when they occur.

When the electrical transmission and distribution system acts as a conduit for harmonics, any user connected to the grid could be responsible for generating them. In this case, work with your utility to identify sources of harmonics and minimize their influence on your plant's electrical system. However, if harmonics are generated within your plant, it's up to you to mitigate them effectively. Attacking the harmonics problem at the source is always the best way to go.

At your plant, minimizing harmonics is better for your equipment and the price you pay for electricity. Beyond that, it is your responsibility to keep your harmonics from feeding back into the electrical distribution medium, thereby affecting power quality of others connected to the grid. Therefore , the supply current has harmonics that will produce undesirable effects, such as source voltage fluctuation, signal interference, supply distortion, additional heating and so on. In order to overcome such problems, a filter is used.

3.6.1 Filters:

A filter is a network which removes unwanted frequency components from the signal and to enhance wanted ones. Filters used in HVDC stations not only for absorb harmonics but also provide VAR support for the converters. The major objective of AC filter is to reduce "Telephone Interference". This can be measured by any one of the following performance indices:

a) Harmonic distortion
b) Telephone interference factor (TIF)
c) Telephone harmonic form factor(THFF)
d) IT product

3.6.2 Types of ac filters:

Various types of ac filter that can be used in the HVDC stations.

1) Single tuned filter
2) Double tuned filter
3) High pass filter:
   I) 2nd order filter
   II) C-type filter

The single tuned filters are designed to filter out characteristics harmonics of single frequency. The double tuned filters are filter two discrete frequencies ,instead of two single tuned filters. The 2^{nd} order filters HPF's are designed to filter out higher harmonics. The tuning of 2^{nd} order filters is not critical. The losses at fundamental frequency can be reduced by using a C-type filters where capacitor, where capacitor is connected in series with L provides a low impedance path to fundamental component of current.

3.7ACTIVE POWER FILTERS:

3.7.1 Introduction to active power filter:

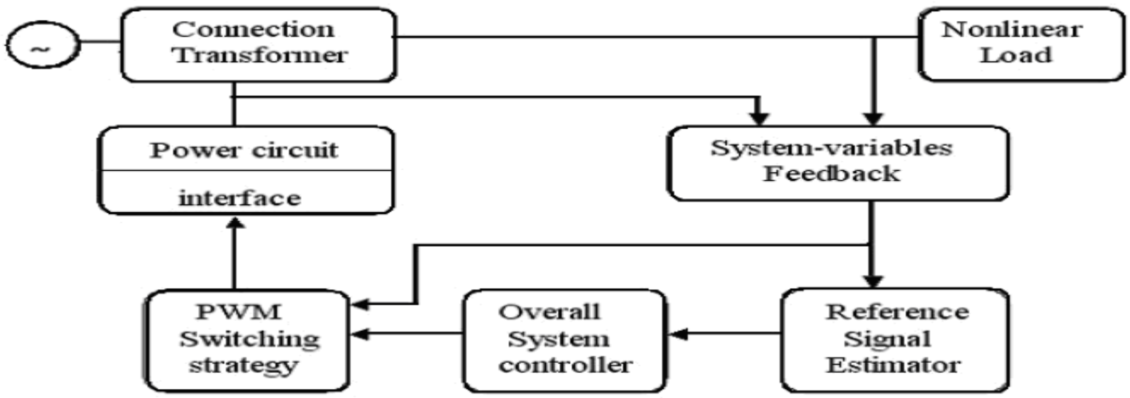


Fig 3.4 Generalized block diagram for active Power filter

Fig 3.4 shows the components of a typical active-power-filter system and their interconnections. The information regarding the harmonic current, generated by a nonlinear load, for example, is supplied to the reference current/voltage estimator together with information about other system variables. The reference signal from the current estimator, as well as other signals, drives the overall system controller. This in turn provides the control for the PWM switching pattern generator.

The output of the PWM pattern generator controls the power circuit via a suitable interface. Thus the voltage or current generated by the power circuit will be coupled to the power system through a connection transformer. The power circuit in the generalized block diagram can be connected in parallel, series or parallel series configurations, depending on the connection transformer used.

3.7.2 CLASSIFICATION OF ACTIVE POWER FILTERS:

Active power filters can be classified using the following criteria.

(a) Classification based on the Converter type

(b) Classification based on the supply system

(c) Power-circuit configuration and connections

(d) System parameters to be compensated.

(e) Classification according to power rating and speed of response required in the compensated system.

(f)Classification based on the control technique.

(g) Classification based on current/voltage reference-estimation technique

CHAPTER 4

CONVERTERS

Many electronic circuits require a rectified DC power supply to power various electronic basic components from the available AC mains supply. Rectifiers are used to convert an AC power to a DC power. Among the rectifiers, the bridge rectifier is the most efficient rectifier circuit. We can define bridge rectifiers as a type of full-wave rectifier that uses four or more diodes in a bridge circuit configuration to efficiently convert alternating (AC) current to a direct (DC) current. In the next few sections, let us learn more about its construction, working, and more.

The construction of a bridge rectifier is shown in the figure below. The bridge rectifier circuit is made of four diodes D_1, D_2, D_3, $D_{4,}$ and a load resistor R_L. The four diodes are connected in a closed-loop configuration to efficiently convert the alternating current (AC) into Direct Current (DC). The main advantage of this configuration is the absence of the expensive center-tapped transformer. Therefore, the size and cost are reduced.

The input signal is applied across terminals A and B and the output DC signal is obtained across the load resistor R_L connected between terminals C and D. The four diodes are arranged in such a way that only two diodes conduct electricity during each half cycle. D_1 and D_3 are pairs that conduct electric current during the positive half cycle/. Likewise, diodes D_2 and D_4 conduct electric current during a negative half cycle.

When an AC signal is applied across the bridge rectifier, during the positive half cycle, terminal A becomes positive while terminal B becomes negative. This results in diodes D_1 and D_3 to become forward biased while D_2 and D_4 become reverse biased.

From the figures given above, we notice that the current flow across load resistor R_L is the same during the positive half cycle and the negative half cycles. The output DC signal polarity may be either completely positive or negative. In our case, it is completely positive. If the direction of diodes is reversed then we get a complete negative DC voltage.

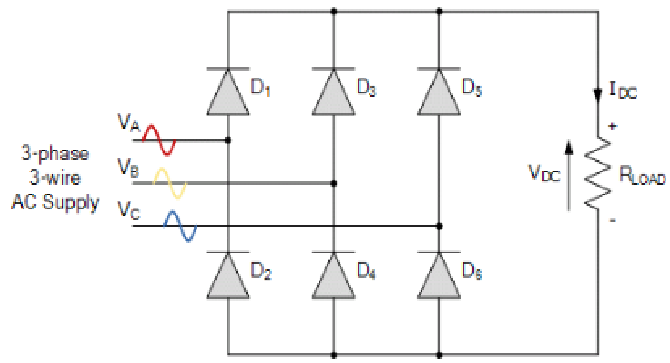


Fig:4.1 Three phase AC DC converter

We saw in the previous tutorial that the process of converting an AC input supply into a fixed DC supply is called *Rectification* with the most popular circuits used to perform this rectification process is one that is based on solid-state semiconductor diodes. In fact, rectification of alternating voltages is one of the most popular applications of diodes, as diodes are inexpensive, small and robust allowing us to create numerous types of rectifier circuits using either individually connected diodes or with just a single integrated bridge rectifier module.

Single phase supplies such as those in houses and offices are generally 120 Vrms or 240 Vrms phase-to-neutral, also called line-to-neutral (L-N), and nominally of a fixed voltage and frequency producing an alternating voltage or current in the form of a sinusoidal waveform being given the abbreviation of "AC".

Three-phase rectification, also known as poly-phase rectification circuits are similar to the previous single-phase rectifiers, the difference this time is that we are using three, single-phase supplies connected together that have been produced by one single three-phase generator.

The advantage here is that 3-phase rectification circuits can be used to power many industrial applications such as motor control or battery charging which require higher power requirements than a single-phase rectifier circuit is able to supply.

3-phase supplies take this idea one step further by combining together three AC voltages of identical frequency and amplitude with each AC voltage being called a "phase". These three phases are 120 electrical degrees out-of-phase from each other producing a phase sequence, or phase rotation of: $360^o \div 3 = 120^o$ as shown.

The advantage here is that a three-phase alternating current (AC) supply can be used to provide electrical power directly to balanced loads and rectifiers. Since a 3-phase supply has a fixed voltage and frequency it can be used by a rectification circuit to produce a fixed voltage DC power which can then be filtered resulting in an output DC voltage with less ripple compared to a single-phase rectifying circuit.

4.1 THREE-PHASE RECTIFICATION:

Having seen that a 3-phase supply is just simply three single-phases combined together, we can use this multi-phase property to create 3-phase rectifier circuits.

As with single-phase rectification, three-phase rectification uses diodes, thyristors, transistors, or converters to create half-wave, full-wave, uncontrolled and fully-controlled rectifier circuits transforming a given three-phase supply into a constant DC output level. In most applications a three-phase rectifier is supplied directly from the mains utility power grid or from a three-phase transformer if different DC output level is required by the connected load.

As with the previous single-phase rectifier, the most basic three-phase rectifier circuit is that of an uncontrolled half-wave rectifier circuit which uses three semiconductor diodes, one diode per phase as shown.

As before, assuming a phase rotation of Red-Yellow-Blue (V_A – V_B – V_C) and the red phase (V_A) starts at 0^o. Each phase connects between a pair of diodes as shown. One diode of the conducting pair powers the positive (+) side of load, while the other diode powers the negative (-) side of load.

Thus diodes D_1 D_3 and D_5 feed the positive rail and depending on which one has a more positive voltage at its anode terminal conducts. Likewise, diodes D_2 D_4 and D_6 feed the negative rail and whichever diode has a more negative voltage at its cathode terminal conducts.

Then we can see that for three-phase rectification, the diodes conduct in matching pairs giving a conduction pattern for the load current of: D_{1-2} D_{1-6} D_{3-6} D_{3-4} D_{5-4} D_{5-2} and D_{1-2} as shown.

4.2 Full-wave Three-phase Rectifier Conduction Waveform:

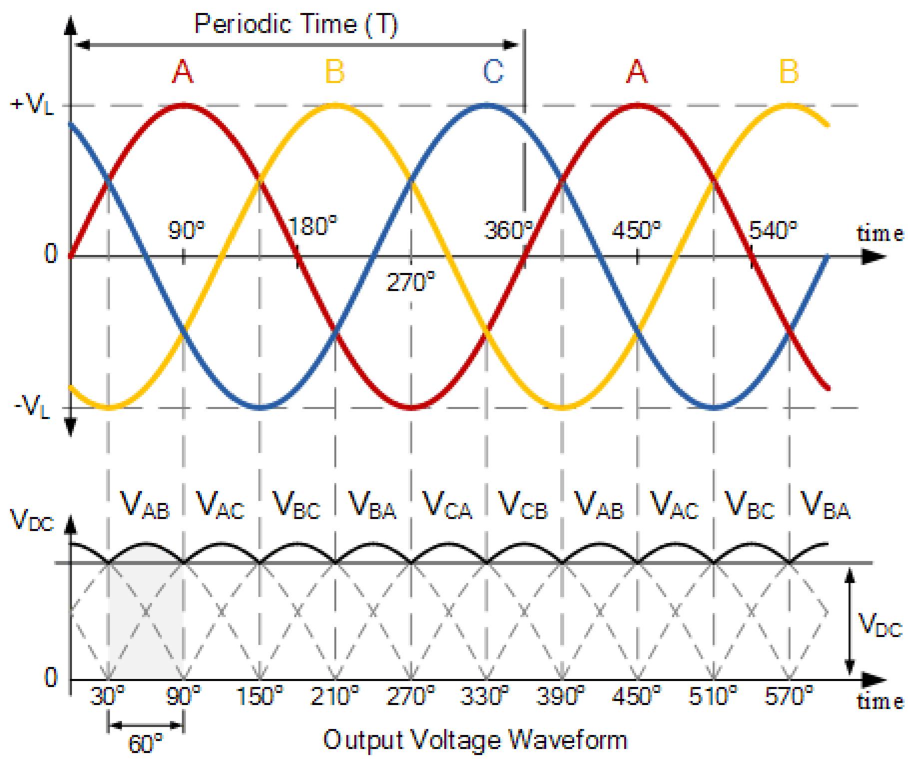


Fig:4.2 full-wave three phase Rectifier conduction waveform

In 3-phase power rectifiers, conduction always occurs in the most positive diode and the corresponding most negative diode. Thus as the three phases rotate across the rectifier terminals, conduction is passed from diode to diode. Then each diode conducts for 120° (one-third) in each supply cycle but as it takes two diodes to conduct in pairs, each pair of diodes will conduct for only 60° (one-sixth) of a cycle at any one time as shown above.

Therefore we can correctly say that for a 3-phase rectifier being fed by "3" transformer secondaries, each phase will be separated by 360°/3 thus requiring 2*3 diodes. Note also that unlike the previous half-wave rectifier, there is no common connection between the rectifiers input and output terminals. Therefore it can be fed by a star connected or a delta connected transformer supply.

So the average DC value of the output voltage waveform from a 3-phase full-wave rectifier is given as:

$$V_{DC} = \frac{3\sqrt{3}}{\pi} V_S = 1.65 * V_S \qquad ......(4.1)$$

Where: V_S is equal to ($V_{L(PEAK)} \div \sqrt{3}$) and where $V_{L(PEAK)}$ is the maximum line-to-line voltage (V_L*1.414).

4.3 3-phase Rectification Example No2:

A 3-phase full-wave bridge rectifier is required to fed a 150Ω resistive load from a 3-phase 127 volt, 60Hz delta connected supply. Ignoring the voltage drops across the diodes, calculate: 1. the DC output voltage of the rectifier and 2. the load current.

1. **The DC output voltage:**

The RMS (Root Mean Squared) line voltage is 127 volts. Therefore the line-to-line peak voltage ($V_{L-L(PEAK)}$) will be:

$$V_{L(PEAK)} = V_{L(RMS)} \times \sqrt{2} = 127 \times 1.414 = 179.6V \quad ....(4.2)$$

As the supply is 3-phase, the phase to neutral voltage (V_{P-N}) of any phase will be:

$$V_S = V_{L(PEAK)} \div \sqrt{3} = 179.6 \div 1.732 = 103.7V \quad ....(4.3)$$

Note that this is basically the same as saying:

$$V_S = \frac{V_{L(RMS)} \times \sqrt{2}}{\sqrt{3}} = 103.7V \quad ....(4.4)$$

Thus the average DC output voltage from the 3-phase full-wave rectifier is given as:

$$V_{DC} = \left[\frac{3\sqrt{3}}{\pi}\right] V_S = 1.654 \times V_S$$

$$\therefore V_{DC} = 1.654 \times 103.7 = 171.5V \quad ....(4.5)$$

Again, we can reduce the maths a bit by correctly saying that for a given line-to-line RMS voltage value, in our example 127 volts, the average DC output voltage is:

$$V_{DC} = \frac{3\sqrt{2}}{\pi} V_{L(RMS)} = 1.35 \times 127 = 171.5V \quad ....(4.6)$$

2. **The rectifiers load current:**

The output from the rectifier is feeding a 150Ω resistive load. Then using Ohms law the load current will be:

$$I_{LOAD} = V_S \div R_L = 171.5 \div 150 = 1.14 \text{ Amps} \quad ....(4.7)$$

Uncontrolled 3-phase rectification uses diodes to provide an average output voltage of a fixed value relative to the value of the input AC voltages. But to vary the output voltage of the rectifier we need to replace the uncontrolled diodes, either some or all of them, with thyristors to create what are called half-controlled or fully-controlled bridge rectifiers.

Thyristors are three terminal semiconductor devices and when a suitable trigger pulse is applied to the the thyristors gate terminal when its Anode–to-Cathode terminal voltage is positive, the device will conduct and pass a load current. So by delaying the timing of the trigger pulse, (firing angle) we can delay the instant in time at which the thyristor would naturally switch "ON" if it were a normal diode and the moment it starts to conduct when the trigger pulse is applied.

Thus with a controlled 3-phase rectification which uses thyristors instead of diodes, we can control the value of the average DC output voltage by controlling the firing angle of the thyristor pairs and so the rectified output voltage becomes a function of the firing angle, α.

Therefore the only difference to the formula used above for the average output voltage of a 3-phase bridge rectifier is in the cosine angle, *cos(α)* of the firing or triggering pulse. So if the firing angle is zero, (cos(0) = 1), the controlled rectifier performs similar to the previous 3-phase uncontrolled diode rectifier with the average output voltages being the same.

Thus, a bridge rectifier allows electric current during both positive and negative half cycles of the input AC signal.

The output waveforms of the bridge rectifier are shown in the below figure.

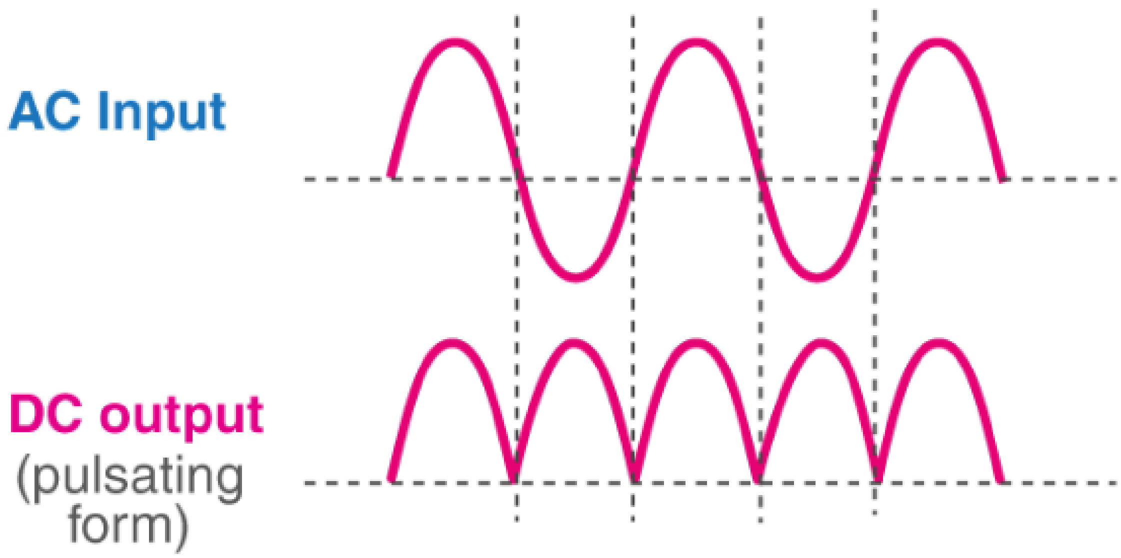


Fig:4.3 output waveforms of bridge rectifier

4.4 CHARACTERISTICS OF BRIDGE RECTIFIER:

4.4.1 Ripple Factor:

The smoothness of the output DC signal is measured by a factor known as the ripple factor. The output DC signal with fewer ripples is considered a smooth DC signal while the output with high ripples is considered a high pulsating DC signal.

Mathematically, the ripple factor is defined as the ratio of ripple voltage to the pure DC voltage.
For bridge rectifiers, the ripple factor is 0.48.

4.4.2 Peak Inverse Voltage:

The maximum voltage that a diode can withstand in the reverse bias condition is known as a peak inverse voltage. During the positive half cycle, the diodes D_1 and D_3 are in the conducting state while D_2 and D_4 are in the non-conducting state. Similarly, during the negative half cycle, diodes D_2 and D_4 are in the conducting state, and diodes D_1 and D_3 are in the non-conducting state.

4.4.3 Efficiency:

The rectifier efficiency determines how efficiently the rectifier converts Alternating Current (AC) into Direct Current (DC). Rectifier efficiency is defined as the ratio of the DC output power to the AC input power. The maximum efficiency of a bridge rectifier is 81.2%.

4.4.4 Advantages:

- The efficiency of the bridge rectifier is higher than the efficiency of a half-wave rectifier. However, the rectifier efficiency of the bridge rectifier and the center-tapped full-wave rectifier is the same.
- The DC output signal of the bridge rectifier is smoother than the output DC signal of a half-wave rectifier.
- In a half-wave rectifier, only half of the input AC signal is used and the other half is blocked. Half of the input signal is wasted in a half-wave rectifier. However, in a bridge rectifier, the electric current is allowed during both positive and negative half cycles of the input AC signal. Hence, the output DC signal is almost equal to the input AC signal.

4.4.5 Disadvantages:

- The circuit of a bridge rectifier is complex when compared to a half-wave rectifier and center-tapped full-wave rectifier. Bridge rectifiers use 4 diodes while half-wave rectifiers and center tapped full wave rectifiers use only two diodes.
- When more diodes are used more power loss occurs. In a center-tapped full-wave rectifier, only one diode conducts during each half cycle. But in a bridge rectifier, two diodes connected in series conduct during each half cycle. Hence, the voltage drop is higher in a bridge rectifier.

CHAPTER-5

CONVENTIONAL AND PROPOSED FAST CHARGING SYSTEM STRUCTURES

5.1 INTRODUCTION:

Efficiency is one of the key parameters to evaluate the performance of electric vehicle (EV) charging system. Among many charging circuit topologies, fast charging systems seem to have a promising future for their shorter charging time for EVs, especially those bidirectional fast chargers which accommodate to the concept "vehicle-to-grid(V2G)". Traditional fast charging system usually consists of two stages, namely an AC/DC converter and a downstream DC/DC converter .Hence the output voltage could be freely adjusted to accommodate the wide battery voltage range (280V-400V) for different EVs. In commercial EV fast chargers, the downstream DC/DC converter is usually designed to be an isolated converter where a high frequency transformer is necessary for isolation.

However, conversion efficiency is limited a lot compared to non-isolated DC/DC converter. Once the non-isolated DC/DC converter is adopted, there must be a power frequency transformer at the grid side to ensure electrical safety. No matter which kind of two-stage converters, it seems difficult to improve the system efficiency further with lower cost. In this project, a single-stage AC/DC structure is considered to replace two-stage structure with lower cost but higher efficiency. To accommodate the battery voltage range, the turn ratio of power frequency transformer is designed to make the input voltage of the AC/DC converter lower than the grid voltage.

A fair system efficiency comparison is carried out between the proposed structure and the traditional two-stage structure. And the efficiency calculation results are validated by the SEMISEL simulation tool. Through the analysis and calculation, the proposed single-stage structure has nearly more than 2% higher power conversion efficiency compared to traditional two-stage structure with no additional cost.

5.2 CONVENTIONAL SYSTEM AND PROPOSED SYSTEM:

A. CONVENTIONAL SYSTEM:

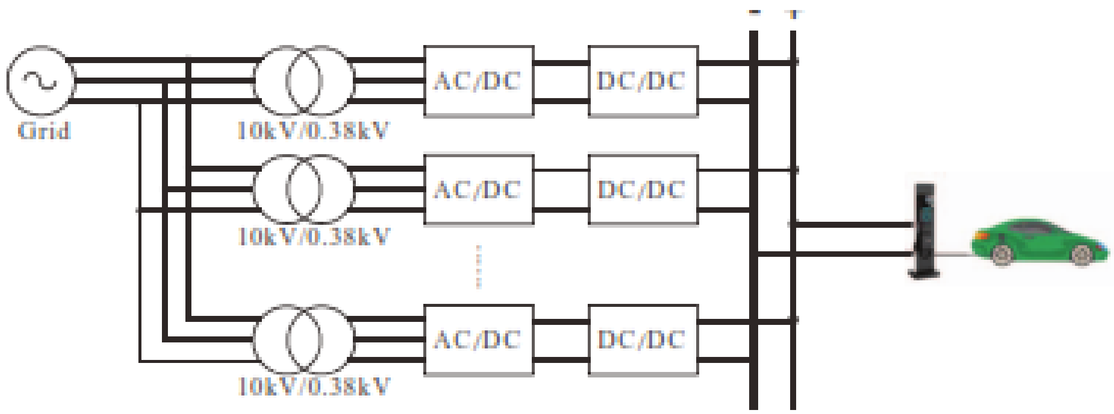


Fig:5.1: Two stage charging system

Traditional fast charging system usually consists of two stages, namely an AC/DC converter and a downstream DC/DC converter. Hence the output voltage could be freely adjusted to accommodate the wide battery voltage range (280V-400V) for different EVs.

In commercial EV fast chargers, the downstream DC/DC converter is usually designed to be an isolated converter where a high frequency transformer is necessary for isolation. However, the power conversion efficiency is limited a lot compared to non-isolated DC/DC converter. Once the non-isolated DC/DC converter is adopted, there must be a power frequency transformer at the grid side to ensure electrical safety as shown in Fig.5.1. No matter which kind of two-stage converters, it seems difficult to improve the system efficiency further with lower cost.

B. PROPOSED SYSTEM:

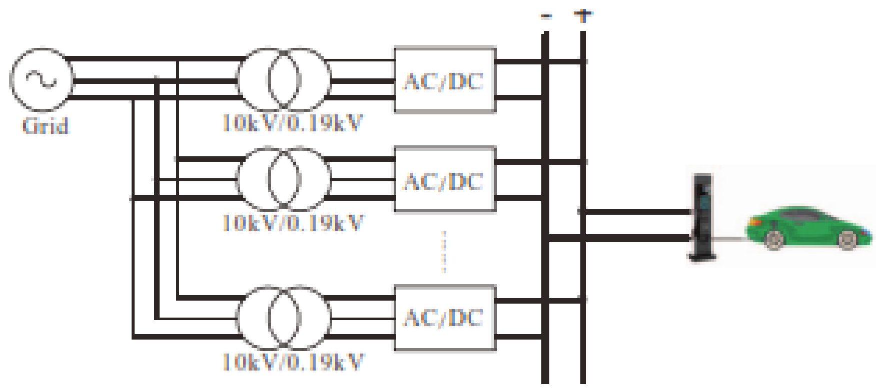


Fig:5.2 Proposed single stage charging system

This project comes up with a novel charger with single-stage structure, where the turn ratio of the transformer is specially designed to obtain a lower input line-to-line voltage (190V) for the single AC/DC converter.

In this project, a single-stage AC/DC structure shown in Fig5.2 is considered to replace two-stage structure with lower cost but higher efficiency. To accommodate the battery voltage range, the turn ratio of power frequency transformer is designed to make the input voltage of the AC/DC converter lower than the grid voltage. A fair system efficiency comparison is carried out between the proposed structure and the traditional two-stage structure. And the efficiency calculation results are validated by the SEMISEL simulation tool. Through the analysis and calculation, the proposed single-stage structure has nearly more than 2% higher power conversion efficiency compared to traditional two-stage structure with no additional cost. Furthermore based on the proposed structure, there is another problem that the harmonic power from the grid can be directly transmitted to the battery packs to be solved . Hence, a small capacity bidirectional half bridge DC/DC converter shown in Fig5.3 is applied in this paper to work as an DC active power filter (DCAPF) to compensate the harmonic current as shown in Fig5.4. Both the simulation and experimental results indicate that the DCAPF method is effective in battery harmonic current compensation.

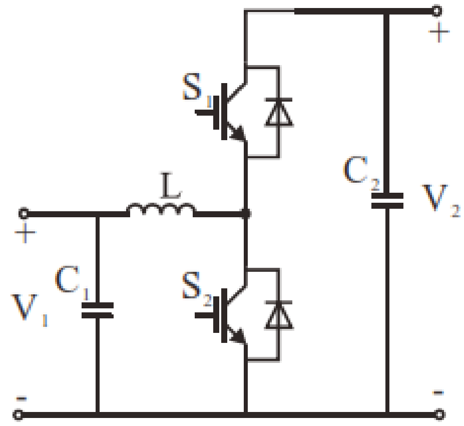


Fig:5.3 Bidirectional half bridge DC/DC converter

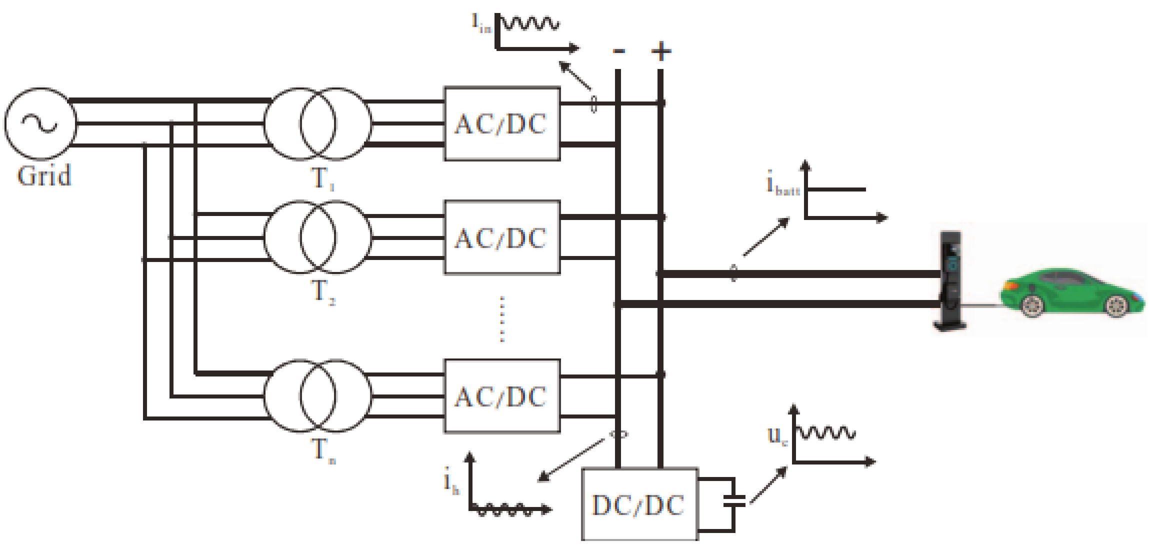


Fig:5.4 Single stage charging system with DCAPF

5.3 BLOCK DIAGRAM:

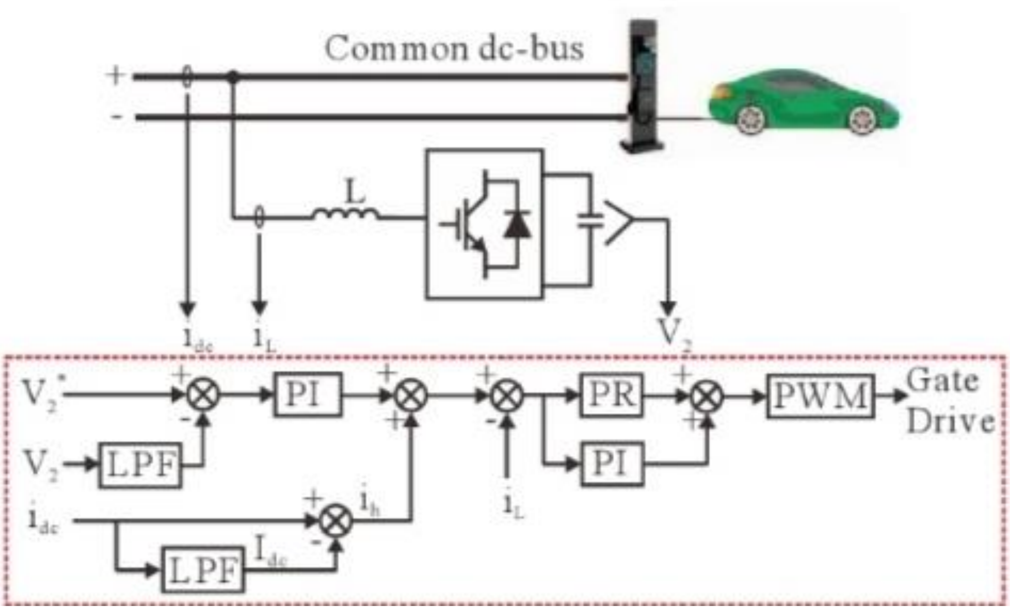


Fig:5.5 Control diagram of DCAPF method

- In single stage system,V2 is the output of DC/DC converter is taken as reference signal and is compared with actual signal.
- Difference of those signals results in generation of error signal, which is given to PI controller.
- And there is a dc link current which is combination of both harmonic current and rated current.
- From this harmonic current is eliminated and dc current (I dc) is taken which generates error signal(I h).
- PI controller current and (I h) current is differentiated to get error . This error is compared with load current
- The resultant signal is fed to cascaded controller I.e PI and PR controllers.
- The output from this cascaded controller is given to PWM controller which generate pure pulsating signals .Which in turn connected to the DC/DC converter ,so that harmonics can be eliminated.
- DC/DC Converter is connected to the dc bus to compensate the harmonic current which may be transmitted to battery packs.

- For the harmonic current extraction, the dc component is obtained by sampling current through a low pass filter.
- As for the voltage loop, it is used to stabilize the voltage of the capacitor C2. There-fore the reference inductor current consists of a small dc component and the extracted harmonic component.
- Naturally the current loop should contain both PI & PR controllers to fit for dc and sinusoidal signals.
- To verify the DCAPF method, both simulations and experiments are conducted in this project.

5.4 ADVATAGES OF PROPOSED SYSTEM:

- The major advantage from this project proposed structure, we can have higher efficiency with lower cost.
- The battery charging will be done faster.
- Due to the fast charging capability , we can have quick travel.
- The harmonics induced in the battery packs are suppressed , which gives more dotage to the battery.

5.5 APPLICATIONS:

- Public transportation ,HEVs, start –stop system.
- Back up and ups systems.
- Systems of energy recuperation.
- Consumer electronics.

CHAPTER 6

PROPOSED SIMULATION SYSTEM

6.1 INTRODUCTION:

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.
Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor. The model depicts the time-dependent mathematical relationships among the system's inputs, states, and outputs. Then, we use Simulink to simulate the behavior of the system over a specified time span. Simulink uses information that you entered into the model to perform the simulation.

6.2 BLOCK DIAGRAM:

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block). The lines represent connections of block inputs to block outputs. Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time. A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate. A block comprises one or more of the following:

1) A set of inputs,
2) A set of states, and
3) A set of outputs.

A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance. Continuous Versus discrete Blocks Simulink's standard block set includes continuous blocks and discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only at integral multiples of a fixed interval called the block's sample time. Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, depending on whether they are driven by continuous or discrete blocks. A block that can be either discrete or continuous is said to have an implicit sample rate. The implicit sample time is continuous if any of the block's inputs are continuous. The implicit sample time is equal to the shortest input sample time if all the input sample times are integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times.

Simulink can optionally color code a block diagram to indicate the sample times of the blocks it contains, e.g., black (continuous), magenta (constant), yellow (hybrid), red (fastest discrete), and so on. The block contains block name, icon, and block library that contain the block, the purpose of the block.

6.3 SIMULINK BLOCK LIBRARIES:

Simulink organizes its blocks into block libraries according to their behavior.

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-time components.
4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.

6) The Functions & Tables library contains blocks that describe general functions and table look-up operations.
7) The Nonlinear library contains blocks that describe nonlinear functions.
8) The Signal & Systems library contains blocks that allow multiplexing and demultiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types of subsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

6.4 SUB SYSTEMS:

Simulink allows to model a complex system as a set of interconnected subsystems each of which is represented by a block diagram. We create a subsystem using Simulink's Subsystem block and the Simulink model editor. We can embed subsystems with subsystems to any depth to create hierarchical models. We can create conditionally executed subsystems that are executed only when a transition occurs on a triggering or enabling input.

6.5 SOLVERS:

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model. The process of computing the successive states of a system from its model is known as solving the model. No single method of solving a model suffices for all systems. Accordingly, Simulink provides a set of programs, known as solvers, that each embody a particular approach to solving a model. The Simulation Parameters dialog box allows us to choose the solver most suitable for our model.

6.5.1 Fixed-Step and Variable-Step Solvers:

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size. Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly and increasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time, required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

6.5.2 Continuous and Discrete Solvers:

Continuous solvers use numerical integration to compute a model's continuous states at the current time step from the states at previous time steps and the state derivatives. Continuous solvers rely on the model's blocks to compute the values of the model's discrete states at each time step. Mathematicians have developed a wide variety of numerical integration techniques for solving the ordinary differential equations (ODEs) that represent the continuous states of dynamic systems. Simulink provides an extensive set of fixed-step and variable-step continuous solvers, each implementing a specific ODE solution method. Some continuous solvers subdivide the simulation time span into major and minor steps, where a minor time step represents a subdivision of the major time step. The solver produces a result at each major time step. It use results at the minor time steps to improve the accuracy of the result at the major time step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time-step for a model and nothing else. They do not compute continuous states and they rely on the model's blocks to update the model's discrete states. We can use a continuous solver, but not a discrete solver, to solve a model that contains both continuous and discrete states. This is because a discrete solver does not handle continuous states. If you select a discrete solver for a continuous model, Simulink disregards your selection and uses a continuous solver instead when solving the model.

Simulink provides two discrete solvers, a fixed-step discrete solver and a variable-step discrete solver. The fixed-step solver by default chooses a step size and hence simulation rate fast enough to track state changes in the fastest block in our model. The variable-step solver adjusts the simulation step size to keep pace with the actual rate of discrete state changes in our model. This can avoid unnecessary steps and hence shorten simulation time for multirate models.

6.6 MODEL EXECUTION PHASE:

In the simulation model execution phase, Simulink successively computes the states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps. The length of time between steps is called the step size. The step size depends on the type of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states have discontinuities (Zero Crossing Detection). At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated. At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

1) Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and states to the output function as it may require these arguments to compute the block's output. Simulink updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.
2) Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's continuous states by numerically integrating the time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.
3) Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.
4) Computes the time for the next time step.

Simulink repeats steps 1 through 4 until the simulation stop time is reached.

6.7 Block Sorting Rules:

Simulink uses the following basic update rules to sort the blocks:

1) Each block must be updated before any of the direct-feed through blocks that it drives. This rule ensures that the inputs to direct-feed through blocks will be valid when they are updated.
2) Non direct-feed through blocks can be updated in any order as long as they are updated before any direct-feed through blocks that they drive. This rule can be met by putting all non direct-feed through blocks at the head of the update list in any order. It thus allows Simulink to ignore non direct-feed through blocks during the sorting process.

The result of applying these rules is an update list in which non direct-feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct-feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output. However, an algebraic loop can represent a set of simultaneous algebraic equations (hence the name) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step. Accordingly, Simulink assumes that loops involving direct-feed through blocks do, in fact, represent a solvable set of algebraic equations and attempts to solve them each time the block is updated during a simulation.

6.8 PROPOSED SYSTEM SIMULATION CIRCUIT:

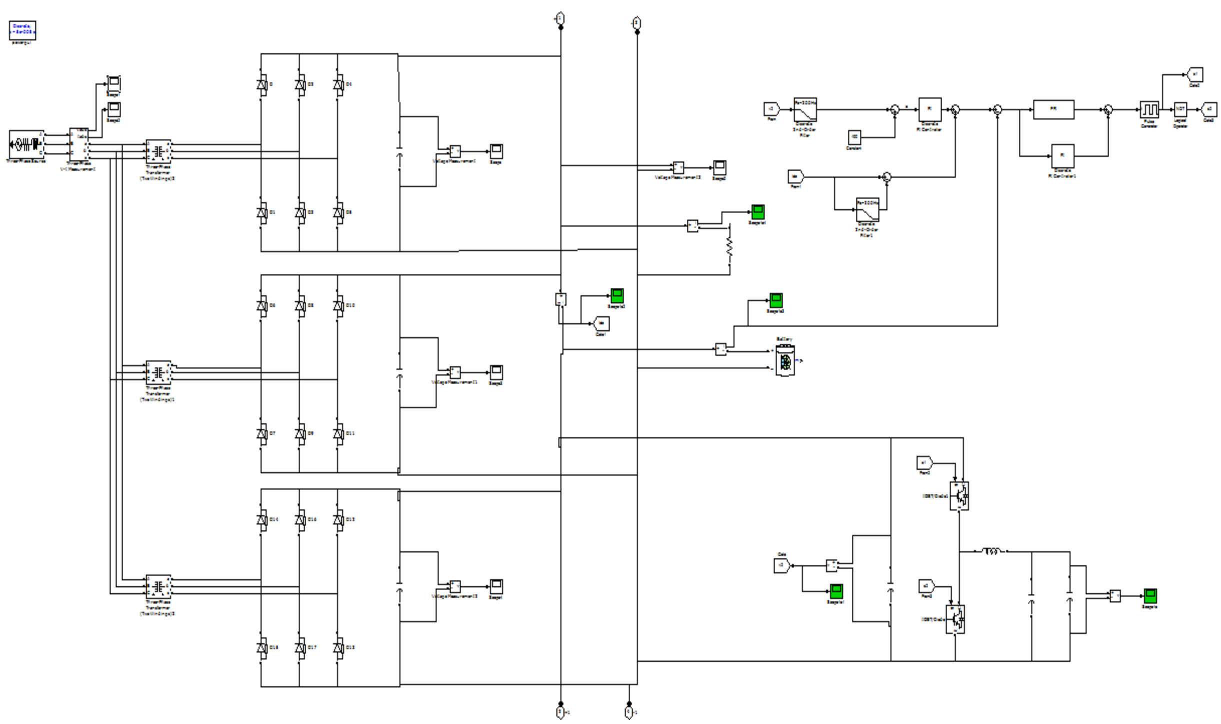
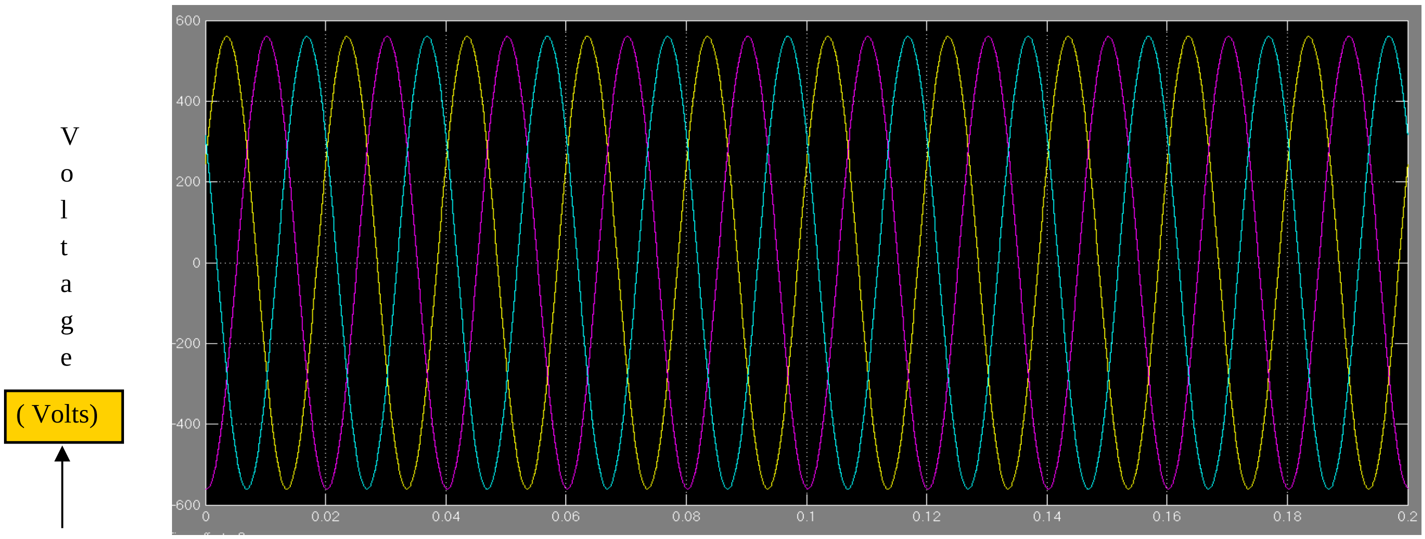


Fig:6.1 Proposed circuit configuration

CHAPTER 07

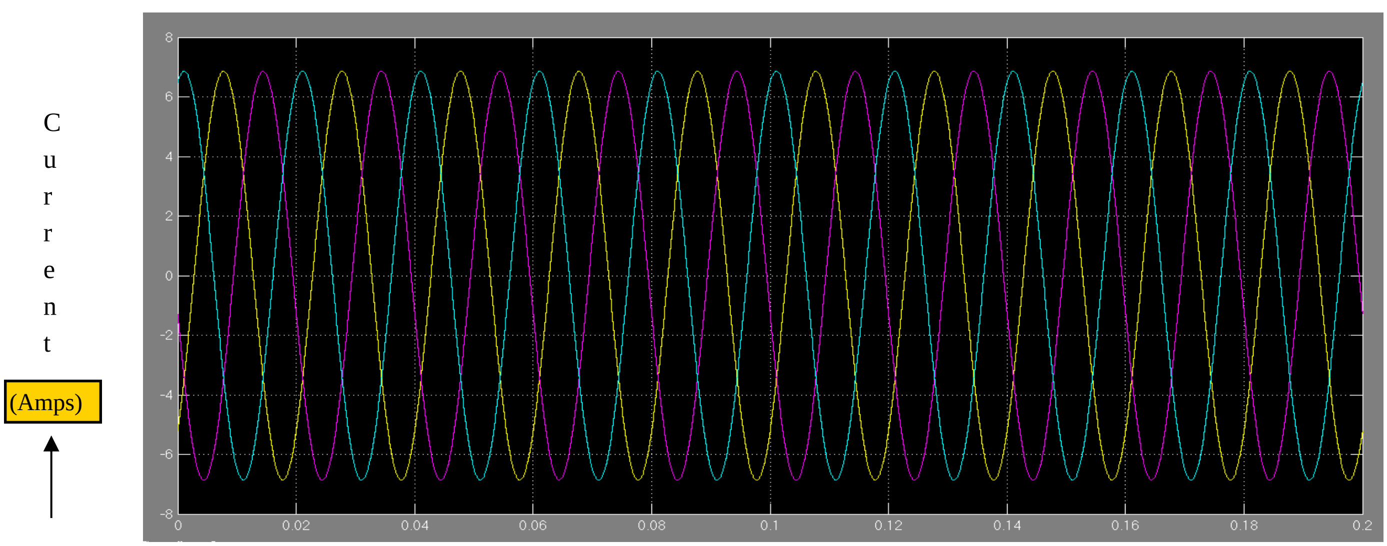
RESULTS



------------Time(sec)

Fig:7.1 Input grid voltage

- We can observe three phase balanced voltages coming from the grid side in this above figure.



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--Fig:7.2 Input grid current

- We can observe the three phase balanced currents at the grid in this figure

C
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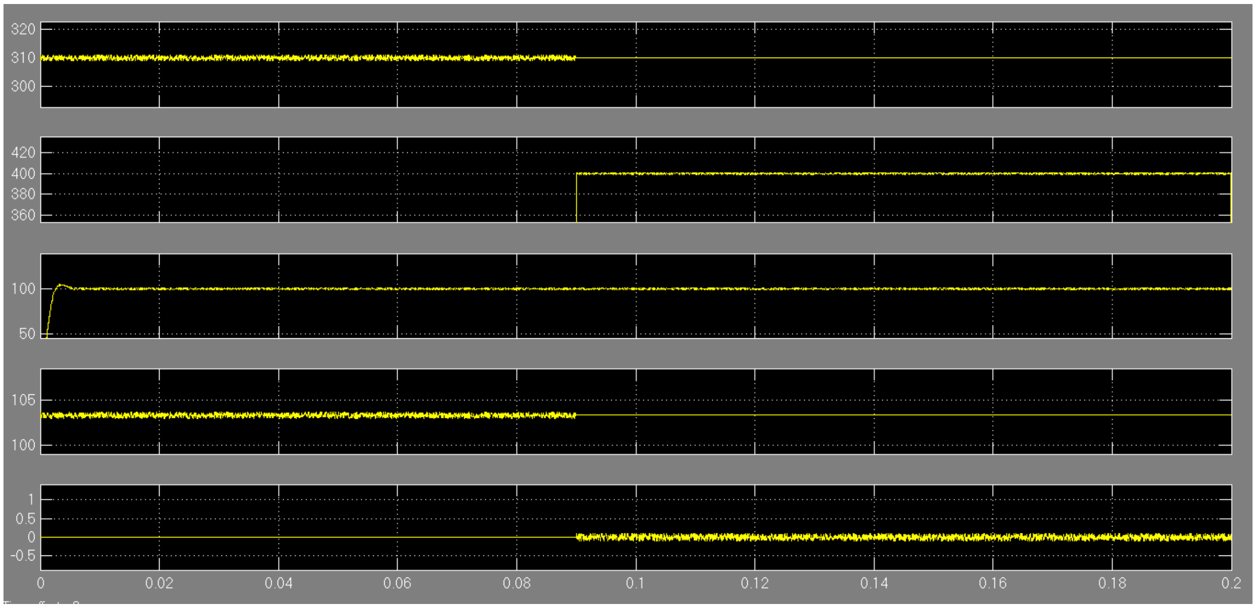
(Amps)



----------------------Time(sec)

Fig:7.3 main output waveforms

C
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n
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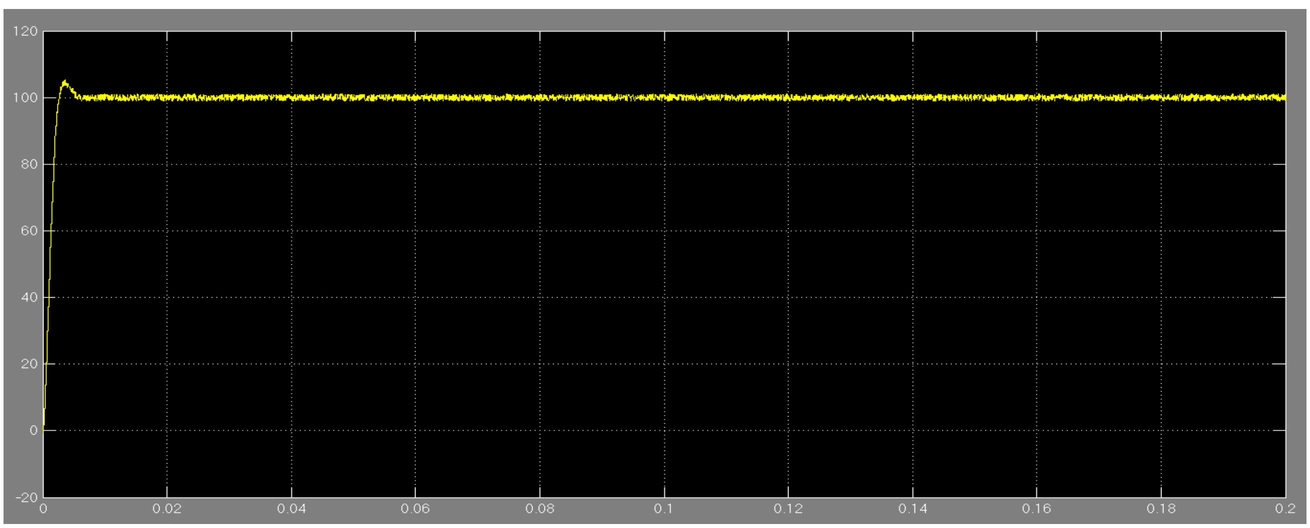
(Amps)



----------------------Time(sec)

fig:7.4 DC bus current

- As DC bus reduces some order of harmonics and provides better total harmonic distortion(THD),we can observe increase in THD in this above figure

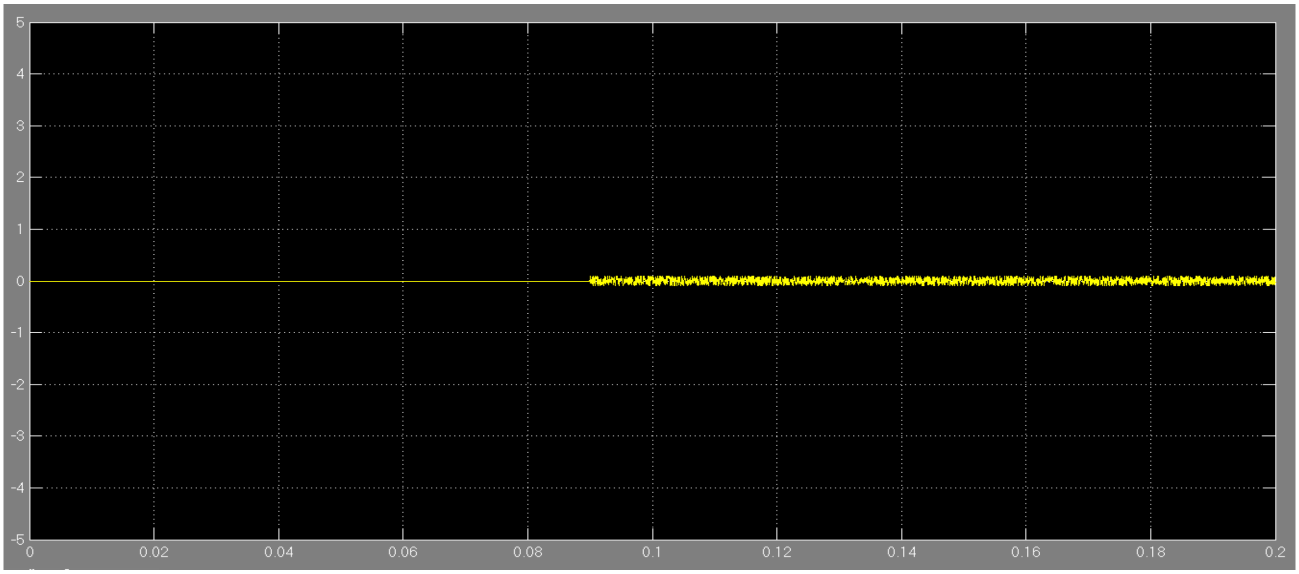


fig:7.5 Inductor current

- This is the waveform we can observe across the inductor in the converter .Here we can see, it is able to handle the peak switching currents thus gives a constant current power supply.

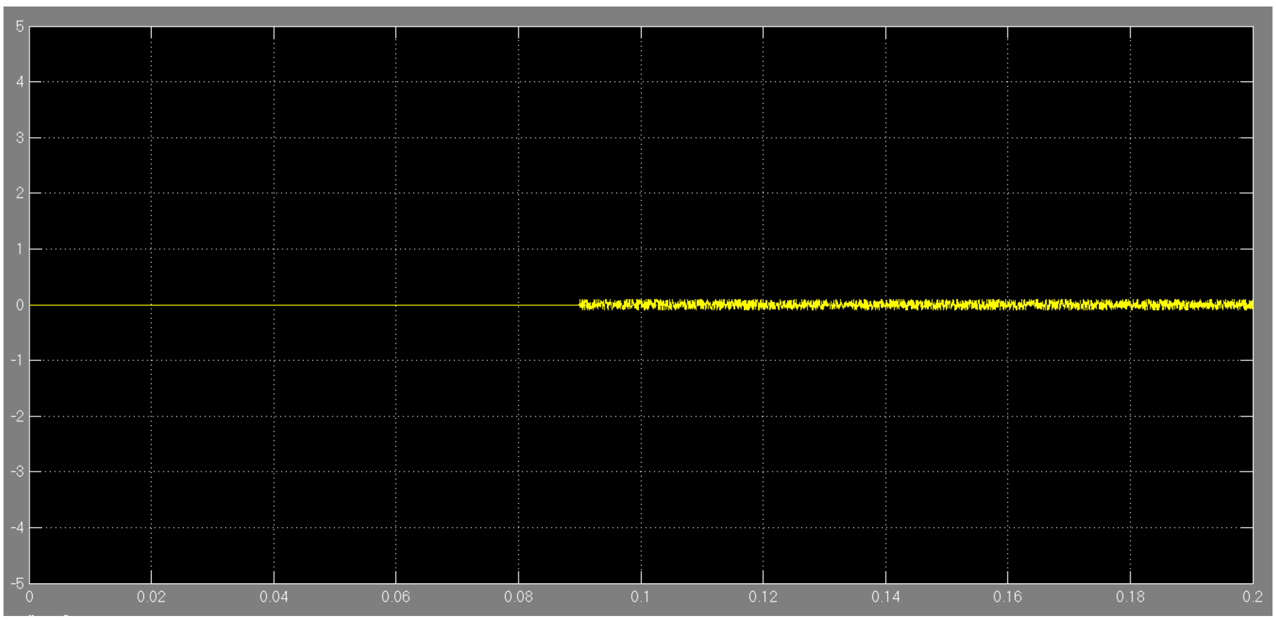


Fig:7.6 Battery current

- We can observe the harmonics suppressed and pure dc signal can be supplied for charging the electric vehicle in this above figure.

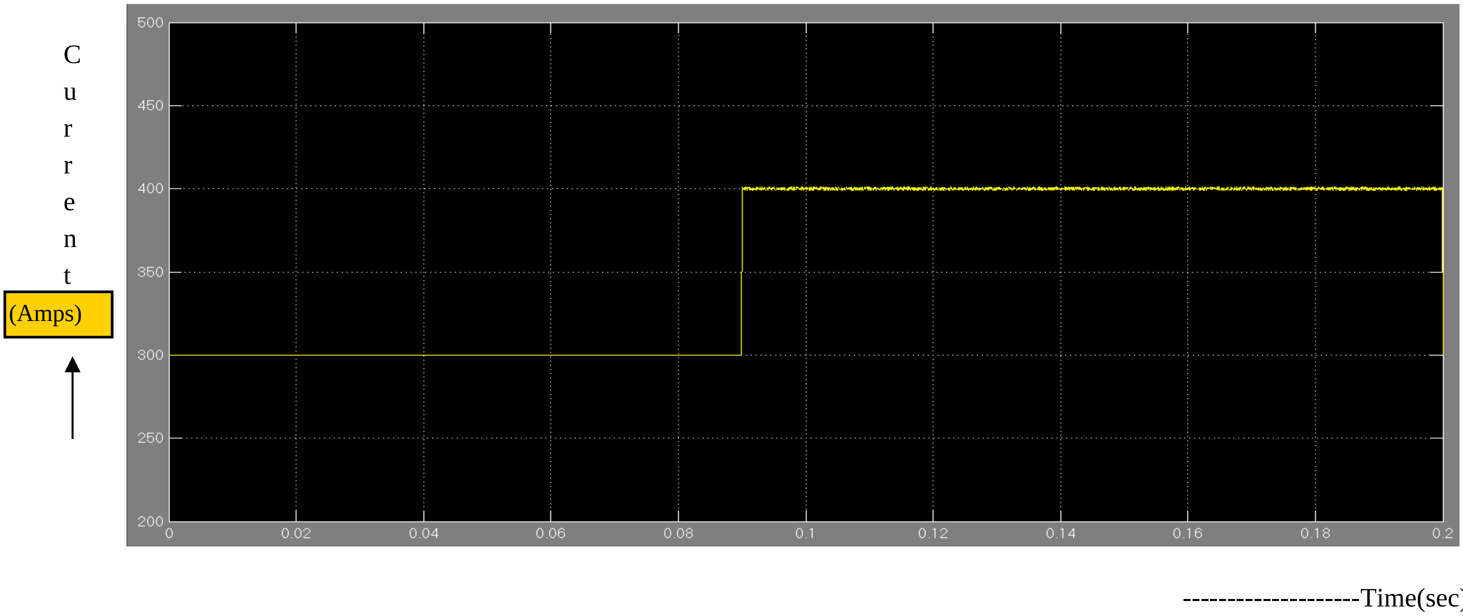


Fig:7.7 Dc link capacitor current

- This is the waveform across the DC link capacitor as it is an essential part of grid provides isolation and suppresses the ripples. The function of the capacitor is energy storage as potential energy.

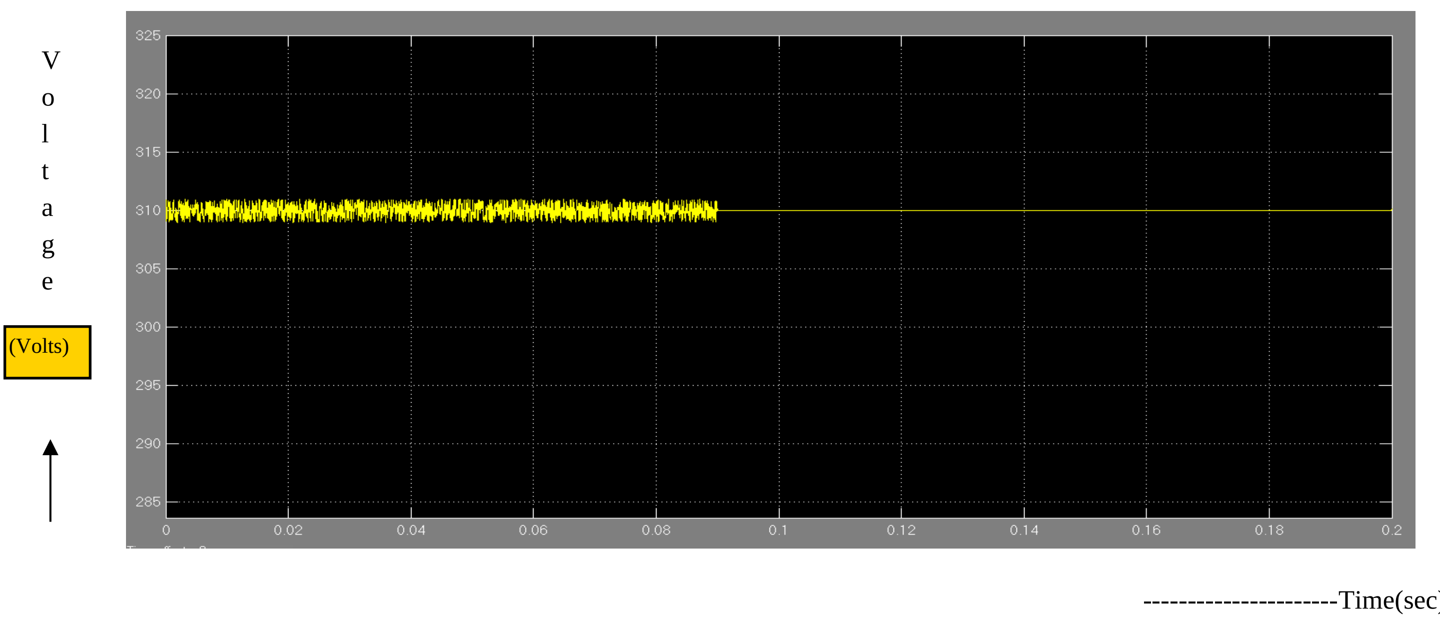


Fig:7.8 DCAPF voltage

- Active power filters will improve the quality of the electrical energy and the efficiency by suppressing harmonics ,we can observe the improvement in electrical energy without any harmonics in this above figure.

CHAPTER 8

CONCLUSIONS

8.1 CONCLUSION:

This paper proposes a novel single-stage EV fast charging system structure with lower cost and higher efficiency. Both single-stage and two-stage structures are compared under fair efficiency analysis and evaluation including the power loss comparison of the transformers and converters. The whole system efficiency calculation results are also validated by the SEMISEL simulation. The comparison results indicate that the proposed single-stage structure fast charging system could be more effective in efficiency improving while cutting the cost. Besides, based on the proposed single-stage structure, a DCAPF method is also adopted in this paper to compensate the harmonic current which may be directly transmitted to the battery packs. The compensation effect is validated by both the simulation and experimental results. The proposed structure and lower order harmonic current compensation method could be simply used for improving the EV's fast charging system performance.

8.2 FUTURE SCOPE:

- The scope of this project is ,to design a better efficient filter than bidirectional dc/dc converter in order to suppress the harmonics periodically.
- So that we have still better efficiency which includes less cost.

APPENDIX 1

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

(a) Development Environment:

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

(b) The MATLAB Mathematical Function Library:

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language:

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics:

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

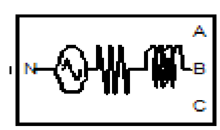
(e) The MATLAB Application Program Interface (API):

This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

(f) MATLAB Documentation:

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

(1) Three phase source block:

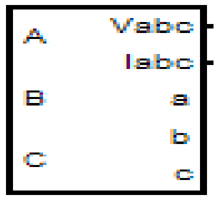


Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

(2) VI measurement block:

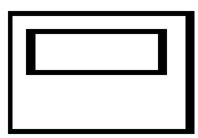
The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents



Three Phase V-I Measurement

(3) Scope:

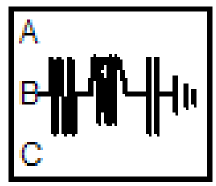
Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes. The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation



Scope

(4) Three-Phase Series RLC Load:

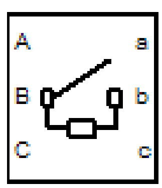
The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.



Three-Phase Series RLC Load

(5) Three-Phase Breaker block:

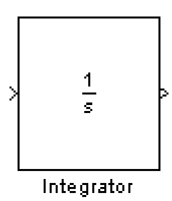
The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.



Three-Phase Breaker Block

(6) Integrator:

Library: Continuous



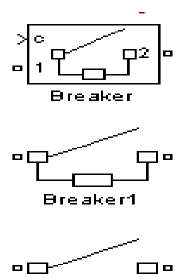
Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

(7) Breaker:

Implement circuit breaker opening at current zero crossing.

Library: Elements



Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it).

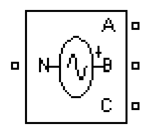
When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

(8) Three-Phase Programmable Voltage Source:

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources



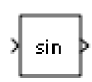
Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

(9) Trigonometric Function:

Specified trigonometric function on input

Library: Math Operations



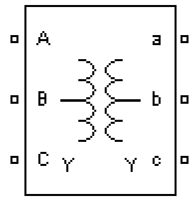
Trigonometric Function

Purpose: The Trigonometric Function block performs common trigonometric functions

(10) Three-Phase Transformer (Two Windings):

Implement three-phase transformer with configurable winding connections

Library: **Elements**



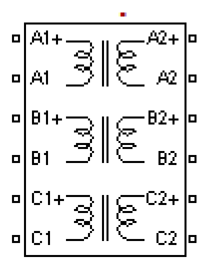
Three Phase Transformer

Purpose: The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

(11) Three-Phase Transformer 12 Terminals:

Implement three single-phase, two-winding transformers where all terminals are accessible

Library: Elements



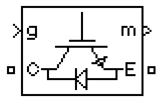
Two winding Transformer

Purpose: The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

(12) IGBT/Diode:

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: **Power Electronics**



IGBT

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

APPENDIX 2

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A

PROJECT REPORT

On

CONSTANT CURRENT FUZZY LOGIC CONTROLLER FOR GRID CONNECTED ELECTRICAL VEHICLE CHARGING

Submitted by

1)Ms.K.Bhavani(17K81A0227)

2)Ms.A.Kavya (17K81A0202)

3)Mr.K.Rakesh (17K81A0226)

4)Ms.A.Ramu(18K85A0222)

in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

Mrs. C.N. Sangeetha, M.Tech,(PhD)

Asst. Professor

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

BONAFIDE CERTIFICATE

This is to certify that the project entitled **CONSTANT CURRENT FUZZY LOGIC CONTROLLER FOR GRID CONNECTED ELECTRICAL VEHICLE CHARGING**, is being submitted by**1.Ms. K.Bhavani 17K81A0227,2.Ms. A.Kavya 17K81A0202 3.Mr. K.Rakesh 17K81A0226 4. Mr. A.Ramu 18K85A0222** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN** Electrical and Electronics Engineering is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

	Head of the Department
Mrs. C.N. Sangeetha	Dr. N.Ramchandra
Department of EEE	Department of EEE

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of **Electrical and Electronics Engineering** ', session: 2017 – 2021, **St. Martin's Engineering College**, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled **CONSTANT CURRENT FUZZY LOGIC CONTROLLER FOR GRID CONNECTED ELECTRICAL VEHICLE CHARGING** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

K. Bhavani (17K81A0227)
A. Kavya (17K81A0202)
K. Rakesh (17K81A0226)
A. Ramu (18K85A0222)

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1. K.Bhavani
2. A.Kavya
3. K.Rakesh
4. A.Ramu

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NOMENCLATURE

EV	:	Electrical Vehicle
HEVs	:	Hybrid Electrical Vehicle
ICE	:	Internal Combustion Engine
FLC	:	Fuzzy Logic Controller
BEVs	:	Battery Electrical Vehicles
VRLA	:	Valve regulated lead-acid battery
AGM	:	Absorbed Glass Mat

ABSTRACT

The increase in demand for clean sources of energy is getting more attention in recent time. Electric vehicle (EV) is an important area to fulfil this demand. However, one of the major obstacles in the growth of EV is the longer charging time. Therefore, there is a definite need for the reduction of charging time in EVs. Constant current charging of EV can help to solve this problem. That's why, the role of DC-DC converter is very important. DC-DC converters are commonly utilized in electronic devices such as mobile phones, computers etc. This paper presents the possibility of grid connected constant current charging of EV with buck DC-DC converter through fuzzy logic control (FLC). FLC is easy to implement without the requirement of intensive mathematical modelling. The complete model of the considered system has been developed in MATLAB/Simulink. The achieved simulation results show the viability and capability of the proposed scheme. Keywords— DC-DC converter, fuzzy logic controller, electric vehicle.

CHAPTER 1
INTRODUCTION

1.1 Introduction to the project:

According to International Energy Agency, about 64% of global oil utilization originates from transport sector. The increase in fossil fuel demand, coupled with the upsurge in climate change, has led to control in the release of CO2 and NOx emissions. Eventually, there is an increase in the demand for clean sources of energy. Electric vehicles (EV) can help to reduce the menace related to climate change. Presently, a lot of research work is going on regrading EV and viability of designing the charging process through power grid connection. However, the charging system of EV needs to be improved considerably. Decrease in charging time is an important requirement in making EV easy to use. As a result of this, fast DC and constant current (CC) charging systems offer a fascinating opportunity. The author describes the two levels of DC fast charging according to the international standard. The DC-DC bus connection is more desirable because it requires lesser switching process which facilitates higher efficiency. Moreover, according to algorithm developed, the CC charging can also be used to determine the charging power requirement, based on the battery capacity, departure time, arrival time and the battery state of charge. A comprehensive review of fast charging process with required charging current and voltage is discussed. Power grid and photovoltaic connected EV charging is developed but the detail design of the EV charging process is not illustrated. a fast DC charging of EV is implemented with a proportional integral (PI) controller but generally PI are often subjected to tuning. a voltage sensing smart charging is used for the energy management with a PI controller for buck converter charging of the EV.

DC voltage source is used as the PV panel and the battery is modelled as a simple resistor with a bang-bang fuzzy logic controller for the EV charging implementation. In contrast to previous works, this paper focuses on buck DC-DC converter charging of grid connected electric vehicles with a constant current fuzzy logic controller (FLC). In this paper, the actual models of the grid connection as well as battery have been used in MATLAB/Simulink for the analysis of the complete EV charging system. FLC can be used in various home and industrial applications.FLC is easy to implement than the classical proportional integral (PI) controller and it easily adjusts to changes in operating conditions.

It can be computed with linguistic variables rather than numbers. Membership functions (MF) are used in describing fuzzy sets.

MF denotes degree of accuracy in fuzzy logic and it is mapped between 0 to 1.

A MF value of 0.2 denotes 20% degree of accuracy in a fuzzy logic. The control algorithm for fuzzy set can be implemented through fuzzy rules by operators for difficult and non-linear systems without the requirement for intensive numerical modelling.

It is also highly reliable and robust to change in circuit parameters and transient conditions . Organized as follows: presents the design of buck converter and the grid connection. Describes the constant current fuzzy logic controller for EV charging. Presents the simulation results.

The complete simulation diagram of the EV charging system is developed in MATLAB/Simulink as presented In this figure, voltage source is modeled as a three phase source and the transformer as a Star-Delta connection. A three-level bridge inverter is used for AC to DC conversion. The adjustment of the DC bus voltage and reactive current of the grid are done by the control system, DC regulator, This comprises of a DC voltage control and a current control. A d-q transformation process is employed with phase loop. The current reference is the output of the DC voltage regulator. The magnitude and voltage phase generated by the current regulator is used to regulate the converter as presented Figure 3 shows DC-DC buck converter system with output Vo. The converter allows the lowering of input voltage magnitude to a desirable level in order to charge the EV. The input of the DC-DC buck converter is connected to the output of the grid supply and the output of the converter is connected to the battery. The duty cycle of the buck converter, which is the ratio of two voltages, can be determined. Controllers are primarily employed to bridge the gap between the measured output parameter and the reference value. The fuzzy logic controller in this paper is based on the bang-bang control Bang-bang control system automatically turns on/off in order to keep the measured output close to the reference value. It is basically known as a two-step controller.

The main reasons for the invention of electric vehicles is the emission of toxic substances into the air by the motor vehicles such as cars, buses, trucks, and so on causing air pollution but the other reason for the development of electric vehicles is that the fossil fuels which are being employed in our daily life will be exhausted not beyond a few years considering the rate of usage. The electric vehicles must be developed in such a way that the vehicle must be charged within a few seconds.

The PID controller used in a fast-charging electric vehicle is always a closed-loop network and receives feedback. This feedback is employed to make adjustments to the deviations in the output.

The capacitor bank is used to obstruct the variable DC voltage, the voltage in the transformer is used to step-up or step-down as per the requirements. In the radial distribution system, buffering loads are used, when there are no vehicles in the charging station these loads are utilized to store the electrical energy, the battery is used as a rectifier, and for fast charging purpose the PID controller along with buck-boost converter are used to control the circuit with the FLC.

Buck-boost converter along with the PID controller and FLC is presented as the advanced controlling circuit. The converter is connected to the electric vehicles which are attached to the grid.

The FLC can be easily accessible in domestic and industrial based applications. The fuzzy logic can be carried out easily when related with the PID controller and is adaptable to the variations in the system.

CHAPTER 2

LITERATURE SURVEY

2.1 Literature survey

Lisheng Shi et al

Presented the basic requirements and specifications for PHEV bidirectional ac dc converter designs. Generally, there are two types of topologies used for PHEVs: an independent topology and a combination topology that utilizes the drive motor's inverter. Evaluations of the two converter topologies are analysed in detail. The combination topology analysis is emphasized because it has more advantages in PHEVs, in respect to savings in cost, volume and weight.

Jia Ying Yong, Vigna K. Ramachandaramurthy, Kang Miao Tan, N. Mithulananthan.

Electrifying transportation is a promising approach to alleviate the climate change issue. The adoption of electric vehicle into market has introduced significant impacts on various fields, especially the power grid. Various policies have been implemented to foster the electric vehicle deployment and the increasing trend of electric vehicle adoption in the recent years has been satisfying. The continual development of electric vehicle power train, battery and charger technologies have further improved the electric vehicle technologies for wider uptake. Despite the environmental and economical benefits, electric vehicles charging introduce negative impacts on the existing network operation. Appropriate charging management strategies can be implemented to cater for this issue. Furthermore, electric vehicle integration in the smart grid can bring many potential opportunities, especially from the perspective of vehicle-to-grid technology and as the solution for the renewable energy intermittency issue. This project reviews the latest development in electric vehicle technologies, impacts of electric vehicle roll out and opportunities brought by electric vehicle deployment.

M. S. Perdigão, J. P. F. Trovão, J. M. Alonso and E. S. Saraiva

This project is focused on core size optimization of power inductors in bidirectional dc–dc converters. It presents an experimental large-signal characterization procedure for power inductors in electric vehicle applications and a method to obtain an inductance reference value for the power inductor in dc–dc converters' simulation studies.

It discusses the importance of the inductor design project by describing important constraints such as core size and saturation. The main contribution of this paper is related to the proposed dc flux cancelation technique in the bidirectional converter. A variable inductor prototype is used to replace the power inductor in order to decrease core size by improving the ripple content of the inductor current. The saturation level of the core is controlled by means of an auxiliary winding whether the converter operates in buck or boost mode. Experimental results validate the proposed methodology showing more than 50% reduction in magnetic material for similar current levels.

Young-Joo Lee et al

Formulated a novel integrated bidirectional ac/dc charger and dc/dc converter (henceforth, the integrated converter) for PHEVs and hybrid/plug-in-hybrid conversions is proposed.The integrated converter is able to function as an ac/dc battery charger and to transfer electrical energy between the battery pack and the high-voltage bus of the electric traction system.

Hyun-Wook Seong et al

Describes non-isolated high step-up DC-DC converters using zero voltage switching (ZVS) boost integration technique (BIT) and their light-load frequency modulation (LLFM) control. The proposed ZVS BIT integrates a bidirectional boost converter with a series output module as a parallel-input and series-output (PISO) configuration.

CHAPTER 3

BATTERY STORAGE SYSTEM

3.1 Introduction:

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to include devices composed of a single cell.

Primary (single-use or "disposable") batteries are used once and discarded, as the electrode materials are irreversibly changed during discharge; a common example is the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and mobile phones.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smartphones, to large lead acid batteries or lithium-ion batteries in vehicles, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centers. Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. In automobiles, this is somewhat offset by the higher efficiency of electric motors in converting chemical energy to mechanical work, compared to combustion engines.The usage of "battery" to describe a group of electrical devices dates to Benjamin Franklin, who in 1748 described multiple Leyden jars by analogy to a battery of cannon (Benjamin Franklin borrowed the term "battery" from the military, which refers to weapons functioning together).

Italian physicist Alessandro Volta built and described the first electrochemical battery, the voltaic pile, in 1800.This was a stack of copper and zinc plates, separated by brine-soaked paper disks, that could produce a steady current for a considerable length of time. Volta did not understand that the voltage was due to chemical reactions.

He thought that his cells were an inexhaustible source of energy, and that the associated corrosion effects at the electrodes were a mere nuisance, rather than an unavoidable consequence of their operation, as Michael Faraday showed in 1834.

Although early batteries were of great value for experimental purposes, in practice their voltages fluctuated and they could not provide a large current for a sustained period. The Daniel cell, invented in 1836 by British chemist John Frederic Daniel, was the first practical source of electricity, becoming an industry standard and seeing widespread adoption as a power source for electrical telegraph networks. It consisted of a copper pot filled with a copper sulfate solution, in which was immersed an unglazed earthenware container filled with sulfuric acid and a zinc electrode. These wet cells used liquid electrolytes, which were prone to leakage and spillage if not handled correctly. Many used glass jars to hold their components, which made them fragile and potentially dangerous. These characteristics made wet cells unsuitable for portable appliances. Near the end of the nineteenth century, the invention of dry cell batteries, which replaced the liquid electrolyte with a paste, made portable electrical devices practical. Batteries convert chemical energy directly to electrical energy. In many cases, the electrical energy released is the difference in the cohesive or bond energies of the metals, oxides, or molecules undergoing the electrochemical reaction. For instance, energy can be stored in Zn or Li, which are high-energy metals because they are not stabilized by d-electron bonding, unlike transition metals. Batteries are designed such that the energetically favorable redox reaction can occur only if electrons move through the external part of the circuit.

A battery consists of some number of voltaic cells. Each cell consists of two half-cells connected in series by a conductive electrolyte containing metal cations. One half-cell includes electrolyte and the negative electrode, the electrode to which anions (negatively charged ions) migrate; the other half-cell includes electrolyte and the positive electrode, to which cations (positively charged ions) migrate. Cations are reduced (electrons are added) at the cathode, while metal atoms are oxidized (electrons are removed) at the anode. Some cells use different electrolytes for each half-cell; then a separator is used to prevent mixing of the electrolytes while allowing ions to flow between half-cells to complete the electrical circuit. Each half-cell has an electromotive force (emf, measured in volts) relative to a standard.

The net emf of the cell is the difference between the emfs of its half cells. Thus, if the electrodes have emfs and then the net emf is in other words, the net emf is the difference between the reduction potentials of the half-reactions.

The electrical driving force or across the terminals of a cell is known as the terminal voltage (difference) and is measured in volts. The terminal voltage of a cell that is neither charging nor discharging is called the open-circuit voltage and equals the emf of the cell.

Because of internal resistance, the terminal voltage of a cell that is discharging is smaller in magnitude than the open-circuit voltage and the terminal voltage of a cell that is charging exceeds the open-circuit voltage. An ideal cell has negligible internal resistance, so it would maintain a constant terminal voltage of until exhausted, then dropping to zero. If such a cell maintained 1.5 volts and produce a charge of one coulomb then on complete discharge it would have performed 1.5 joules of work. In actual cells, the internal resistance increases under discharge and the open-circuit voltage also decreases under discharge. If the voltage and resistance are plotted against time, the resulting graphs typically are a curve; the shape of the curve varies according to the chemistry and internal arrangement employed.

The voltage developed across a cell's terminals depends on the energy release of the chemical reactions of its electrodes and electrolyte. Alkaline and zinc–carbon cells have different chemistries, but approximately the same emf of 1.5 volts; likewise NiCd and NiMH cells have different chemistries, but approximately the same emf of 1.2 volts. The high electrochemical potential changes in the reactions of lithium compounds give lithium cells emfs of 3 volts or more.

3.2 Batteries are classified into primary and secondary forms:

Primary batteries are designed to be used until exhausted of energy then discarded. Their chemical reactions are generally not reversible, so they cannot be recharged. When the supply of reactants in the battery is exhausted, the battery stops producing current and is useless. Secondary batteries can be recharged; that is, they can have their chemical reactions reversed by applying electric current to the cell. This regenerates the original chemical reactants, so they can be used, recharged, and used again multiple times. Some types of primary batteries used, for example, for telegraph circuits, were restored to operation by replacing the electrodes. Secondary batteries are not indefinitely rechargeable due to dissipation of the active materials, loss of electrolyte and internal corrosion.

3.2.1Primary:

Main article: Primary cell, Primary batteries, or primary cells, can produce current immediately on assembly. These are most commonly used in portable devices that have low current drain, are used only intermittently, or are used well away from an alternative power source, such as in alarm and communication circuits where other electric power is only intermittently available. Disposable primary cells cannot be reliably recharged, since the chemical reactions are not easily reversible and active materials may not return to their original forms.

Battery manufacturers recommend against attempting to recharge primary cells. In general, these have higher energy densities than rechargeable batteries, but disposable batteries do not fare well under high-drain applications with loads under 75 ohms (75 Ω). Common types of disposable batteries include zinc–carbon batteries and alkaline batteries.

3.2.2 Secondary:

Main article: Rechargeable battery

Secondary batteries, also known as secondary cells, or rechargeable batteries, must be charged before first use; they are usually assembled with active materials in the discharged state. Rechargeable batteries are (re)charged by applying electric current, which reverses the chemical reactions that occur during discharge/use. Devices to supply the appropriate current are called chargers.

The oldest form of rechargeable battery is the lead–acid battery, which are widely used in automotive and boating applications. This technology contains liquid electrolyte in an unsealed container, requiring that the battery be kept upright and the area be well ventilated to ensure safe dispersal of the hydrogen gas it produces during overcharging.

The lead–acid battery is relatively heavy for the amount of electrical energy it can supply. Its low manufacturing cost and its high surge current levels make it common where its capacity (over approximately 10 Ah) is more important than weight and handling issues.

A common application is the modern car battery, which can, in general, deliver a peak current of 450 amperes.

The sealed valve regulated lead–acid battery (VRLA battery) is popular in the automotive industry as a replacement for the lead–acid wet cell.

The VRLA battery uses an immobilized sulfuric acid electrolyte, reducing the chance of leakage and extending shelf life. VRLA batteries immobilize the electrolyte. The two types are: Gel batteries (or "gel cell") use a semi-solid electrolyte.

3.3 Absorbed Glass Mat (AGM) batteries absorb the electrolyte in a special fiberglass matting.

Other portable rechargeable batteries include several sealed "dry cell" types, that are useful in applications such as mobile phones and laptop computers. Cells of this type (in order of increasing power density and cost) include nickel–cadmium (NiCd), nickel–zinc (NiZn), nickel metal hydride (NiMH), and lithium-ion (Li-ion) cells. Li-ion has by far the highest share of the dry cell rechargeable market.NiMH has replaced NiCd in most applications due to its higher capacity, but NiCd remains in use in power tools, two-way radios, and medical equipment.

In the 2000s, developments include batteries with embedded electronics such as USBCELL, which allows charging an AA battery through a USB connector,[28] nanoball batteries that allow for a discharge rate about 100x greater than current batteries, and smart battery packs with state-of-charge monitors and battery protection circuits that prevent damage on over-discharge. Low self-discharge (LSD) allows secondary cells to be charged prior to shipping.

3.4 Cell types:

Many types of electrochemical cells have been produced, with varying chemical processes and designs, including galvanic cells, electrolytic cells, fuel cells, flow cells and voltaic piles.

3.4.1 Wet cell:

A wet cell battery has a liquid electrolyte. Other names are flooded cell, since the liquid covers all internal parts, or vented cell, since gases produced during operation can escape to the air. Wet cells were a precursor to dry cells and are commonly used as a learning tool for electrochemistry. They can be built with common laboratory supplies, such as beakers, for demonstrations of how electrochemical cells work. A particular type of wet cell known as a concentration cell is important in understanding corrosion. Wet cells may be primary cells (non-rechargeable) or secondary cells (rechargeable). Originally, all practical primary batteries such as the Daniel cell were built as open-top glass jar wet cells. Other primary wet cells are the Leclanche cell, Grove cell, Bunsen cell, Chromic acid cell, Clark cell, and Weston cell.

The Leclanche cell chemistry was adapted to the first dry cells. Wet cells are still used in automobile batteries and in industry for standby power for switchgear, telecommunication or large uninterruptible power supplies, but in many places batteries with gel cells have been used instead. These applications commonly use lead–acid or nickel–cadmium cells.

A dry cell uses a paste electrolyte, with only enough moisture to allow current to flow. Unlike a wet cell, a dry cell can operate in any orientation without spilling, as it contains no free liquid, making it suitable for portable equipment. By comparison, the first wet cells were typically fragile glass containers with lead rods hanging from the open top and needed careful handling to avoid spillage. Lead–acid batteries did not achieve the safety and portability of the dry cell until the development of the gel battery. A common dry cell is the zinc–carbon battery, sometimes called the dry Leclanché cell, with a nominal voltage of 1.5 volts, the same as the alkaline battery (since both use the same zinc–manganese dioxide combination). A standard dry cell comprises a zinc anode, usually in the form of a cylindrical pot, with a carbon cathode in the form of a central rod. The electrolyte is ammonium chloride in the form of paste next to the zinc anode.

The remaining space between the electrolyte and carbon cathode is taken up by a second paste consisting of ammonium chloride and manganese dioxide, the latter acting as a depolariser. In some designs, the ammonium chloride is replaced by zinc chloride.

3.4.2 Molten salt:

Molten salt batteries are primary or secondary batteries that use a molten salt as electrolyte. They operate at high temperatures and must be well insulated to retain heat.

3.5 Reserve:

A reserve battery can be stored unassembled (un activated and supplying no power) for a long period (perhaps years). When the battery is needed, then it is assembled (e.g., by adding electrolyte); once assembled, the battery is charged and ready to work. For example, a battery for an electronic artillery fuse might be activated by the impact of firing a gun. The acceleration breaks a capsule of electrolyte that activates the battery and powers the fuse's circuits. Reserve batteries are usually designed for a short service life (seconds or minutes) after long storage (years). A water-activated battery for oceanographic instruments or military applications becomes activated on immersion in water.

3.6 Cell performance:

A battery's characteristics may vary over load cycle, over charge cycle, and over lifetime due to many factors including internal chemistry, current drain, and temperature. At low temperatures, a battery cannot deliver as much power. As such, in cold climates, some car owners install battery warmers, which are small electric heating pads that keep the car battery warm.

A battery's capacity is the amount of electric charge it can deliver at the rated voltage. The more electrode material contained in the cell the greater its capacity. A small cell has less capacity than a larger cell with the same chemistry, although they develop the same open-circuit voltage. Capacity is measured in units such as amp-hour (Ah). The rated capacity of a battery is usually expressed as the product of 20 hours multiplied by the current that a new battery can consistently supply for 20 hours at 68 °F (20 °C), while remaining above a specified terminal voltage per cell. For example, a battery rated at 100 Ah can deliver 5 A over a 20-hour period at room temperature. The fraction of the stored charge that a battery can deliver depends on multiple factors, including battery chemistry, the rate at which the charge is delivered (current), the required terminal voltage, the storage period, ambient temperature and other factors.

The higher the discharge rate, the lower the capacity. The relationship between current, discharge time and capacity for a lead acid battery is approximated (over a typical range of current values) by Peukert's law:

Where is the capacity when discharged at a rate of 1 amp is the current drawn from battery (A).

Is the amount of time (in hours) that a battery can sustain. is a constant around 1.3.

Batteries that are stored for a long period or that are discharged at a small fraction of the capacity lose capacity due to the presence of generally irreversible side reactions that consume charge carriers without producing current. This phenomenon is known as internal self-discharge. Further, when batteries are recharged, additional side reactions can occur, reducing capacity for subsequent discharges. After enough recharges, in essence all capacity is lost and the battery stops producing power.

Internal energy losses and limitations on the rate that ions pass through the electrolyte cause battery efficiency to vary. Above a minimum threshold, discharging at a low rate delivers more of the battery's capacity than at a higher rate.

Installing batteries with varying Ah ratings does not affect device operation (although it may affect the operation interval) rated for a specific voltage unless load limits are exceeded. High-drain loads such as digital cameras can reduce total capacity, as happens with alkaline batteries. For example, a battery rated at 2 Ah for a 10- or 20-hour discharge would not sustain a current of 1 A for a full two hours as its stated capacity implies.

The C-rate is a measure of the rate at which a battery is being charged or discharged. It is defined as the current through the battery divided by the theoretical current draw under which the battery would deliver its nominal rated capacity in one hour. It has the units h^{-1}.C-rate is used as a rating on batteries to indicate the maximum current that a battery can safely deliver on a circuit. Standards for rechargeable batteries generally rate the capacity over a 4-hour, 8 hour or longer discharge time. Types intended for special purposes, such as in a computer uninterruptible power supply, may be rated by manufacturers for discharge periods much less than one hour. Because of internal resistance loss and the chemical processes inside the cells, a battery rarely delivers nameplate rated capacity in only one hour.

3.7 Fast-charging, large and light batteries:

As of 2017, the world's largest battery was built in South Australia by Tesla. It can store 129 MWh. A battery in Hebei Province, China which can store 36 MWh of electricity was built in 2013 at a cost of $500 million. Another large battery, composed of Ni–Cd cells, was in Fairbanks, Alaska. It covered 2,000 square meters (22,000 sq ft)—bigger than a football pitch—and weighed 1,300 tons.It was manufactured by ABB to provide backup power in the event of a blackout.

The battery can provide 40 MW of power for up to seven minutes. Sodium–sulfur batteries have been used to store wind power. A 4.4 MWh battery system that can deliver 11 MW for 25 minutes stabilizes the output of the Auwahi wind farm in Hawaii.

Lithium–sulfur batteries were used on the longest and highest solar-powered flight.

3.8 Lifetime:

Battery life (and its synonym battery lifetime) has two meanings for rechargeable batteries but only one for non-chargeables. For re chargeables, it can mean either the length of time a device can run on a fully charged battery or the number of charge/discharge cycles possible before the cells fail to operate satisfactorily. For a non-rechargeable these two lives are equal since the cells last for only one cycle by definition. (The term shelf life is used to describe how long a battery will retain its performance between manufacture and use.)

Available capacity of all batteries drops with decreasing temperature. In contrast to most of today's batteries, the Zamboni pile, invented in 1812, offers a very long service life without refurbishment or recharge, although it supplies current only in the nanoamp range. The Oxford Electric Bell has been ringing almost continuously since 1840 on its original pair of batteries, thought to be Zamboni piles.

3.8.1 Self-discharge:

Disposable batteries typically lose 8 to 20 percent of their original charge per year when stored at room temperature (20–30 °C). This is known as the "self-discharge" rate, and is due to non-current-producing "side" chemical reactions that occur within the cell even when no load is applied. The rate of side reactions is reduced for batteries stored at lower temperatures, although some can be damaged by freezing.

Old rechargeable batteries self-discharge more rapidly than disposable alkaline batteries, especially nickel-based batteries; a freshly charged nickel cadmium (Ni Cd) battery loses 10% of its charge in the first 24 hours, and thereafter discharges at a rate of about 10% a month. However, newer low self-discharge nickel metal hydride (NiMH) batteries and modern lithium designs display a lower self-discharge rate (but still higher than for primary batteries).

3.9 Corrosion:

Internal parts may corrode and fail, or the active materials may be slowly converted to inactive forms. Physical component changes. The active material on the battery plates changes chemical composition on each charge and discharge cycle; active material may be lost due to physical changes of volume, further limiting the number of times the battery can be recharged.

Most nickel-based batteries are partially discharged when purchased, and must be charged before first use. Newer NiMH batteries are ready to be used when purchased, and have only 15% discharge in a year.

Some deterioration occurs on each charge–discharge cycle. Degradation usually occurs because electrolyte migrates away from the electrodes or because active material detaches from the electrodes.

Low-capacity NiMH batteries (1,700–2,000 m Ah) can be charged some 1,000 times, whereas high-capacity NiMH batteries (above 2,500 m Ah) last about 500 cycles. Ni Cd batteries tend to be rated for 1,000 cycles before their internal resistance permanently increases beyond usable values.

CHAPTER 4
VOLTAGE SOURCE CONVERTER

4.1 Introduction:

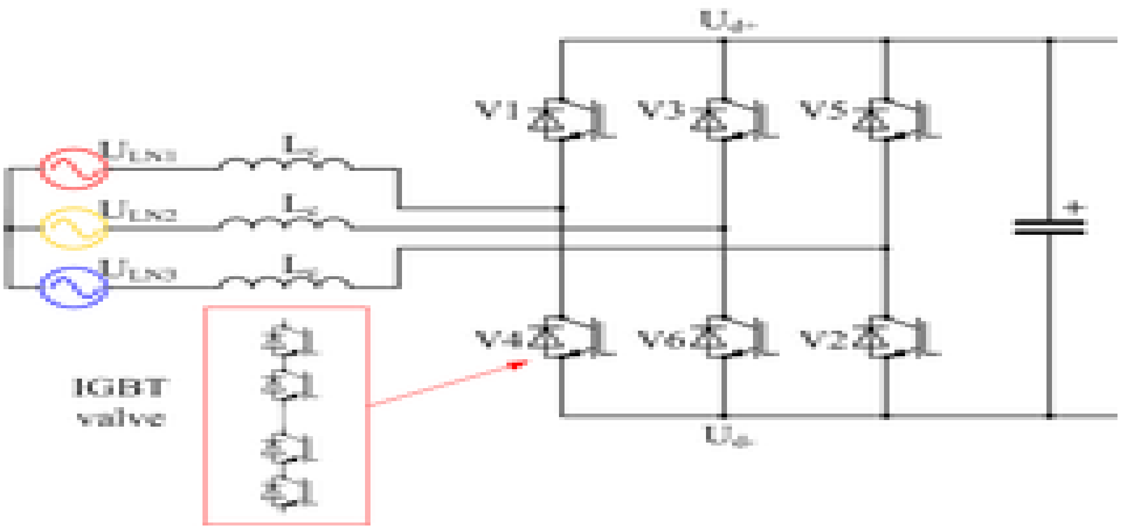
Because thyristors can only be turned on (not off) by control action, and rely on the external AC system to effect the turn-off process, the control system only has one degree of freedom – when to turn on the thyristor. This limits the usefulness of HVDC in some circumstances because it means that the AC system to which the HVDC converter is connected must always contain synchronous machines in order to provide the commutating voltage – the HVDC converter cannot feed power into a passive system. With some other types of semiconductor device such as the insulated-gate bipolar transistor (IGBT), both turn-on and turn-off can be controlled, giving a second degree of freedom. As a result, IGBTs can be used to make self-commutated converters. In such converters, the polarity of DC voltage is usually fixed and the DC voltage, being smoothed by a large capacitance, can be considered constant. For this reason, an HVDC converter using IGBTs is usually referred to as a voltage-source converter (or voltage-sourced converter). The additional controllability gives many advantages, notably the ability to switch the IGBTs on and off many times per cycle in order to improve the harmonic performance, and the fact that (being self-commutated) the converter no longer relies on synchronous machines in the AC system for its operation. A voltage-sourced converter can therefore feed power to an AC network consisting only of passive loads, something which is impossible with LCC HVDC. Voltage-source converters are also considerably more compact than line-commutated converters (mainly because much less harmonic filtering is needed) and are preferable to line-commutated converters in locations where space is at a premium, for example on offshore platforms.

In contrast to line-commutated HVDC converters, voltage-source converters maintain a constant polarity of DC voltage and power reversal is achieved instead by reversing the direction of current. This makes voltage-source converters much easier to connect into a Multi-terminal HVDC system or “DC Grid”. HVDC systems based on voltage-source converters normally use the six-pulse connection because the converter produces much less harmonic distortion than a comparable LCC and the twelve-pulse connection is unnecessary.

This simplifies the construction of the converter transformer. However, there are several different configurations of voltage-source converter and research is continuing to take place into new alternatives.

4.2 Two-level Converter:

From the very first VSC-HVDC scheme installed (the Hellsjon experimental link commissioned in Sweden in 1997) until 2012, most of the VSC HVDC systems built were based on the two level converter. The two-level converter is the simplest type of three-phase voltage-source converter and can be thought of as a six pulse bridge in which the thyristors have been replaced by IGBTs with inverse-parallel diodes, and the DC smoothing reactors have been replaced by DC smoothing capacitors. Such converters derive their name from the fact that the voltage at the AC output of each phase is switched between two discrete voltage levels, corresponding to the electrical potentials of the positive and negative DC terminals. When the upper of the two valves in a phase is turned on, the AC output terminal is connected to the positive DC terminal, resulting in an output voltage of +½ U_d with respect to the midpoint potential of the converter. Conversely when the lower valve in a phase is turned on, the AC output terminal is connected to the negative DC terminal, resulting in an output voltage of -½ U_d. The two valves corresponding to one phase must never be turned on simultaneously, as this would result in an uncontrolled discharge of the DC capacitor, risking severe damage to the converter equipment.



wqeFig 4.1: Three-phase, two-level voltage-source converter

The simplest (and also, the highest-amplitude) waveform that can be produced by a two-level converter is a square wave; however this would produce unacceptable levels of harmonic distortion, so some form of Pulse-width modulation (PWM) is always used to improve the harmonic distortion of the converter.

As a result of the PWM, the IGBTs are switched on and off many times (typically 20) in each mains cycle. This results in high switching losses in the IGBTs and reduces the overall transmission efficiency.
Several different PWM strategies are possible for HVDC but in all cases the efficiency of the two-level converter is significantly poorer than that of a LCC because of the higher switching losses. A typical LCC HVDC converter station has power losses of around 0.7% at full load (per end, excluding the HVDC line or cable) while with 2-level voltage-source converters the equivalent figure is 2-3% per end.

Another disadvantage of the two-level converter is that, in order to achieve the very high operating voltages required for an HVDC scheme, several hundred IGBTs have to be connected in series and switched simultaneously in each valve. This requires specialized types of IGBT with sophisticated gate drive circuits, and can lead to very high levels of electromagnetic interference. In an attempt to improve on the poor harmonic performance of the two-level converter, some HVDC systems have been built with three level converters. Three-level converters can synthesize three (instead of only two) discrete voltage levels at the AC terminal of each phase: +½ U_d, 0 and -½ U_d. A common type of three-level converter is the diode-clamped (or neutral-point-clamped) converter, where each phase contains four IGBT valves, each rated at half of the DC line to line voltage, along with two clamping diode valves. The DC capacitor is split into two series-connected branches, with the clamping diode valves connected between the capacitor midpoint and the one-quarter and three-quarter points on each phase. To obtain a positive output voltage (+½ U_d) the top two IGBT valves are turned on, to obtain a negative output voltage (-½ U_d) the bottom two IGBT valves are turned on and to obtain zero output voltage the middle two IGBT valves are turned on. In this latter state, the two clamping diode valves complete the current path through the phase.

In a refinement of the diode-clamped converter, the so-called active neutral-point clamped converter, the clamping diode valves are replaced by IGBT valves, giving additional controllability. Such converters were used on the Murray link project in Australia and the Cross Sound Cable link in the United States.

However, the modest improvement in harmonic performance came at a considerable price in terms of increased complexity, and the design proved to be difficult to scale up to DC voltages higher than the ±150 kV used on those two projects. Another type of three-level converter, used in some adjustable-speed drives but never in HVDC, replaces the clamping diode valves by a separate, isolated, flying capacitor connected between the one-quarter and three-quarter points. The operating principle is similar to that of the diode-clamped converter.

Both the diode-clamped and flying capacitor variants of three-level converter can be extended to higher numbers of output levels (for example, five), but the complexity of the circuit increases disproportionately and such circuits have not been considered practical for HVDC applications.

First proposed for HVDC applications in 2003 by Marquardt and first used commercially in the Trans Bay Cable project in San Francisco, the Modular Multi-Level Converter (MMC) is now becoming the most common type of voltage-source converter for HVDC.

Like the two-level converter and the six-pulse line-commutated converter, a MMC consists of six valves, each connecting one AC terminal to one DC terminal.

However, where each valve of the two-level converter is effectively a high-voltage controlled switch consisting of a large number of IGBTs connected in series, each valve of a MMC is a separate controllable voltage source in its own right. Each MMC valve consists of a number of independent converter submodules, each containing its own storage capacitor. In the most common form of the circuit, the half-bridge variant, each submodule contains two IGBTs connected in series across the capacitor, with the midpoint connection and one of the two capacitor terminals brought out as external connections. Depending on which of the two IGBTs in each submodule is turned on, the capacitor is either bypassed or connected into the circuit. Each submodule therefore acts as an independent two-level converter generating a voltage of either 0 or U_{sm} (where U_{sm} is the submodule capacitor voltage). With a suitable number of submodules connected in series, the valve can synthesize a stepped voltage waveform that approximates very closely to a sine-wave and contains very low levels of harmonic distortion.

The MMC differs from other types of converter in that current flows continuously in all six valves of the converter throughout the mains-frequency cycle. As a result, concepts such as "on-state" and "off-state" have no meaning in the MMC.

The direct current splits equally into the three phases and the alternating current splits equally into the upper and lower valve of each phase. The current in each valve is therefore related to the direct current I_d and alternating current I_{ac} as follows:

Upper valve: $$I_v = \frac{I_d}{3} + \frac{I_{ac}}{2}$$

Lower valve: $$I_v = \frac{I_d}{3} - \frac{I_{ac}}{2}$$

` A typical MMC for an HVDC application contains around 300 submodules connected in series in each valve and is therefore equivalent to a 301 level converter. Consequently the harmonic performance is excellent and usually no filters are needed. A further advantage of the MMC is that PWM is not necessary, with the result that the power losses are much lower than those of the 2-level converter, at around 1% per end. Finally, because direct series-connection of IGBTs is not necessary, the IGBT gate drives do not need to be as sophisticated as those for a 2-level converter.

The MMC has two principal disadvantages. Firstly, the control is much more complex than that of a 2-level converter. Balancing the voltages of each of the submodule capacitors is a significant challenge and requires considerable computing power and high-speed communications between the central control unit and the valve. Secondly, the submodule capacitors themselves are large and bulky. A MMC is considerably larger than a comparable-rated 2-level converter, although this may be offset by the saving in space from not requiring filters.

As of 2012 the largest-capacity MMC HVDC system in operation is still the 400 MW Trans Bay Cable scheme but many larger schemes are under construction, including an underground cable interconnection from France to Spain consisting of two 1000 MW links in parallel at a voltage of ±320 kV. A variant of the MMC, proposed by one manufacturer, involves connecting multiple IGBTs in series in each of the two switches that make up the submodule. This gives an output voltage waveform with fewer, larger, steps than the conventional MMC arrangement. This arrangement is referred to as the Cascaded Two Level (CTL) converter. Functionally it is exactly equivalent to the conventional half-bridge MMC in every respect except for the harmonic performance, which is slightly inferior – although still claimed to be good enough to avoid the need for filtering in most instances. Another alternative replaces the half bridge MMC submodule described above, with a full bridge submodule containing four IGBTs in an H bridge arrangement, instead of two.

The full-bridge variant of MMC allows the submodule capacitor to be inserted into the circuit in either polarity.

This confers additional flexibility in controlling the converter and allows the converter to block the fault current which arises from a short-circuit between the positive and negative DC terminals (something which is impossible with any of the preceding types of VSC). Furthermore it allows the DC voltage to be of either polarity (like a LCC HVDC scheme), giving rise to the possibility of hybrid LCC and VSC HVDC systems. However, the full-bridge arrangement requires twice as many IGBTs and has higher power losses than the equivalent half-bridge arrangement.

CHAPTER 5
BUCK CONVERTER

5.1 INTRODUCTION:

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

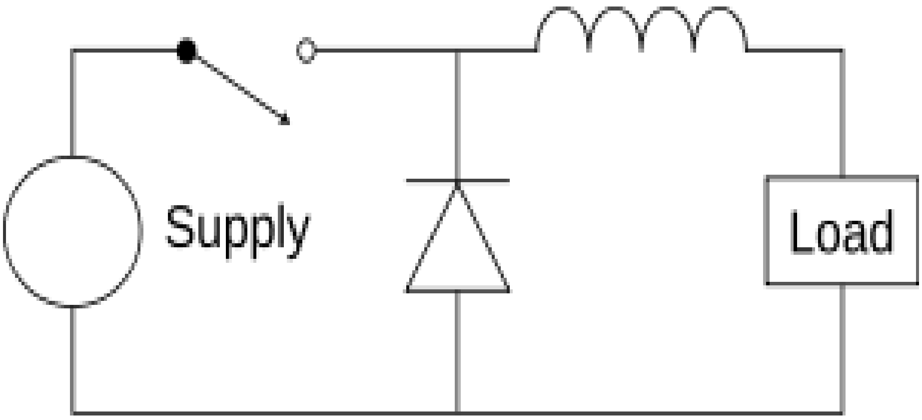


Fig. 5.1: Buck converter circuit diagram.

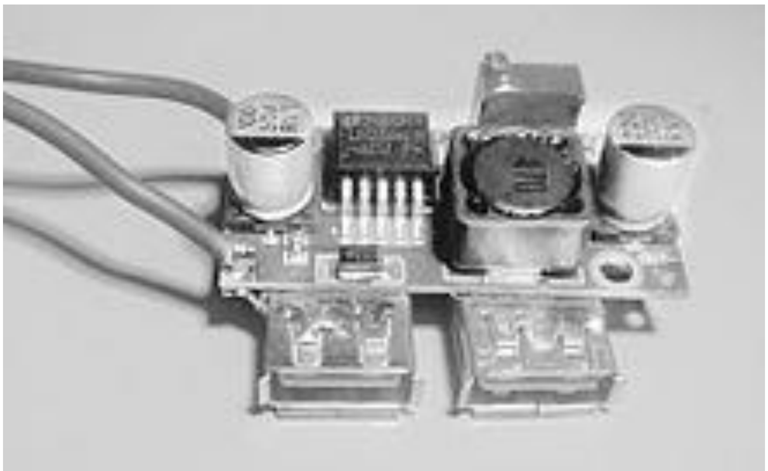


Fig.5.1. A buck converter

Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that lower voltages by dissipating power as heat, but do not step up output current.

Buck converters can be highly efficient (often higher than 90%), making them useful for tasks such as converting a computer's main (bulk) supply voltage (often 12 V) down to lower voltages needed by USB, DRAM and the CPU (1.8 V or less).

5.2 Theory of operation:

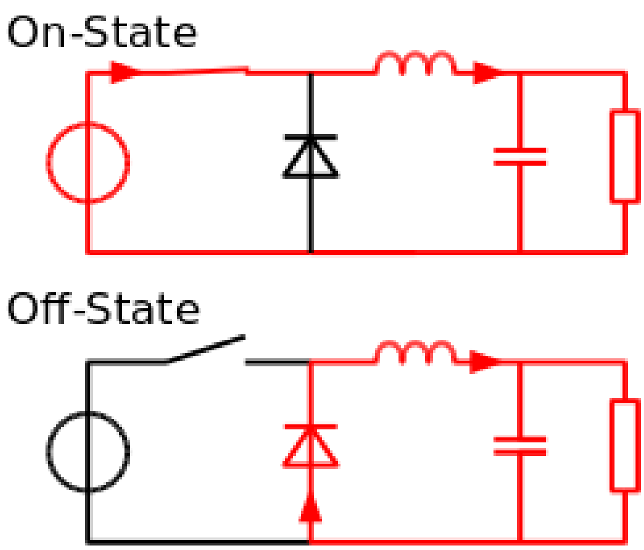


Fig. 5.2: The two circuit configurations of a buck converter: on-state, when the switch is closed; and off-state, when the switch is open (arrows indicate current according to the direction conventional current model).

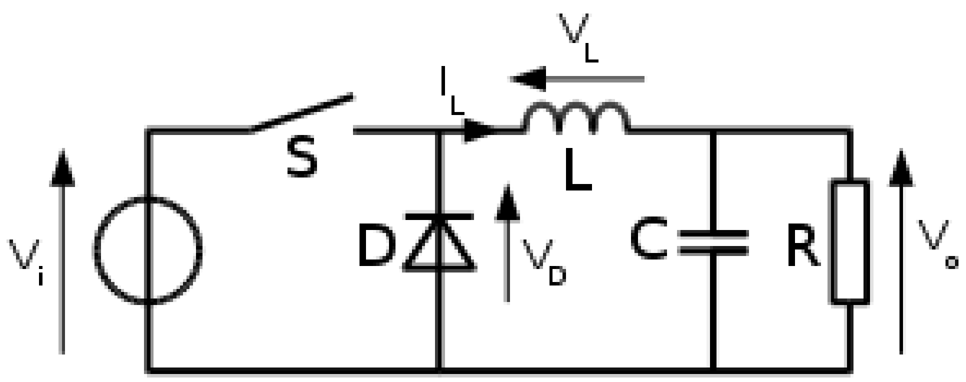


Fig. 5.3 : Naming conventions of the components, voltages and current of the buck converter.

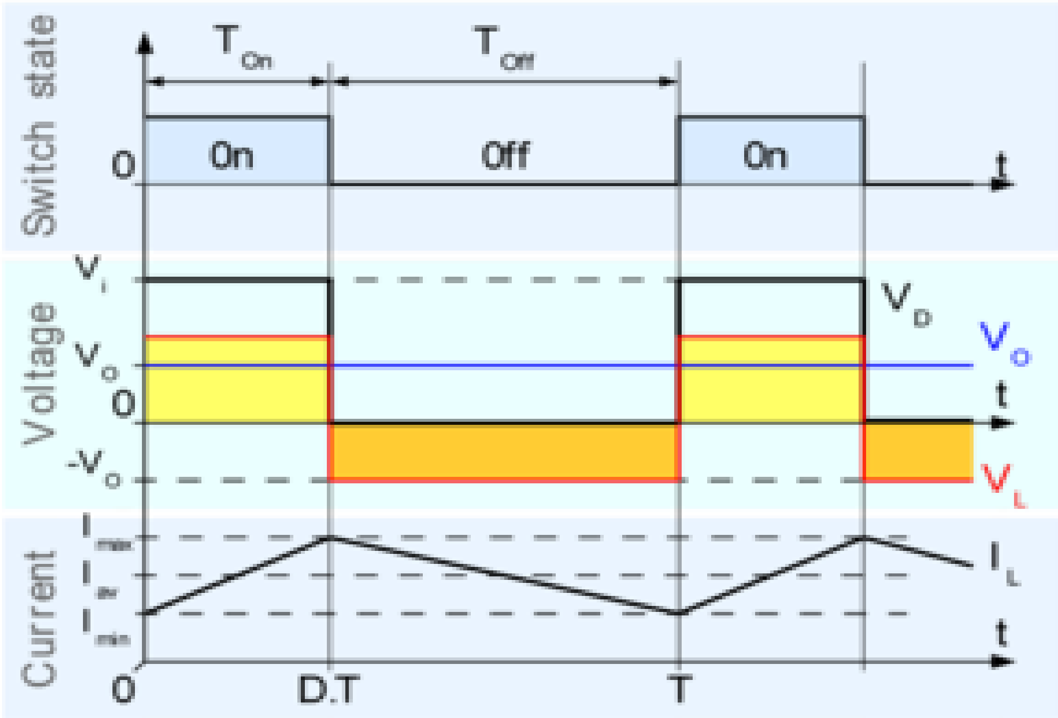


Fig. 5.4: Evolution of the voltages and currents with time in an ideal buck converter operating in continuous mode.

The basic operation of the buck converter has the current in an inductor controlled by two switches (usually a transistor and a diode). In the idealized converter, all the components are considered to be perfect.

Specifically, the switch and the diode have zero voltage drop when on and zero current flow when off, and the inductor has zero series resistance. Further, it is assumed that the input and output voltages do not change over the course of a cycle (this would imply the output capacitance as being infinite).

5.3 Concept:

The conceptual model of the buck converter is best understood in terms of the relation between current and voltage of the inductor. Beginning with the switch open (off-state), the current in the circuit is zero.

When the switch is first closed (on-state), the current will begin to increase, and the inductor will produce an opposing voltage across its terminals in response to the changing current.

This voltage drop counteracts the voltage of the source and therefore reduces the net voltage across the load. Over time, the rate of change of current decreases, and the voltage across the inductor also then decreases, increasing the voltage at the load.

During this time, the inductor stores energy in the form of a magnetic field. If the switch is opened while the current is still changing, then there will always be a voltage drop across the inductor, so the net voltage at the load will always be less than the input voltage source.

When the switch is opened again (off-state), the voltage source will be removed from the circuit, and the current will decrease.The decreasing current will produce a voltage drop across the inductor (opposite to the drop at on-state), and now the inductor becomes a Current Source. The stored energy in the inductor's magnetic field supports the current flow through the load. This current, flowing while the input voltage source is disconnected, when concatenated with the current flowing during on-state, totals to current greater than the average input current (being zero during off-state). The "increase" in average current makes up for the reduction in voltage, and ideally preserves the power provided to the load. During the off-state, the inductor is discharging its stored energy into the rest of the circuit. If the switch is closed again before the inductor fully discharges (on-state), the voltage at the load will always be greater than zero.

5.3.1 Continuous mode:

A buck converter operates in continuous mode if the current through the inductor never falls to zero during the commutation cycle. In this mode, the operating principle is described by the plots in figure 4.4: The current through the inductor rises linearly (in approximation, so long as the voltage drop is almost constant).

As the diode is reverse-biased by the voltage source V, no current flows through it; When the switch is opened (bottom of figure 2), the diode is forward biased. The voltage across the inductor is (neglecting diode drop). Current decreases.

5.3.2 Discontinuous mode:

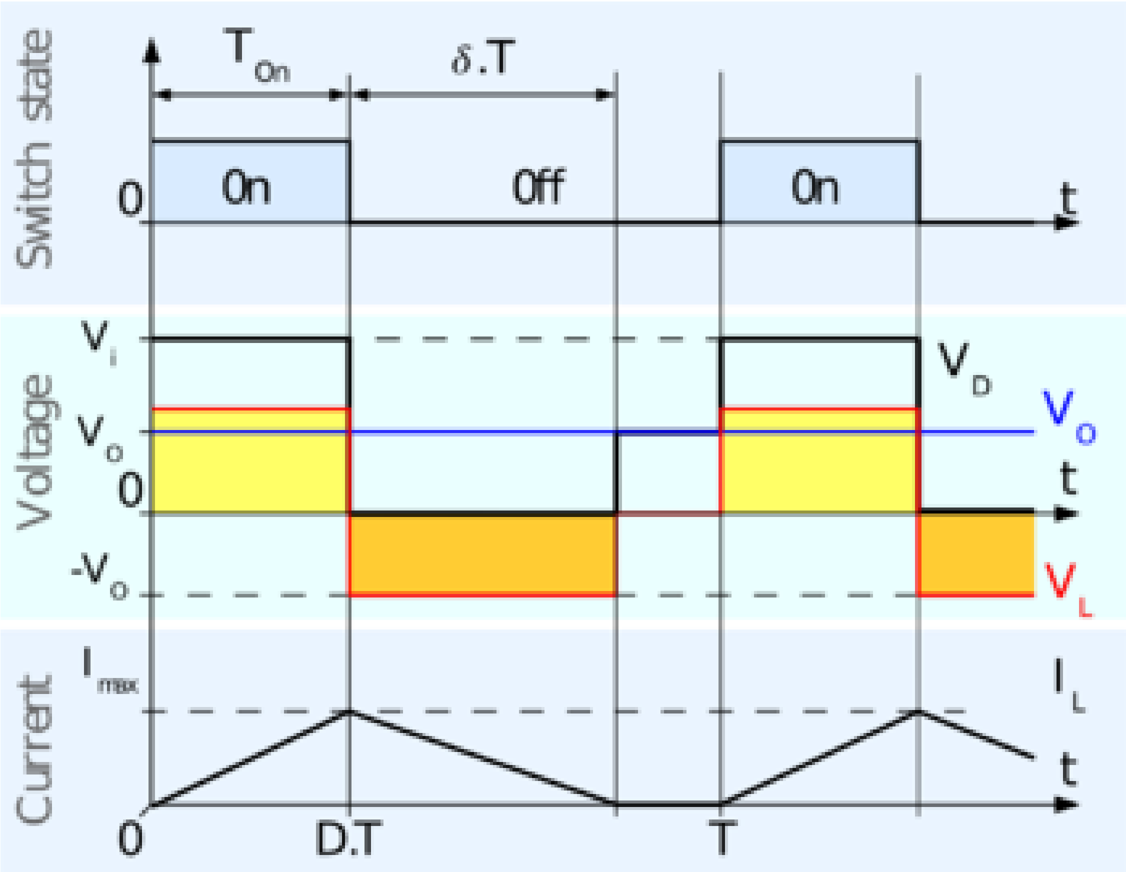


Fig.5.5: Evolution of the voltages and currents with time in an ideal buck converter operating in discontinuous mode.

In some cases, the amount of energy required by the load is too small. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle (see figure 5). This has, however, some effect on the previous equations. The inductor current falling below zero results in the discharging of the output capacitor during each cycle and therefore higher switching losses. A different control technique known as Pulse-frequency modulation can be used to minimize these losses.

we still consider that the converter operates in steady state. Therefore, the energy in the inductor is the same at the beginning and at the end of the cycle (in the case of discontinuous mode, it is zero).

This means that the average value of the inductor voltage (V_L) is zero; i.e., that the area of the yellow and orange rectangles in figure 5.5 are the same.

This yields: Qualitatively, as the output capacitor or switching frequency increase, the magnitude of the ripple decreases.

Output voltage ripple is typically a design specification for the power supply and is selected based on several factors. Capacitor selection is normally determined based on cost, physical size and non-idealities of various capacitor types. Switching frequency selection is typically determined based on efficiency requirements, which tends to decrease at higher operating frequencies, as described below in Effects of non-ideality on the efficiency. Higher switching frequency can also raise EMI concerns.

Output voltage ripple is one of the disadvantages of a switching power supply, and can also be a measure of its quality.

5.4 Effects of non-ideality on the efficiency:

A simplified analysis of the buck converter, as described above, does not account for non-idealities of the circuit components nor does it account for the required control circuitry. Power losses due to the control circuitry are usually insignificant when compared with the losses in the power devices (switches, diodes, inductors, etc.) The non-idealities of the power devices account for the bulk of the power losses in the converter. Both static and dynamic power losses occur in any switching regulator. Static power losses include (conduction) losses in the wires or PCB traces, as well as in the switches and inductor, as in any electrical circuit. Dynamic power losses occur as a result of switching, such as the charging and discharging of the switch gate, and are proportional to the switching frequency.

For N-MOSFETs, the high-side switch must be driven to a higher voltage than V_i. To achieve this, MOSFET gate drivers typically feed the MOSFET output voltage back into the gate driver. The gate driver then adds its own supply voltage to the MOSFET output voltage when driving the high-side MOSFETs to achieve a V_{GS} equal to the gate driver supply voltage. Because the low-side V_{GS} is the gate driver supply voltage, this results in very similar V_{GS} values for high-side and low-side MOSFETs.
A complete design for a buck converter includes a tradeoff analysis of the various power losses. Designers balance these losses according to the expected uses of the finished design. A converter expected to have a low switching frequency does not require switches with low gate transition losses.

A converter operating at a high duty cycle requires a low-side switch with low conduction losses.

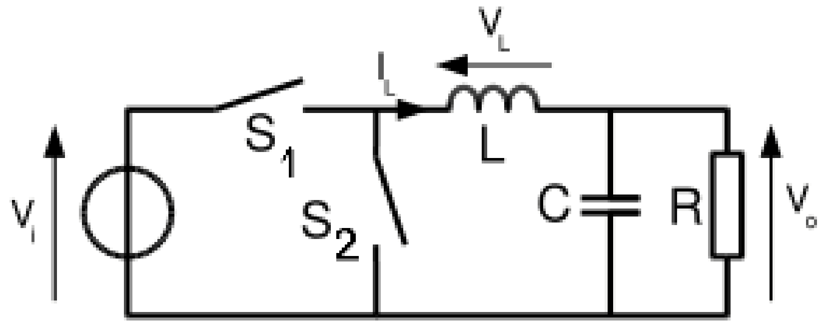


Fig. 5.6: Simplified schematic of a synchronous converter, in which D is replaced by a second switch, S_2.

A synchronous buck converter is a modified version of the basic buck converter circuit topology in which the diode, D, is replaced by a second switch, S_2. This modification is a tradeoff between increased cost and improved efficiency.

In a standard buck converter, the flyback diode turns on, on its own, shortly after the switch turns off, as a result of the rising voltage across the diode.

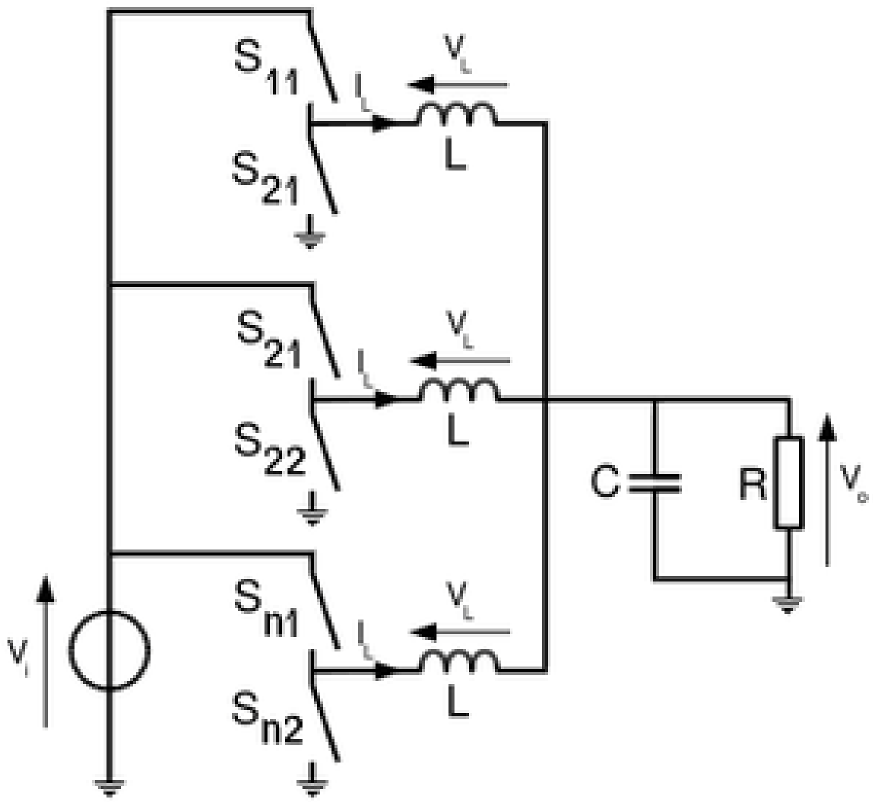


Fig. 5.7: Schematic of a generic synchronous n-phase buck converter.

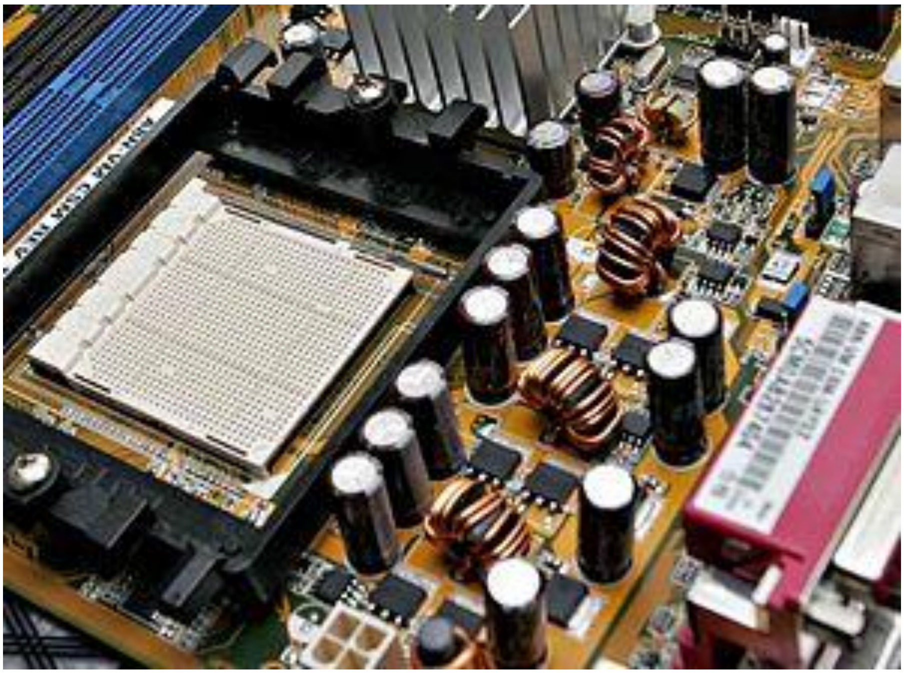


Fig. 5.8: Closeup picture of a multiphase CPU power supply for an AMD Socket 939 processor.

The three phases of this supply can be recognized by the three black toroidal inductors in the foreground. The smaller inductor below the heat sink is part of an input filter.

The multiphase buck converter is a circuit topology where basic buck converter circuits are placed in parallel between the input and load. Each of the n "phases" is turned on at equally spaced intervals over the switching period. This circuit is typically used with the synchronous buck topology, described above.

This type of converter can respond to load changes as quickly as if it switched n times faster, without the increase in switching losses that would cause. Thus, it can respond to rapidly changing loads, such as modern microprocessors. There is also a significant decrease in switching ripple. Not only is there the decrease due to the increased effective frequency, but any time that n times the duty cycle is an integer, the switching ripple goes to 0; the rate at which the inductor current is increasing in the phases which are switched on exactly matches the rate at which it is decreasing in the phases which are switched off.

Another advantage is that the load current is split among the n phases of the multiphase converter. This load splitting allows the heat losses on each of the switches to be spread across a larger area. This circuit topology is used in computer motherboards to convert the

12 V_{DC} power supply to a lower voltage (around 1 V), suitable for the CPU.

Modern CPU power requirements can exceed 200 W, can change very rapidly, and have very tight ripple requirements, less than 10 mV. Typical motherboard power supplies use 3 or 4 phases.

One major challenge inherent in the multiphase converter is ensuring the load current is balanced evenly across the n phases. This current balancing can be performed in a number of ways.

Current can be measured "loss lessly" by sensing the voltage across the inductor or the lower switch (when it is turned on).

This technique is considered lossless because it relies on resistive losses inherent in the buck converter topology. Another technique is to insert a small resistor in the circuit and measure the voltage across it. This approach is more accurate and adjustable, but incurs several costs—space, efficiency and money.

Finally, the current can be measured at the input. Voltage can be measured loss lessly, across the upper switch, or using a power resistor, to approximate the current being drawn. This approach is technically more challenging, since switching noise cannot be easily filtered out. However, it is less expensive than emplacing a sense resistor for each phase.

CHAPTER 6
PROPOSED CONTROLLER

6.1 Introduction about Fuzzy Logic Technique:

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalve logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with un-sharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of fl. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalve logical system.

The basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if-then rule or, simply, fuzzy rule. Although rule-based systems have a long history of use in Artificial Intelligence (AI), what is missing in such systems is a mechanism for dealing with fuzzy consequents and fuzzy antecedents. In fuzzy logic, this mechanism is provided by the calculus of fuzzy rules. The calculus of fuzzy rules serves as a basis for what might be called the Fuzzy Dependency and Command Language (FDCL). Although FDCL is not used explicitly in the toolbox, it is effectively one of its principal constituents. In most of the applications of fuzzy logic, a fuzzy logic solution is, in reality, a translation of a human solution into FDCL. A trend that is growing in visibility relates to the use of fuzzy logic in combination with neuro computing and genetic algorithms. More generally, fuzzy logic, neuro-computing, and genetic algorithms may be viewed as the principal constituents of what might be called soft computing. Unlike the traditional, hard computing, soft computing accommodates the imprecision of the real world. The guiding principle of soft computing is: Exploit the tolerance for imprecision, uncertainty, and partial truth to achieve tractability, robustness, and low solution cost. In the future, soft computing could play an increasingly important role in the conception and design of systems who’s MIQ (Machine IQ) is much higher than that of systems designed by conventional methods.

Among various combinations of methodologies in soft computing, the one that has highest visibility at this juncture is that of fuzzy logic and neuro computing, leading to neuro-fuzzy systems. Within fuzzy logic, such systems play a particularly important role in the induction of rules from observations.

Fuzzy logic is a fascinating area of research because it does a good job of trading off between significance and precision. something that humans have been managing for a very long time. In this sense, fuzzy logic is both old and new because, although the modern and methodical science of fuzzy logic is still young, the concept of fuzzy logic relies on age-old skills of human reasoning.

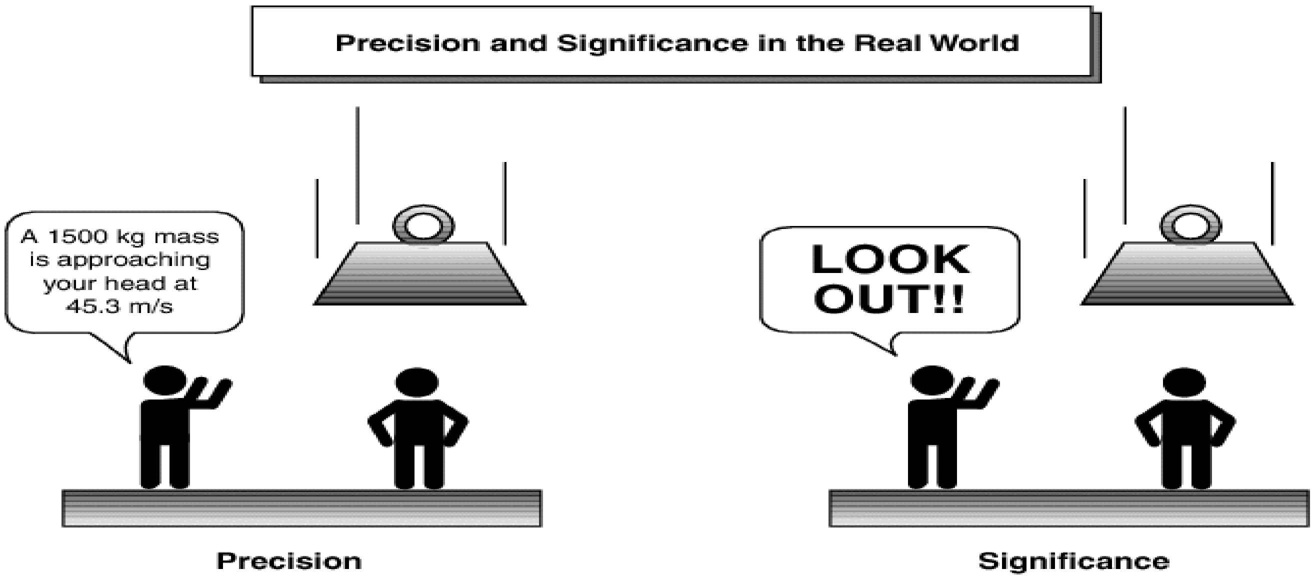


Fig. 6.1 Fuzzy Description

6.2. Uses of fuzzy logic:

Fuzzy logic is a convenient way to map an input space to an output space. Mapping input to output is the starting point for everything. Consider the following examples:

- With information about how good your service was at a restaurant, a fuzzy logic system can tell you what the tip should be.
- With your specification of how hot you want the water, a fuzzy logic system can adjust the faucet valve to the right setting.
- With information about how far away the subject of your photograph is, a fuzzy logic system can focus the lens for you.

- With information about how fast the car is going and how hard the motor is working, a fuzzy logic system can shift gears for you.

To determine the appropriate amount of tip requires mapping inputs to the appropriate outputs.

Between the input and the output, the preceding figure shows a black box that can contain any number of things: fuzzy systems, linear systems, expert systems, neural networks, differential equations, interpolated multidimensional lookup tables, or even a spiritual advisor, just to name a few of the possible options.

Clearly the list could go on and on. Fuzzy is faster and cheaper.

6.3. Fuzzy Logic Controller:

6.3.1. Simple Fuzzy Logic Controllers

First-generation simple fuzzy logic controllers can generally be depicted by a block diagram.

The knowledge-base module contains knowledge about all the input and output fuzzy partitions. It will include the term set and the corresponding membership functions defining the input variables to the fuzzy rule-base system and the output variables, or control actions, to the plant under control.

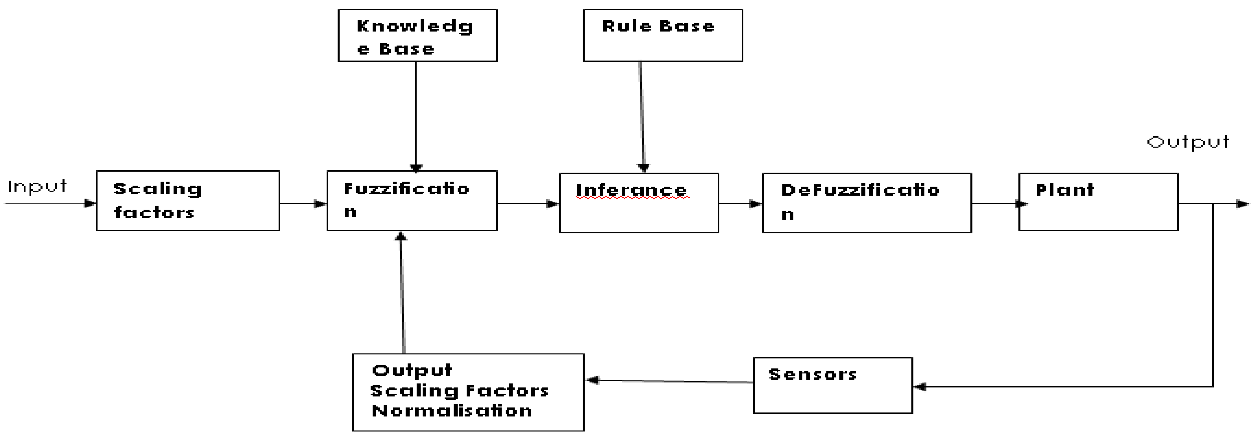


Fig. 6.2 A Simple Fuzzy Logic Control System

- The steps in designing a simple fuzzy logic control system are as follows:
- Identify the variables (inputs, states and outputs) of the plant. Partition the universe of discourse or the interval spanned by each variable into a number of fuzzy subsets, assigning each a linguistic label (subsets include all the elements in the universe).
- Assign or determine a membership function for each fuzzy subset.
- Assign the fuzzy relationships between the inputs or states fuzzy subsets on the one hand and the outputs fuzzy subsets on the other hand, thus forming the rule-base.
- Choose appropriate scaling factors for the input and output variables in order to normalize the variables to the [0, 1] or the [-1, 1] interval.
- Fuzzily the inputs to the controller.
- Use fuzzy approximate reasoning to infer the output contributed from each rule.
- Aggregate the fuzzy outputs recommended by each rule.
- Apply defuzzification to form a crisp output.

In a nonadaptive simple fuzzy logic controller, the methodology used and the results of the nine steps mentioned above are fixed, whereas in an adaptive fuzzy logic controller, they are adaptively modified based on some adaptation law in order to optimize the control.

A simple fuzzy logic control system has the following features:

- Fixed and uniform input- and output- scaling factors.
- Flat, single-partition rule-base with fixed and noninteractive rules. All the rules have the same degree of certainty and confidence, equal to unity
- Fixed membership functions.
- Limited number of rules, which increase exponentially with the number of input variables.
- Fixed metaknowledge including the methodology for approximate reasoning, rules-aggregation, and output defuzzification.
- Low-level control and no hierarchical rule structure.

6.3.2. General Fuzzy Logic Controllers:

The principal design elements in a general fuzzy logic control system are as follows:

1. Fuzzification strategies and the interpretation of a fuzzification operator, or fuzzifier.

2. Knowledge base:

a. Discrimination/normalization of the universe of discourse.

b. Fuzzy partitions of the input and output spaces.

c. Completeness of the partitions.

d. Choice of the membership functions of a primary fuzzy set.

3. Rule-base:

a. Choice of process state (input) variables and control (output) variables.

b. Source of derivation of fuzzy control rules.

c. Types of fuzzy control rules.

d. Consistency, interactivity, and completeness of fuzzy control rules.

4. Decision-making logic:

a. Definition of a fuzzy implication.

b. Interpretation of sentence connective and

c. Interpretation of sentence connective or.

d. Inference mechanism.

5. Defuzzification strategies and the interpretation of a defuzzification operator (defuzzifier).

Adaptation or change in any of the five design parameters above creates an adaptive fuzzy logic control system. If all are fixed, the fuzzy logic control system is simple and nonadaptive.

6.4. Membership Functions:

Definition: A graph that defines how each point in the input space is mapped to membership value between 0 and 1. Input space is often referred as the universe of discourse or universal set (u), which contain all the possible elements of concern in each particular application.

6.4.1. Types of membership functions:

Before we start defining different types of membership functions, let us consider a Fuzzy IF-THEN rule for a car:

IF the speed of a car is high, THEN apply less force to the accelerator

IF the speed is low, THEN apply more force to the accelerator

Straight line:

The simplest membership function is formed by straight line. We consider the speed of car in Fig. 6.3 and plot the membership function for high. Where the horizontal represent the speed of the car and vertical axis represent the membership value for high.

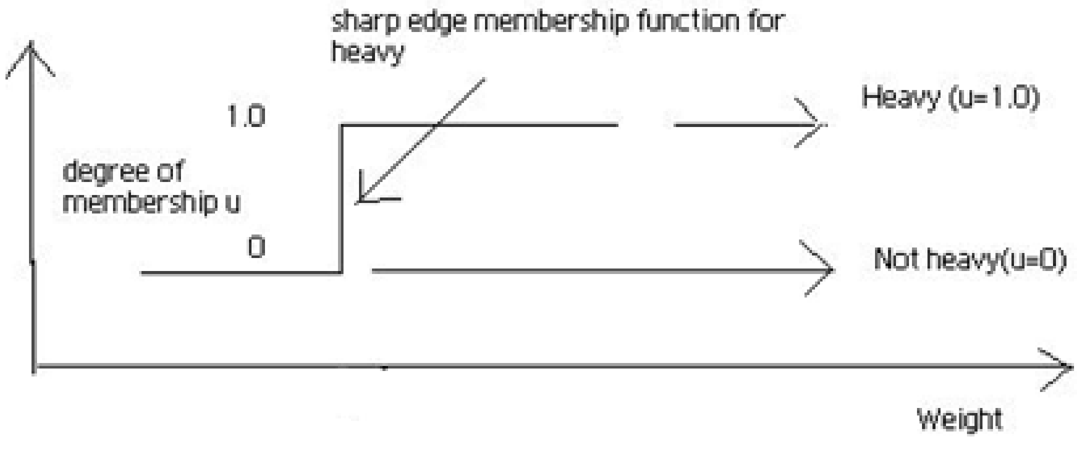


Fig. 6.1 Straight Line Membership Function

Trapezoidal:

If we consider the case 6.2 and plot the membership function for “less”, we get a trapezoidal membership function. Fig. 6.2 shows a graphical representation, where the horizontal axis represent the force applied to the accelerator and the vertical shows membership value for “less”. The function is often represented by “trapmf”.

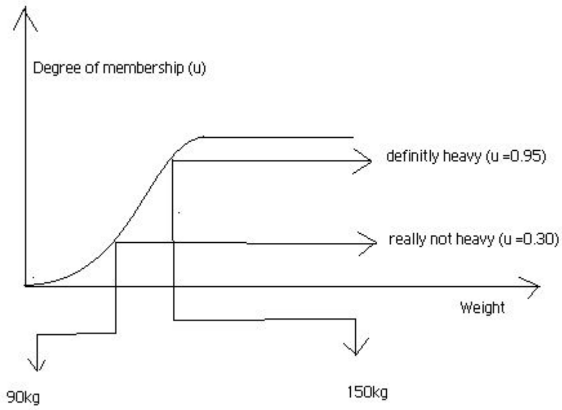


Fig. 6.2 Trapezoidal Membership Function

Gaussian:

Let say a fuzzy set Z which represent “number close to zero”. The possible membership function for Z is

$\mu_Z(x) = e^{-x^2}$ If we plot this function we get a graph shown in Fig 6.3 and are refer as Gaussian membership function.

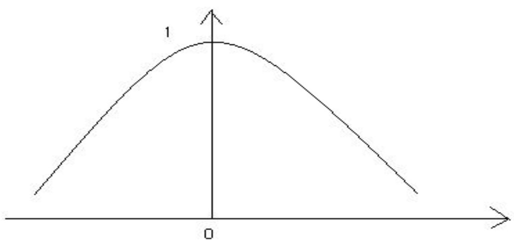


Fig. 6.3 Gaussian Membership Function

Triangular:

This is formed by the combination of straight lines. The function is name as “trimf” .We considers the above case i.e. fuzzy set Z to represent the “number close to zero”.

So mathematically we can also represent it as

0 if X<-1

$\mu_Z(x)$ = X + 1 if -1 ≤ X <0

=1–X if 0 ≤ X <1

=0 if 1≤ X

Fig. 6.4 called “triangular membership function”

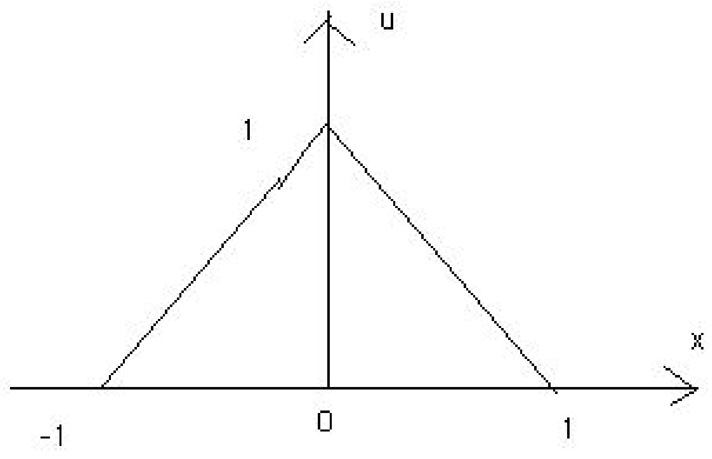


Fig. 6.4 Traingular Membership Function

6.5. Fuzzy Logic Tool Box:

In fuzzy Logic Toolbox software, fuzzy logic should be interpreted as FL, that is, fuzzy logic in its wide sense. The basic ideas underlying FL are explained very clearly and insightfully in Foundations of Fuzzy Logic. What might be added is that the basic concept underlying FL is that of a linguistic variable, that is, a variable whose values are words rather than numbers. In effect, much of FL may be viewed as a methodology for computing with words rather than numbers.

Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution

The fuzzy logic toolbox is highly impressive in all respects. It makes fuzzy logic an effective tool for the conception and design of intelligent systems. The fuzzy logic toolbox is easy to master and convenient to use. And last, but not least important, it provides a reader friendly and up-to-date introduction to methodology of fuzzy logic and its wide ranging applications. You can create and edit fuzzy inference systems with Fuzzy Logic Toolbox software. You can create these systems using graphical tools or command-line functions, or you can generate them automatically using either clustering or adaptive neuro-fuzzy techniques.

If you have access to SIMULINK software, you can easily test your fuzzy system in a block diagram simulation environment. The toolbox also lets you run your own stand-alone C programs directly. This is made possible by a stand-alone Fuzzy Inference Engine that reads the fuzzy systems saved from a MATLAB session.

You can customize the stand-alone engine to build fuzzy inference into your own code. All provided code is ansi compliant. Because of the integrated nature of the MATLAB environment, you can create your own tools to customize the toolbox or harness it with another toolbox, such as the Control System Toolbox, Neural Network Toolbox, or Optimization Toolbox software.

The Fuzzy Logic Toolbox extends the MATLAB technical computing environment with tools for designing systems based on fuzzy logic. Graphical user interfaces (GUIs) guide you through the steps of fuzzy inference system design. Functions are provided for many common fuzzy logic methods, including fuzzy clustering and adaptive neuro fuzzy learning. The toolbox lets you model complex system behaviors using simple logic rules and then implements these rules in a fuzzy inference system. You can use the toolbox as a standalone fuzzy inference engine. Alternatively, you can use fuzzy inference blocks in SIMULINK and simulate the fuzzy systems within a comprehensive model of the entire dynamic system.

6.6 Working with the fuzzy logic toolbox:

The Fuzzy Logic Toolbox provides GUIs to let you perform classical fuzzy system development and pattern recognition. Using the toolbox, you can develop and analyze fuzzy inference systems, develop adaptive neuro fuzzy inference systems, and perform fuzzy clustering. In addition, the toolbox provides a fuzzy controller block that you can use in SIMULINK to model and simulate a fuzzy logic control system. From SIMULINK, you can generate C code for use in embedded applications that include fuzzy logic.

6.6.1. Building a fuzzy inference system:

Fuzzy inference is a method that interprets the values in the input vector and, based on user defined rules, assigns values to the output vector. Using the GUI editors and viewers in the Fuzzy Logic Toolbox, you can build the rules set, define the membership functions, and analyze the behavior of a fuzzy inference system (FIS). The following editors and viewers are provided.

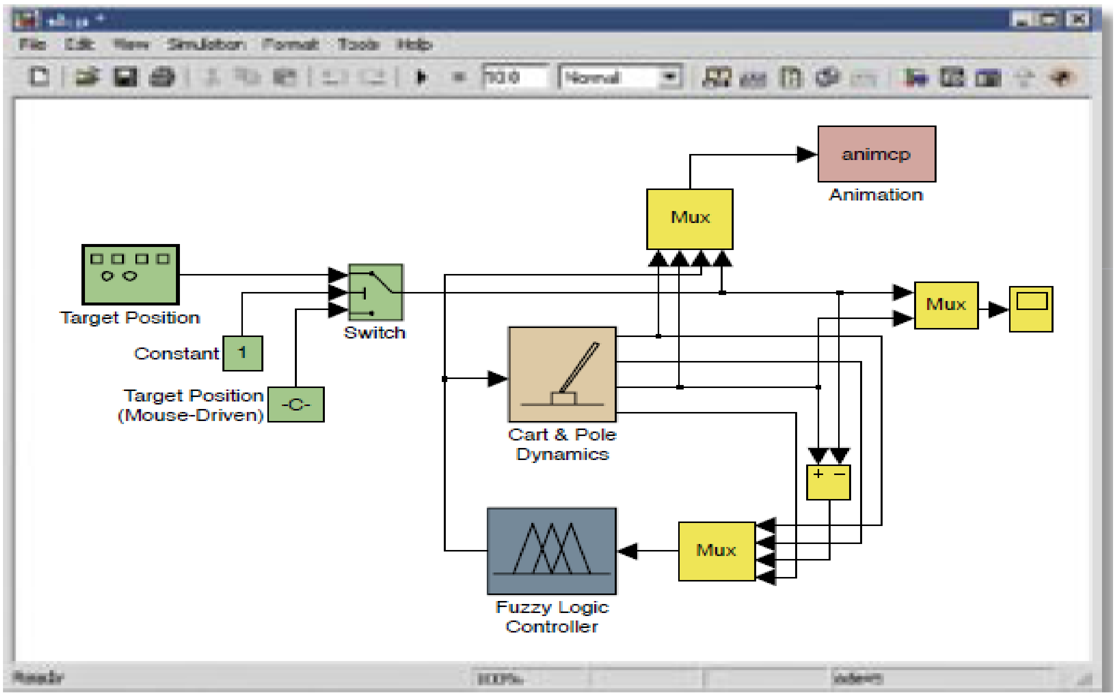


Fig. 6.3 Fuzzy Interference System

6.7 Key features:

- ■ Specialized GUIs for building fuzzy inference systems and viewing and analyzing results
- ■ Membership functions for creating fuzzy inference systems
- ■ Support for AND, OR, and NOT logic in user-defined rules
- ■ Standard Mamdani and Sugeno-type fuzzy inference systems
- ■ Automated membership function shaping through neuroadaptive and fuzzy clustering learning techniques

■ Ability to embed a fuzzy inference system in a SIMULINK model

■Ability to generate embeddable C code or stand-alone executable fuzzy inference engines.

In this section we'll be building a simple tipping example using the graphical user interface (GUI) tools provided by the Fuzzy Logic Toolbox. Although it's possible to use the Fuzzy Logic Toolbox by working strictly from the command line, in general it's much easier to build a system graphically. There are five primary GUI tools for building, editing, and observing fuzzy inference systems in the Fuzzy Logic Toolbox. The Fuzzy Inference System or FIS Editor, the Membership Function Editor, the Rule Editor, the Rule Viewer, and the Surface Viewer. These GUIs are dynamically linked, in that changes you make to the FIS using one of them, can affect what you see on any of the other open GUIs.
You can have any or all of them open for any given system. These are shown in Fig. 6.4

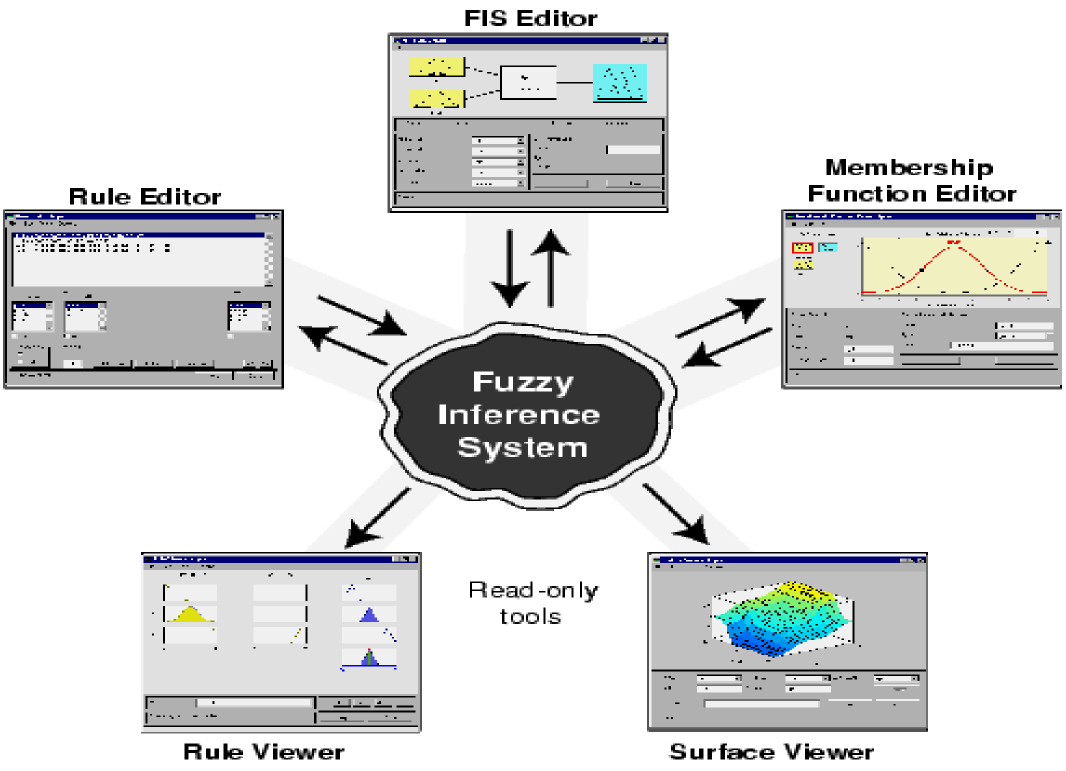


Fig. 6.4 The Primary GUI Tools of the Fuzzy Logic Toolbox

The Fuzzy Logic Toolbox doesn't limit the number of inputs. However, the number of inputs may be limited by the available memory of your machine. If the number of inputs is too large, or the number of membership functions is too big, then it may also be difficult to analyze the FIS using the other GUI tools .

The Membership Function Editor is used to define the shapes of all the membership functions associated with each variable. The Rule Editor is for editing the list of rules that defines the behavior of the system.

The Rule Viewer and the Surface Viewer are used for looking at, as opposed to editing, the FIS. They are strictly read-only tools. The Rule Viewer is a MATLAB-based display of the fuzzy inference diagram shown at the end of the last section. Used as a diagnostic, it can show (for example) which rules are active, or how individual membership function shapes are influencing the results. The Surface Viewer is used to display the dependency of one of the outputs on any one or two of the inputs that is, it generates and plots an output surface map for the system. The five primary GUIs can all interact and exchange information.

Any one of them can read and write both to the workspace and to the disk (the read-only viewers can still exchange plots with the workspace and/or the disk). For any fuzzy inference system, any or all of these five GUIs may be open. If more than one of these editors is open for a single system, the various GUI windows are aware of the existence of the others, and will, if necessary, update related windows. Thus if the names of the membership functions are changed using the Membership Function Editor, those changes are reflected in the rules shown in the Rule Editor. The editors for any number of different FIS systems may be open simultaneously. The FIS Editor, the Membership Function Editor, and the Rule Editor can all read and modify the FIS data, but the Rule Viewer and the Surface Viewer do not modify the FIS data in any way. The starting point is to write down the three golden rules of tipping, based on years of personal experience in restaurants.

1. If the service is poor or the food is rancid, then tip is cheap.
2. If the service is good, then tip is average.
3. If the service is excellent or the food is delicious, then tip is generous.

We'll assume that an average tip is 15%, a generous tip is 25%, and a cheap tip is 5%. It's also useful to have a vague idea of what the tipping function should look like. A simple tipping function is shown as in Fig. 5.1. Obviously the numbers and the shape of the curve are subject to local traditions, cultural bias, and so on, but the three rules are pretty universal. Now we know the rules, and we have an idea of what the output should look like. Let's begin working with the GUI tools to construct a fuzzy inference system for this decision process.

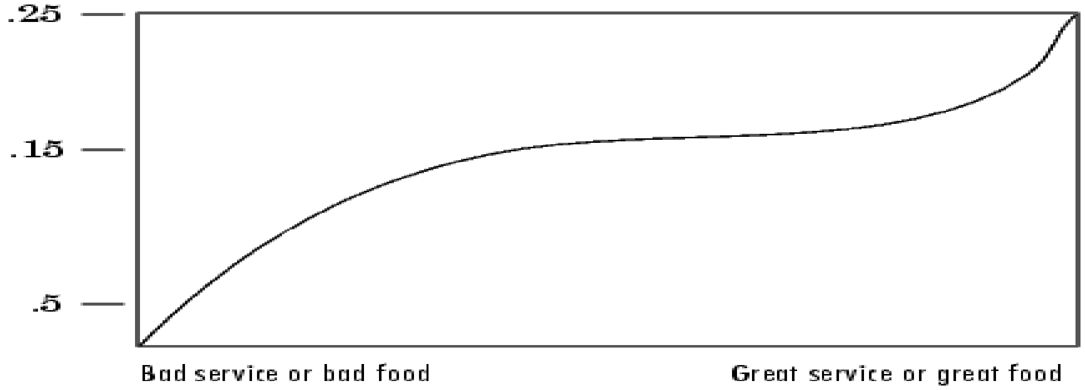


Fig 6.7 The Tipping Function

6.8 The FIS editor:

The following discussion walks you through building a new fuzzy inference system from scratch. If you want to save time and follow along quickly, you can load the already built system by typing fuzzy tipper This will load the FIS associated with the file tipper. FIS (the .FIS implied) and launch the FIS Editor. However, if you load the pre-built system, you will not be building rules and constructing membership functions. The FIS Editor displays general information about a fuzzy inference system. There's a simple diagram as shown in Fig. 6.5That shows the names of each input variable on the left, and those of each output variable on the right. The sample membership functions shown in the boxes are just icons and do not depict the actual shapes of the membership functions. Below the diagram is the name of the system and the type of inference used. The default, Madman-type inference, is what we'll continue to use for this example. Another slightly different type of inference, called Surgeon-type inference, is also available. Below the name of the fuzzy inference system, on the left side of the figure, are the pop-up menus that allow you to modify the various pieces of the inference process. On the right side at the bottom of the figure is the area that displays the name of an input or output variable, its associated membership function type, and its range. The latter two fields are specified only after the membership functions have been. Below that region are the Help and Close buttons that call up online help and close the window, respectively. At the bottom is a status line that relays information about the system. To start this system from scratch, type fuzzy at the mat lab prompt. The generic untitled FIS Editor opens, with one input, labeled input1, and one output, labeled output1.

For this example, we will construct a two-input, one output system, so go to the Edit menu and select Add input. A second yellow box labeled input2 will appear. The two inputs we will have in our example are service and food. Our one output is tip.

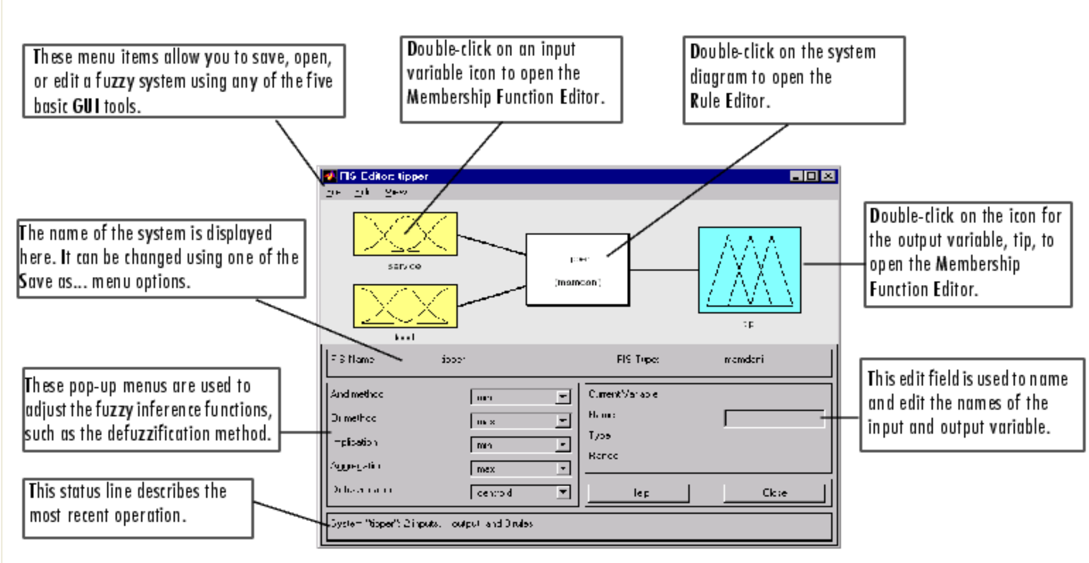


Fig. 6.5 the FIS Editor

We'd like to change the variable names to reflect that, though:

- Click once on the left-hand (yellow) box marked input1 (the box will be highlighted in red).
- In the white edit field on the right, change input1 to service and press Return.
- Click once on the left-hand (yellow) box marked **i**nput2 (the box will be highlighted in red).
- In the white edit field on the right, change input2 to food and press Return.
- Click once on the right-hand (blue) box marked output1.
- In the white edit field on the right, change output1 to tip.
- From the File menu select Save to workspace as... and a window appears as shown in Fig. 6.6
- Enter the variable name tipper and click on ok.

You will see the diagram updated to reflect the new names of the input and output variables. There is now a new variable in the workspace called tipper that contains all the information about this system.

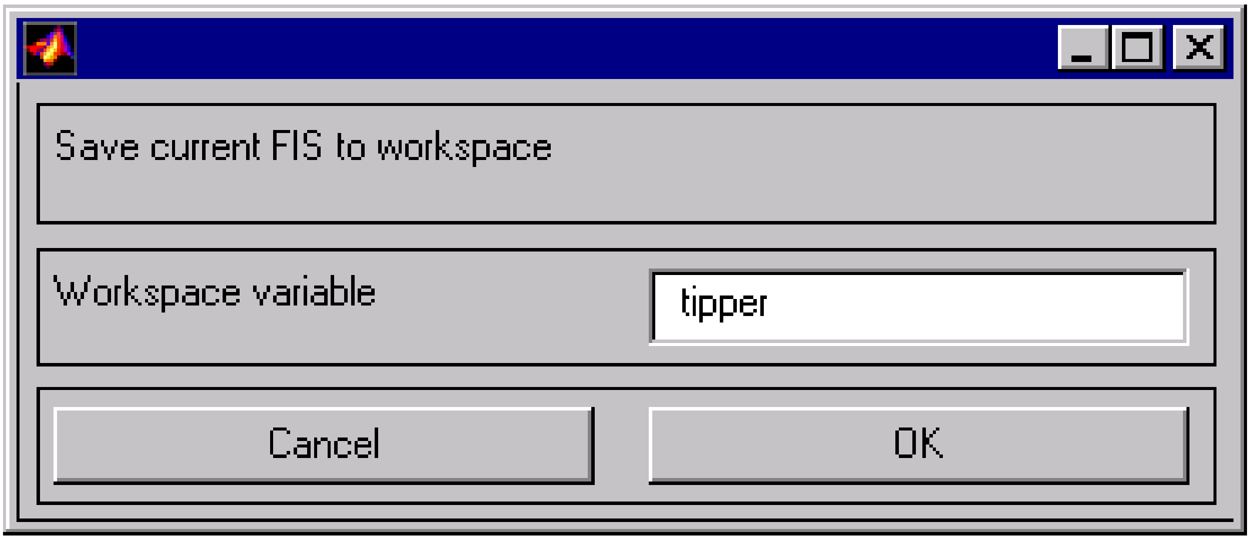


Fig. 6.6 'saves to workspace as...' Window

By saving to the workspace with a new name, you also rename the entire system. Your window will look like as shown in Fig.6.6

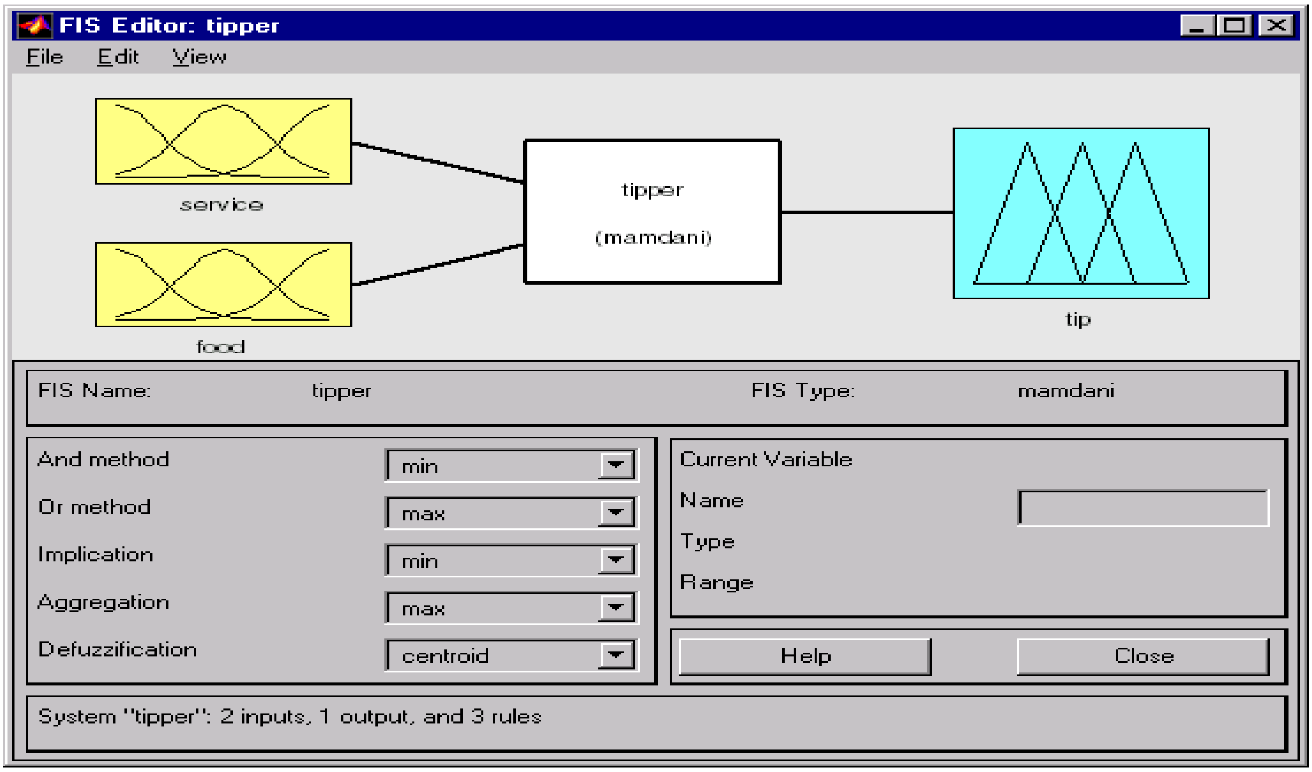


Fig. 6.7the Updated FIS Editor

Leave the inference options in the lower left in their default positions for now. You've entered all the information you need for this particular GUI.

Next define the membership functions associated with each of the variables. To do this, open the Membership Function Editor. You can open the Membership Function Editor in one of three ways:

- Pull down the View menu item and select Edit Membership Functions....
- Double-click on the icon for the output variable, tip.
- Type MFEDIT at the command line.

6.8.1. The Membership Function:

The Membership Function Editor shares some features with the FIS Editor. In fact, all of the five basic GUI tools have similar menu options, status lines, and Help and Close buttons. The Membership Function Editor is the tool that lets you display and edits all of the membership functions associated with all of the input and output variables for the entire fuzzy inference system. Fig.6.7. shows the Membership Function Editor.

When you open the Membership Function Editor to work on a fuzzy inference system that does not already exist in the workspace, there is not yet any membership functions associated with the variables that you have just defined with the FIS Editor.

On the upper left side of the graph area in the Membership Function Editor is a "Variable Palette" that lets you set the membership functions for a given variable. To set up your membership functions associated with an input or an output variable for the FIS, select an FIS variable in this region by clicking on it.

Next select the Edit pull-down menu, and choose Add MFs.... A new window will appear which allows you to select both the membership function type and the number of membership functions associated with the selected variable. In the lower right corner of the window are the controls that let you change the name, type, and parameters (shape), of the membership function, once it has been selected.

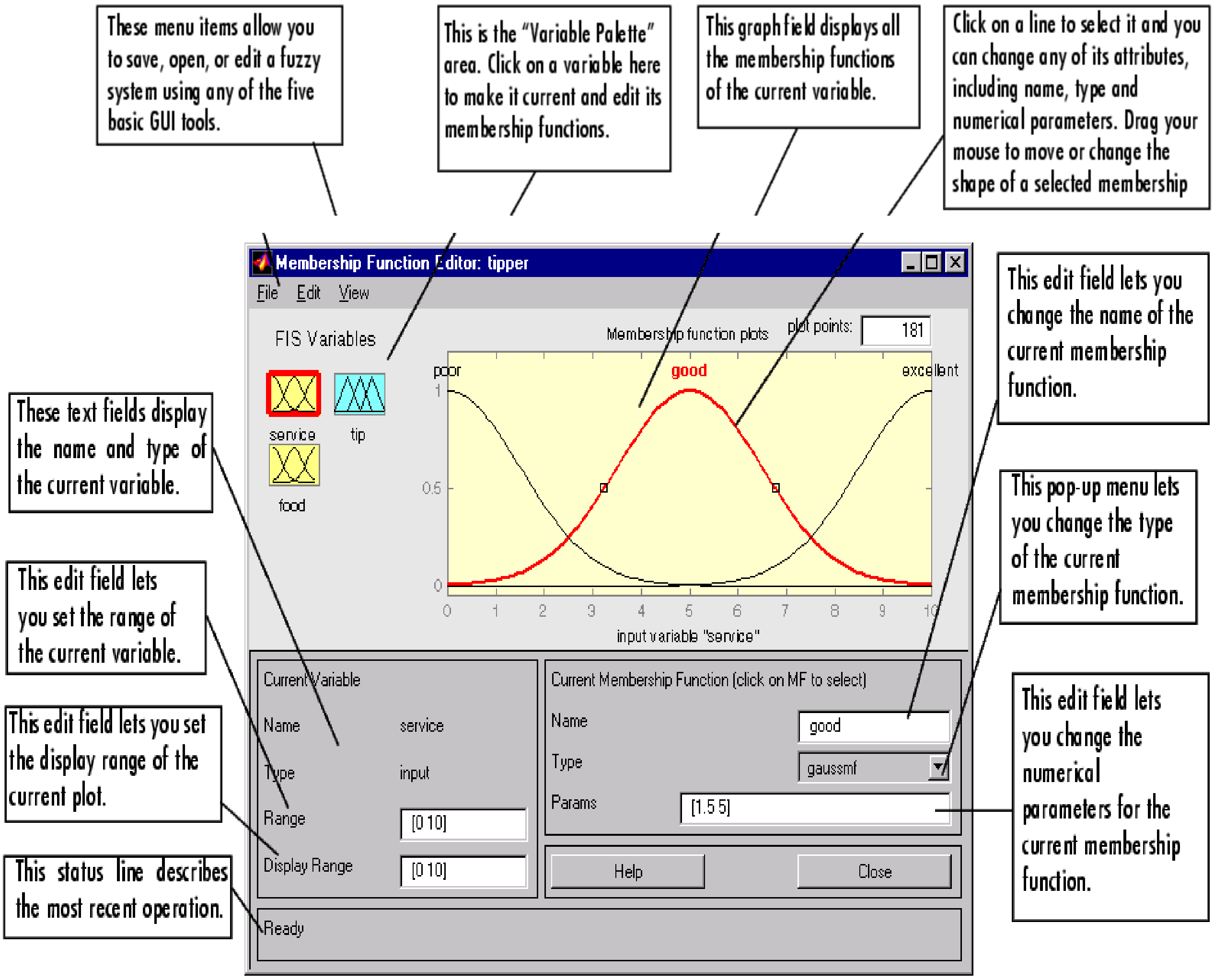


Fig.6.8 The Membership Function Editor

The membership functions from the current variable are displayed in the main graph. These membership functions can be manipulated in two ways. You can first use the mouse to select a particular membership function associated with a given variable quality, (such as poor, for the variable, service), and then drag the membership function from side to side. This will affect the mathematical description of the quality associated with that membership function for a given variable.

The selected membership function can also be tagged for dilation or contraction by clicking on the small square drag points on the membership function, and then dragging the function with the mouse toward the outside, for dilation, or toward the inside, for contraction. This will change the parameters associated with that membership function.

Below the Variable Palette is some information about the type and name of the current variable. There is a text field in this region that lets you change the limits of the current variable's range (universe of discourse) and another that lets you set the limits of the current plot (which has no real effect on the system).

The process of specifying the input membership functions for this two input tipper problem is as follows:

- Select the input variable, service, by double-clicking on it. Set both the Range and the Display Range to the vector [0 10].
- Select Add MFs... from the Edit menu. A window pops open as shown in Fig.6.9.

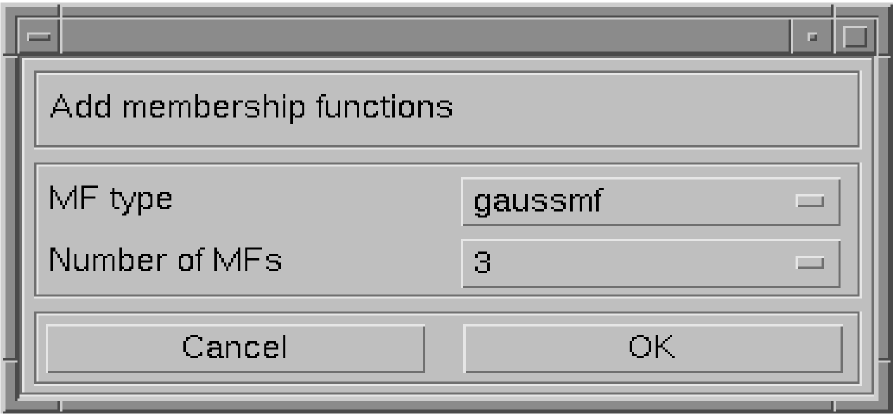


Fig. 6.9 Add MFs… Window

- Use the pull-down tab to choose gauss mf for MF Type and 3 for Number of MFs. This adds three Gaussian curves to the input variable service.
- Click once on the curve with the leftmost hump. Change the name of the curve to poor. To adjust the shape of the membership function, either use the mouse, as described above, or type in a desired parameter change, and then click on the membership function.
- The default parameter listing for this curve is [1.5 0].
- Name the curve with the middle hump, good, and the curve with the rightmost hump, excellent. Reset the associated parameters if desired.
- Select the input variable, food, by clicking on it. Set both the Range and the Display Range to the vector [0 10].
- Select Add MFs... From the Edit menu and add two trap mf curves to the input variable food.
- Click once directly on the curve with the leftmost trapezoid. Change the name of the curve to rancid.
- To adjust the shape of the membership function, either use the mouse, as described above, or type in a desired parameter change, and then click on the membership function. The default parameter listing for this curve is [0 0 1 3].

Name the curve with the rightmost trapezoid, delicious, and reset the associated parameters if desired.

Next you need to create the membership functions for the output variable, tip. To create the output variable membership functions, use the Variable Palette on the left, selecting the output variable, tip. The inputs ranged from 0 to 10, but the output scale is going to be a tip between 5 and 25 percent. Use triangular membership function types for the output. First, set the Range (and the Display Range) to [0 30], to cover the output range. Initially, the cheap membership function will have the parameters [0 5 10], the average membership function will be [10 15 20], and the generous membership function will be [20 25 30]. Your system should look something like shown in Fig. 6.10

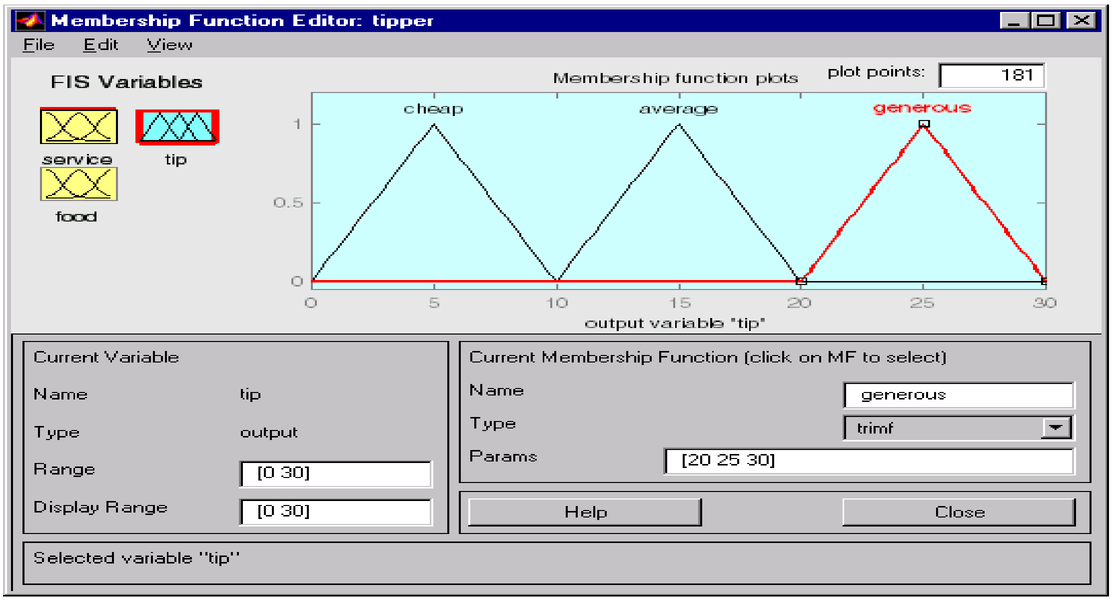


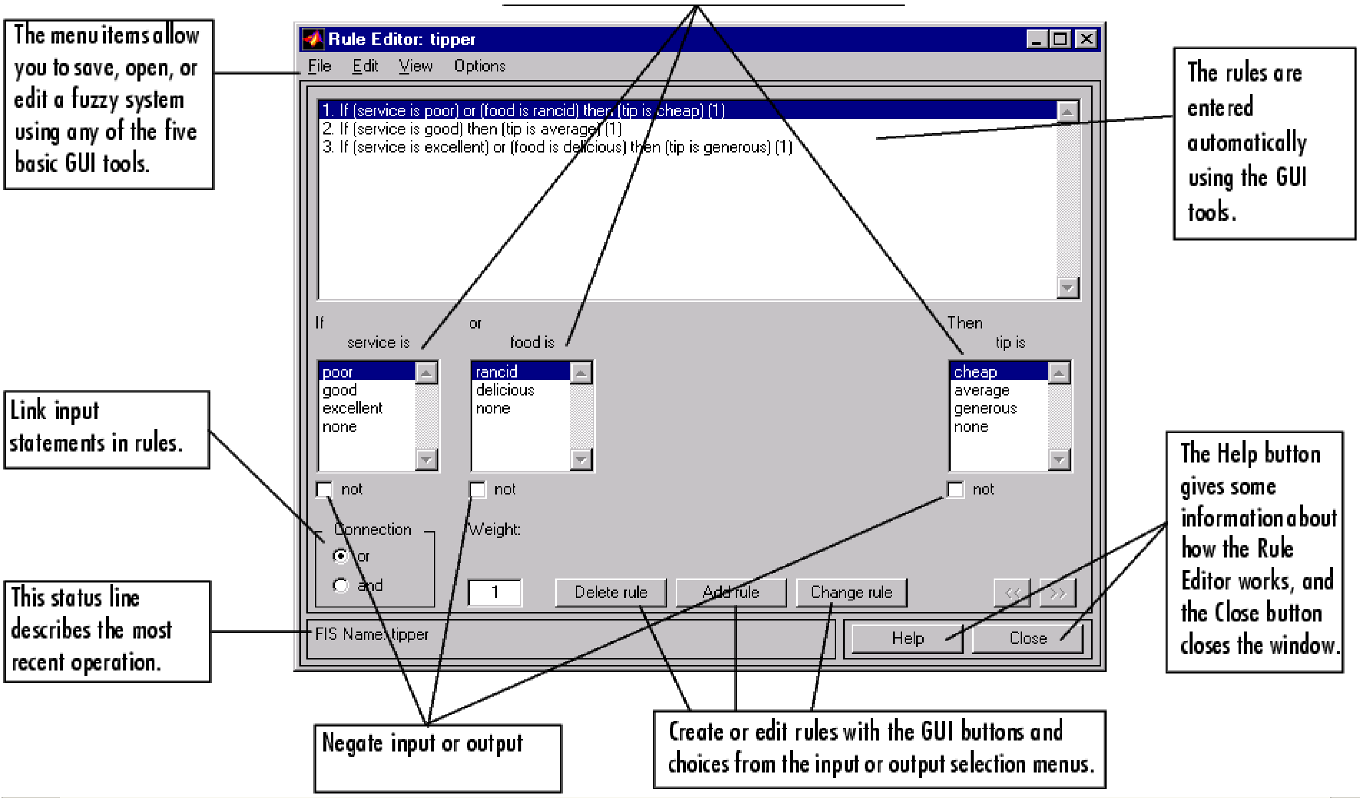
Fig. 6.10 The Updated Membership Function Editor

Now that the variables have been named, and the membership functions have appropriate shapes and names, you're ready to write down the rules. To call up the Rule Editor, go to the View menu and select Edit rules..., or type rule edit at the command line. The Rule Editor Window pops open as shown in Fig. 6.10

6.8.2 The rule editor:

Constructing rules using the graphical Rule Editor interface is fairly self-evident. Based on the descriptions of the input and output variables defined with the FIS Editor, the Rule Editor allows you to construct the rule statements automatically, by clicking on and selecting one item in each input variable box, one item in each output box, and one connection item.

Choosing none as one of the variable qualities will exclude that variable from a given rule. Choosing not under any variable name will negate the associated quality. Rules may be changed, deleted, or added, by clicking on the appropriate button. The Rule Editor also has some familiar landmarks, similar to those in the FIS Editor and the Membership Function Editor, including the menu bar and the status line. The Format pop-up menu is available from the Options pull-down menu from the top menu bar. Similarly, Language can be set from under



Options as well. The Help button will bring up a MATLAB Help window.

Fig. 6.11 The Rule Editor

To insert the first rule in the Rule Editor, select the following:

Poor under the variable service

- Rancid under the variable food
- The radio button, or, in the Connection block
- Cheap, under the output variable, tip.

The resulting rule is

1. If (service is poor) or (food is rancid) then (tip is cheap) (1)

The numbers in the parentheses represent weights that can be applied to each rule if desired. You can specify the weights by typing in a desired number between zero and one under the Weight setting.

If you do not specify them, the weights are assumed to be unity (1).

Follow a similar procedure to insert the second and third rules in the Rule Editor to get

1. If (service is poor) or (food is rancid) then (tip is cheap) (1)
2. If (service is good) then (tip is average) (1)
3. If (service is excellent) or (food is delicious) then (tip is generous) (1)

To change a rule, first click on the rule to be changed. Next make the desired changes to that rule, and then click on Change rule. For example, to change the first rule to

1. If (service not poor) or (food not rancid) then (tip is not cheap) (1)

Click not under each variable, and then click Change rule.

This is the version that the machine deals with. The first column in this structure corresponds to the input variable, the second column corresponds to the output variable, the third column displays the weight applied to each rule, and the fourth column is shorthand that indicates whether this is an OR (2) rule or an AND (1) rule. The numbers in the first two columns refer to the index number of the membership function.

A literal interpretation of rule 1 is: "if input 1 is MF1 (the first membership function associated with input 1) then output 1 should be MF1 (the first membership function associated with output 1) with the weight 1." Since there is only one input for this system, the AND connective implied by the 1 in the last column is of no consequence.At this point, the fuzzy inference system has been completely defined, in that the variables, membership functions, and the rules necessary to calculate tips are in place. It would be nice, at this point, to look at a fuzzy inference diagram like the one presented at the end of the previous section and verify that everything is behaving the way we think it should. This is exactly the purpose of the Rule Viewer, the next of the GUI tools we'll look at. From the View menu, select “View rules....”

Influences the overall result. Since it plots every part of every rule, it can become unwieldy for particularly large systems, but, for a relatively small number of inputs and outputs, it performs well (depending on how much screen space you devote to it) with up to 30 rules and as many as 6 or 7 variables.

CHAPTER 7
PROPOSED SIMULATION RESULTS

7.1 INTRODUCTION:

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems. Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor. The model depicts the time-dependent mathematical relationships among the system's inputs, states, and outputs. Then, we use Simulink to simulate the behavior of the system over a specified time span. Simulink uses information that you entered into the model to perform the simulation.

7.2 BLOCK DIAGRAM:

block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either A Simulink continuously (a continuous block) or at specific points in time (a discrete block).

The lines represent connections of block inputs to block outputs.
Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time.

A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate.

A block comprises one or more of the following:

1) A set of inputs,
2) A set of states, and
3) A set of outputs.

A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance. Continuous Versus discrete Blocks Simulink's standard block set includes continuous blocks and discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only at integral multiples of a fixed interval called the block's sample time. Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, depending on whether they are driven by continuous or discrete blocks. A block that can be either discrete or continuous is said to have an implicit sample rate. The implicit sample time is continuous if any of the block's inputs are continuous. The implicit sample time is equal to the shortest input sample time if all the input sample times are integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times.

Simulink can optionally color code a block diagram to indicate the sample times of the blocks it contains, e.g., black (continuous), magenta (constant), yellow (hybrid), red (fastest discrete), and so on. The block contains block name, icon, and block library that contain the block, the purpose of the block

7.3 SIMULINK BLOCK LIBRARIES:

Simulink organizes its blocks into block libraries according to their behavior.

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-time components.
4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.
6) The Functions & Tables library contains blocks that describe general function and table look-up operations.
7) The Nonlinear library contains blocks that describe nonlinear functions.

8) The Signal & Systems library contains blocks that allow multiplexing and demultiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types of subsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

7.4 SUB SYSTEMS:

Simulink allows to model a complex system as a set of interconnected subsystems each of which is represented by a block diagram.

We create a subsystem using Simulink's Subsystem block and the Simulink model editor. We can embed subsystems with subsystems to any depth to create hierarchical models. We can create conditionally executed subsystems that are executed only when a transition occurs on a triggering or enabling input.

7.5 SOLVERS:

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model. The process of computing the successive states of a system from its model is known as solving the model. No single method of solving a model suffices for all systems.

Accordingly, Simulink provides a set of programs, known as solvers, that each embody a particular approach to solving a model. The Simulation Parameters dialog box allows us to choose the solver most suitable for our model.

7.6 Fixed-Step and Variable-Step Solvers:

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size. Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly and increasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time, required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

7.7. Continuous and Discrete Solvers:

Continuous solvers use numerical integration to compute a model's continuous states at the current time step from the states at previous time steps and the state derivatives. Continuous solvers rely on the model's blocks to compute the values of the model's discrete states at each time step.

Mathematicians have developed a wide variety of numerical integration techniques for solving the ordinary differential equations (ODEs) that represent the continuous states of dynamic systems. Simulink provides an extensive set of fixed-step and variable-step continuous solvers, each implementing a specific ODE solution method. Some continuous solvers subdivide the simulation time span into major and minor steps, where a minor time step represents a subdivision of the major time step. The solver produces a result at each major time step. It use results at the minor time steps to improve the accuracy of the result at the major time step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time-step for a model and nothing else. They do not compute continuous states and they rely on the model's blocks to update the model's discrete states. We can use a continuous solver, but not a discrete solver, to solve a model that contains both continuous and discrete states. This is because a discrete solver does not handle continuous states. If you select a discrete solver for a continuous model,.

Simulink disregards your selection and uses a continuous solver instead when solving the model.

Simulink provides two discrete solvers, a fixed-step discrete solver and a variable-step discrete solver. The fixed-step solver by default chooses a step size and hence simulation rate fast enough to track state changes in the fastest block in our model. The variable-step solver adjusts the simulation step size to keep pace with the actual rate of discrete state changes in our model. This can avoid unnecessary steps and hence shorten simulation time for multi rate models.

7.8 MODEL EXECUTION PHASE:

In the simulation model execution phase, Simulink successively computes the states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps.

The length of time between steps is called the step size. The step size depends on the type of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states have discontinuities (Zero Crossing Detection). At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated.

At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and states to the output function as it may require these arguments to compute the block's output. Simulink updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.

1) Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's continuous states by numerically integrating the time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.
2) Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.
3) Computes the time for the next time step. Simulink repeats steps 1 through 4 until the simulation stop time is reached.

7.9 Block Sorting Rules:

Simulink uses the following basic update rules to sort the blocks:

1) Each block must be updated before any of the direct-feed through blocks that it drives.This rule ensures that the inputs to direct-feed through blocks will be valid when they are updated.
2) Non direct-feed through blocks can be updated in any order as long as they are updated before any direct-feed through blocks that they drive. This rule can be met by putting all non direct-feed through blocks at the head of the update list in any order. It thus allows Simulink to ignore non direct-feed through blocks during the sorting process.

The result of applying these rules is an update list in which non direct-feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct-feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output.

However, an algebraic loop can represent a set of simultaneous algebraic equations (hence the name) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step.

Accordingly, Simulink assumes that loops involving direct-feed through blocks do, in fact, represent a solvable set of algebraic equations and attempts to solve them each time the block is updated during a simulation.

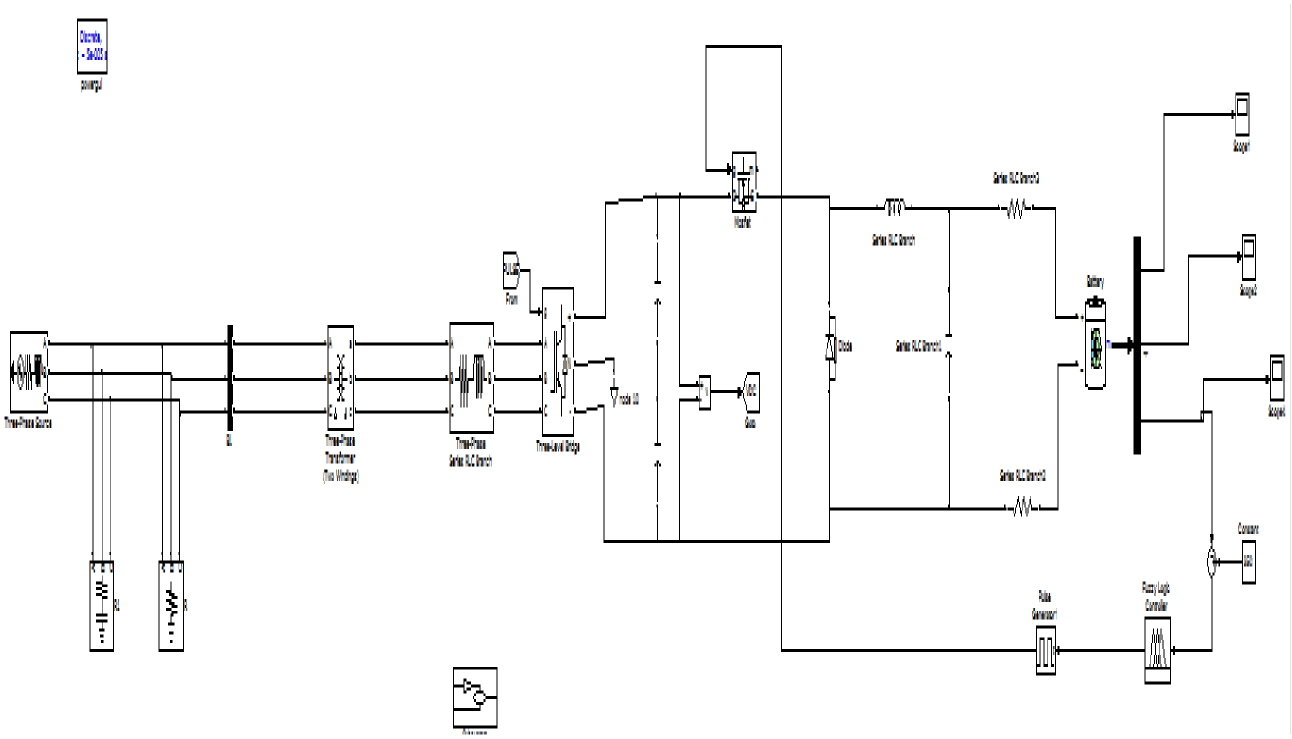


Fig 7.1 Proposed circuit simulation system

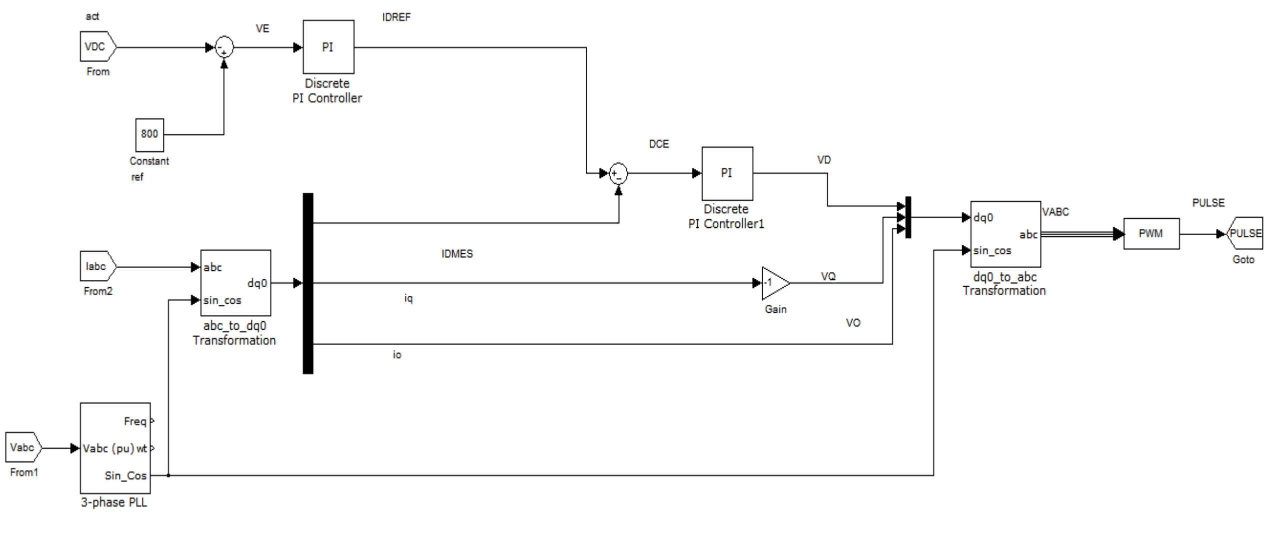


Fig 7.2 Proposed circuit simulation

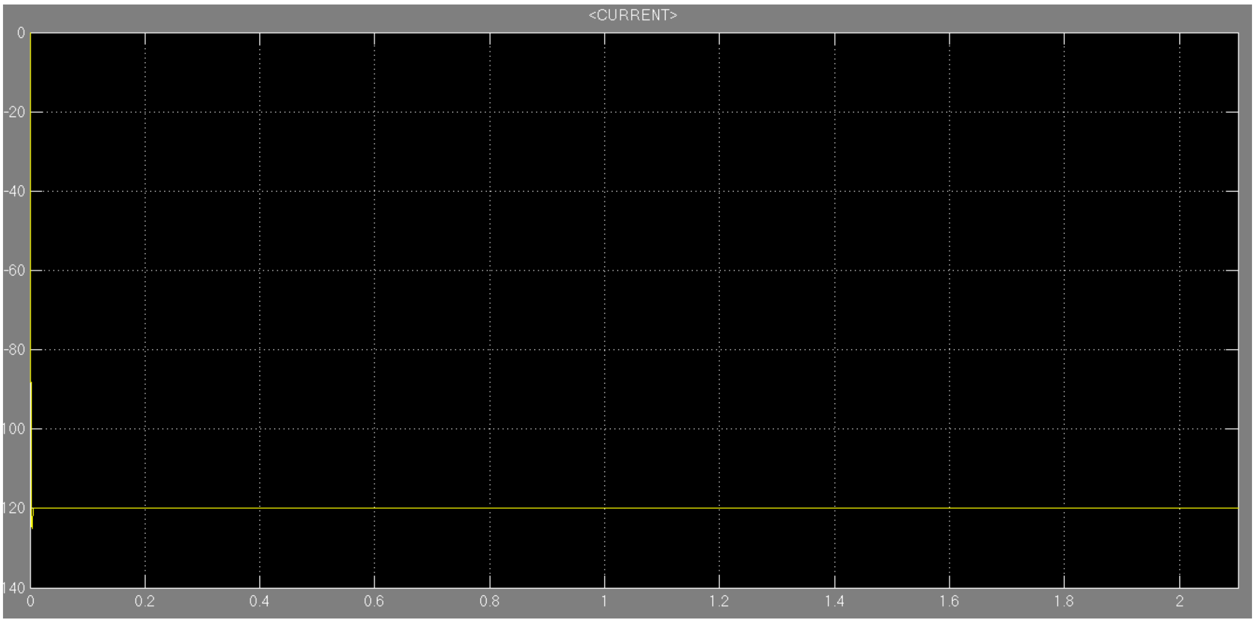


Fig 7.3Proposed battery current

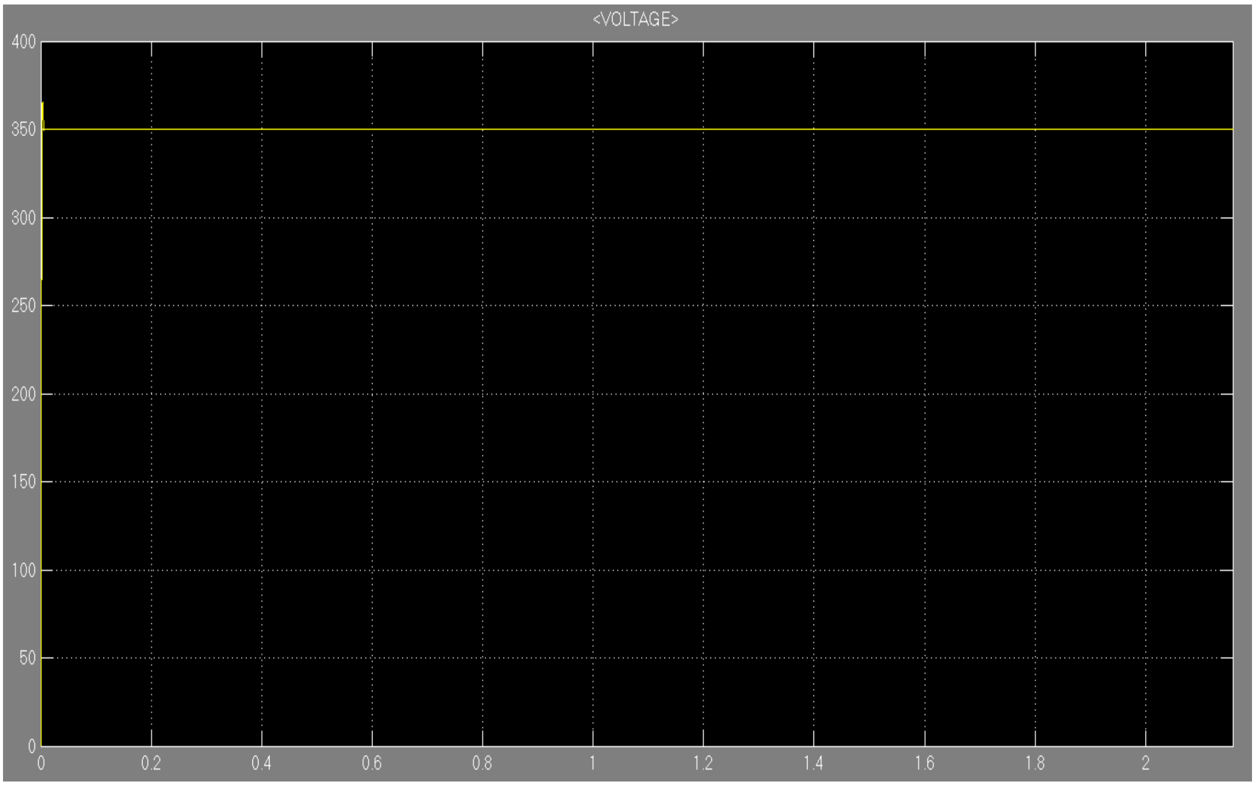


Fig 7.4 Battery voltage

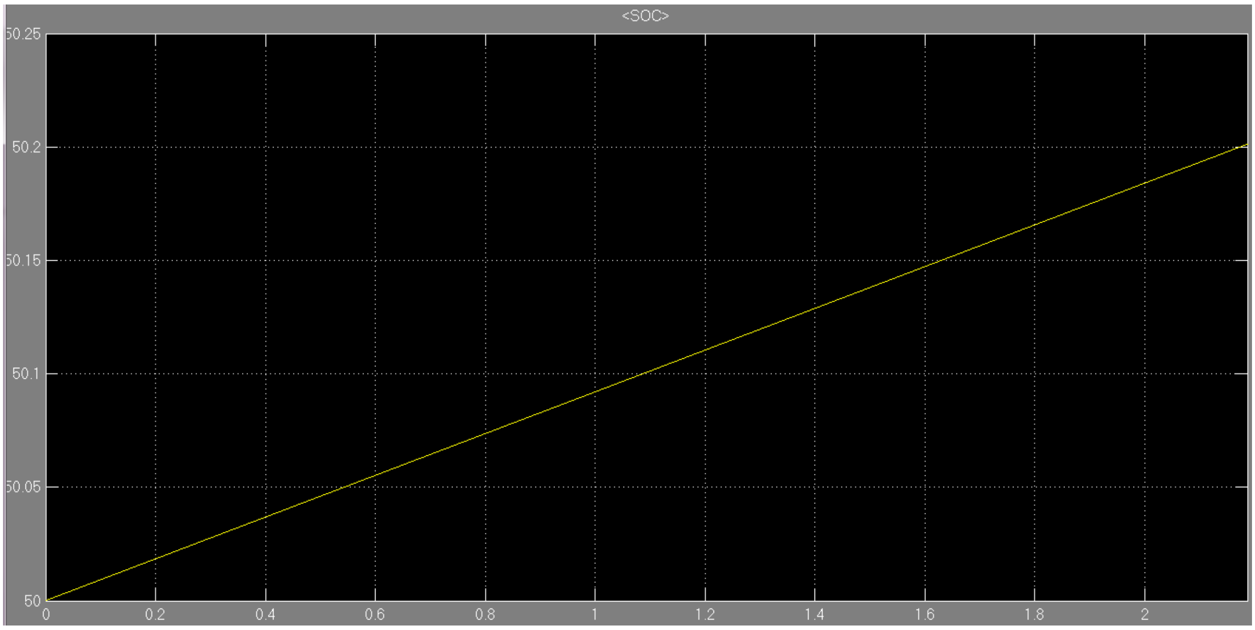


Fig 7.5 SOC for proposed system

CHAPTER 8
CONCLUSION

In this project, the complete model of EV charging system with the utilization of fuzzy logic controller is presented. The complete simulation model has been developed in MATLAB /Simulink. The achieved simulation results show how easy FLC can be used in EV charging without the requirement for any tuning like with PI controller. In perspective of this work, experimental validation of the proposed scheme can be performed.

APPENDIX

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

(a)Development Environment:

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

(b) The MATLAB Mathematical Function Library:

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language:

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features.

It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics:

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

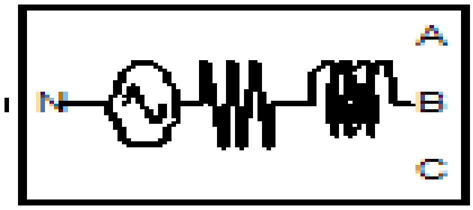
(e) The MATLAB Application Program Interface (API):

This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

(f) MATLAB Documentation:

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

(1) Three phase source block

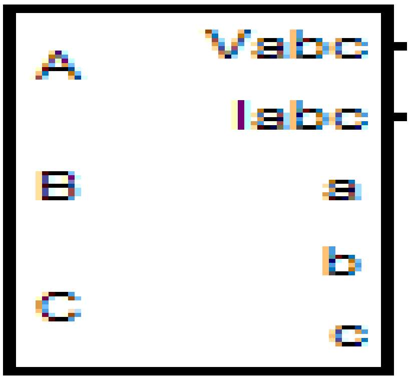


Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

(2) VI measurement block

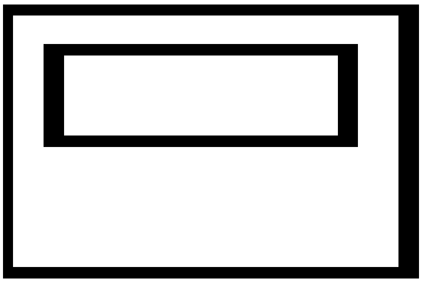
The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents.



Three Phase V-I Measurement

(3) Scope

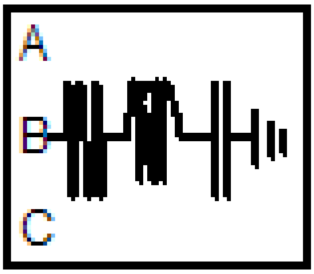
Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes.The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation



Scope

(4) Three-Phase Series RLC Load

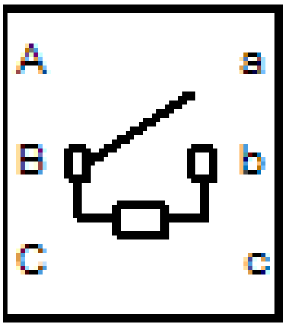
The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.



Three-Phase Series RLC Load

(5) Three-Phase Breaker block

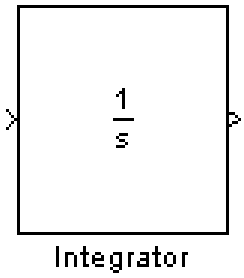
The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.



Three-Phase Breaker Block

(6) Integrator

Library: Continuous



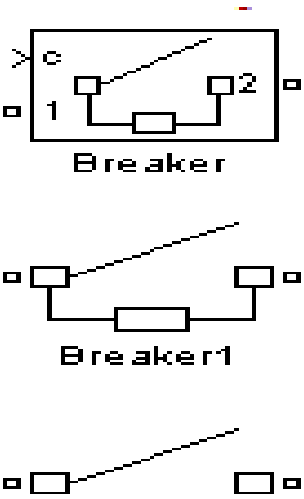
Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

(7) Breaker

Implement circuit breaker opening at current zero crossing.

Library: Elements



Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

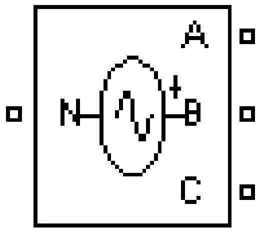
When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it). When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

*(*8) Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources



Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

(9) Trigonometric Function

Specified trigonometric function on input

Library: Math Operations

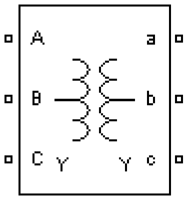
Trigonometric Function

Purpose: The Trigonometric Function block performs common trigonometric functions

(10) Three-Phase Transformer (Two Windings)

Implement three-phase transformer with configurable winding connections

Library: Elements



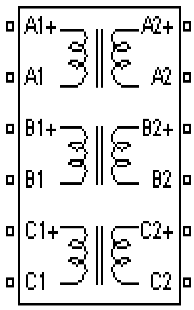
Three Phase Transformer

Purpose: The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

(11) Three-Phase Transformer 12 Terminals

Implement three single-phase, two-winding transformers where all terminals are accessible

Library: Elements



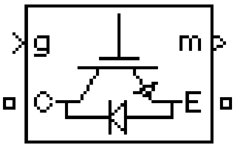
Two winding Transformer

Purpose***:*** The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

(12) IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: **Power Electronics**



IGBT

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

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A

PROJECT REPORT

On

A DESIGN AND CONTROL OF AN UPQC TO ASSURE POWER QUALITY IN ELECTRIC DISTRIBUTION GRIDS

Submitted by

1)P.RAMYA (18K85A0207)   2)M.RAJASHEKAR (18K85A0206)

3)T.MANEESHA(18K85A0208) 4)G.SAI PRASANNA (18K85A0215)

in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

T.V.SAI KALYANI

ASSISTANT PROFESSOR

DEPARTMENT OF ELECTRICAL AND ELECTRONICS

ST.MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled "**A DESIGN AND CONTROL OF AN UPQC TO ASSURE POWER QUALITY IN ELECTRIC DISTRIBUTION GRIDS**", is being submitted by **1. P . RAMYA (18K85A0207) 2. M . RAJASHEKAR (18K85A0206) 3) T.MANEESHA(18K85A0208) 4. G.SAI PRASANNA (18K85A0215**) in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN** Electrical and Electronics Engineering is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Assistant Professor
T.V. SAI KALYANI
Dept. of Electrical and Electronics Engineering

Head of the Department
Dr. N. RAMCHANDRA
Dept. of Electrical and Electronics Engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in Department of Electrical and Electronics Engineering , session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled "**A DESIGN AND CONTROL OF AN UPQC TO ASSURE POWER QUALITY IN ELECTRIC DISTRIBUTION GRIDS"** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of anydegree.

1)P.RAMYA (18K85A0207)
2) M.RAJASHEKAR (18K85A0206)
3) T.MANEESHA (18K85A0208)
4) G.SAI PRASANNA (18K85A0215)

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1. P.Ramya
2. M.Rajashekar
3. T.Maneesha
4. G.Sai Prasanna

TABLE OF CONTENTS

ABSTRACT

In today's world there is great importance of electrical energy as it is the most famous from of energy and all are massively relying on it. Without supply of electricity life cannot be imagined. At the same time the quality and continuousness of the electric power supplied is also very important for the efficient functioning of the end user equipment. Many of the commercial and industrial loads require high quality undisturbed and constant power. Thus maintaining thequalitative power is topmost important in today's world. Due to power electronics devices there is serious effect on quality and continuousness of electric supply. Because of power electronics devices there is uninterrupted power supply, flicker, harmonics, voltage fluctuations e.tc.

There is also PQ problems such as voltage rise/dip due to network faults, lightning, switching of capacitor banks. With the excessive uses of non-linear load (computer, lasers, printers, rectifiers) there is reactive power disturbances and harmonics in power distribution system. It is very essential to overcome this type of problems as its effect may increase in future and cause adverse effect.
Traditionally passive filters were used for reactive power disturbances and harmonics generation but there is many problems with them like they are large in size, resonance problem, effect of source impedance on performance. Active Power Filters are used for power quality enhancement. Active power filters can be classified according to system configuration. Active power filters are of two types series and shunt. Combining both series APF & shunt APF we get a device known as UPQC. UPQC eliminates the voltage and current based distortions together. A Shunt APF eliminates all kind of current problems like current harmonic compensation, reactive power compensation, power factor enhancement. A Series APF compensates voltage dip/rise so that voltage at load side is perfectly regulated. The Shunt APF is connected in parallel with transmission line and series APF is connected in series with transmission line. UPQC is formed by combining both series APF and shunt APF connected back to back on DC side.

LIST OF FIGURES

LIST OF OUTPUT SCREENS

LIST OF ACRONYMS

APF	:	**ACTIVE POWER FILTER**
UPQC	:	**UNIFIED POWER QUALITY CONTROL**
SPF	:	**SERIES POWER FILTER**
SHPF	:	**SHUNT POWER FILTER**
VSI	:	**VOLTAGE SOURCE INVERTER**
DSTATCOM	:	**DISTRIBUTION STATIC COMPENSATOR**
DVR	:	**DYNAMIC VOLTAGE RESTORER**
IGBT	:	**INSULATED GATE BIPOLAR TRANSISTOR**

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The widespread use of non-linear loads is leading to a variety of undesirable phenomena in the operation of power systems. The harmonic components in current and voltage waveforms are the most important among these. Conventionally, passive filters have been used to eliminate line current harmonics. However, they introduce resonance in the power system and tend to be bulky. So, active power line conditioners have become more popular than passive filters as it compensates the harmonics and reactive power simultaneously.

The active power filter topology can be connected in series or shunt and combinations of both. Shunt active filter is more popular than series active filter because most of the industrial applications require current harmonic compensation. Different types of active filters have been proposed to increase the electric system quality. The classification is based on following criteria.

- Power rating and speed of response required in compensated system.
- System parameters to be compensated (e.g. current harmonics, power factor and voltage harmonics)
- Technique used for estimating the reference current/voltage.

Current controlled voltage source inverters can be utilized with an appropriate control strategy to perform active filter functionality. The electrical grid will include a very large number of small producers that use renewable energy sources, like solar panels or wind generators.

1.2. LITERATURE SURVEY

Johan H. R. Enslin and Peter J. M. Heskes,[1]

*"Harmonic interaction between a large number of distributed power inverters and the distribution network,"*In this paper discussed the harmonic interaction between a large number of distributed power inverters and the distribution network. This paper is to

analyze the observed phenomena of harmonic interference of large populations of these inverters and to compare the network interaction of different inverter topologies and control options.

Uffe Borup, Frede Blaabjerg and Prasad N. Enjeti ,[2]

"Sharing of nonlinear load in parallel-connected three-phase converters,"

Presented about the sharing of linear and nonlinear loads in three-phase power converters connected in parallel, without communication between the converters. The paper focuses on solving the problem that arises when two converters with harmonic compensation are connected in parallel.

Pichai Jintakosonwit Hideaki Fujita, Hirofumi Akagi and Satoshi Ogasawara, [3]

"Implementation and performance of cooperative control of shunt active filters for harmonic damping throughout a power distribution system,"

This paper proposes cooperative control of multipleactive filters based on voltage detection for harmonic damping throughout a power distribution system. The arrangement of a real distribution system would be changed according to system operation, and/or fault conditions. In addition, shunt capacitors and loads are individually connected to, or disconnected from, the distribution system.

Pedro Rodríguez, JosepPou, Joan Bergas,J. Ignacio Candela , Rolando P. Burgos and DushanBoroyevich ,[4]

"Decoupled double synchronous reference frame PLL for power converters control,"

Presented the detection ofthe fundamental-frequency positive-sequence component of theutility voltage under unbalanced and distorted conditions. Specifically, it proposes a positive-sequence detector based on a new decoupled double synchronous reference frame phase-locked loop (PLL), which completely eliminates the detection errors of conventional synchronous reference frame PLL's. This is achieved by transforming both positive- and negative-sequence components of the utility voltage into the double SRF, from which a decoupling network is developed in order to cleanly extract and separate the positive- and negative-sequence components.

SoerenBaekhoejKjaer, John K. Pedersenand Frede Blaabjerg,[5]

"A review of single-phase grid-connected inverters for photovoltaic modules"

presents a Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules. This paper focuses on inverter technologies forconnecting photovoltaic (PV) modules to a single-phase grid. The inverters are categorized into four classifications: 1) the number of power processing stages in cascade; 2) the type of power decoupling between the PV module(s) and the single-phase grid; 3) whether they utilizes a transformer (either line or high frequency) or not; and 4) the type of grid-connected power stage.

F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus,[6]

"Overview of control and grid synchronization for distributed power generation systems," This paper gives an overview of the structures for the DPGS based on fuel cell, photovoltaic, and wind turbines. In addition, control structures of the grid-side converter are presented, and the possibility of compensation for low-order harmonics is also discussed. Moreover, control strategies when running on grid faults are treated. This paper ends up with an overview of synchronization methods and a discussion about their

importance in the control.

J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galván, R. C. P. Guisado, M. Á. M. Prats, J. I. León, and N. M. Alfonso,[7]

"Power electronicsystems for the grid integration of renewable energy sources: A survey," This paper proposes about distributed energy resource is increasingly being pursued as a supplement and an alternative to large conventional central power stations. The specification of a power electronic interface is subject to requirements related not only to the renewable energy source itself but also to its effects on the power-system operation, especially where the intermittent energy source constitutes a significant part of the total

system capacity.

1.3 BACKGROUND AND MOTIVATION

1.3.1 Power Quality Problems in Microgrids

A microgrid comprises a group of interconnected renewable energy sources, energy storage units and loads . In a microgrid, some common renewable energy sources are wind power , solar power, and wave power .

Nowadays, the usage of the renewable energy sources is growing rapidly. The percentage of world renewable generation over the total electricity generation is illustrated in Figure 1-1

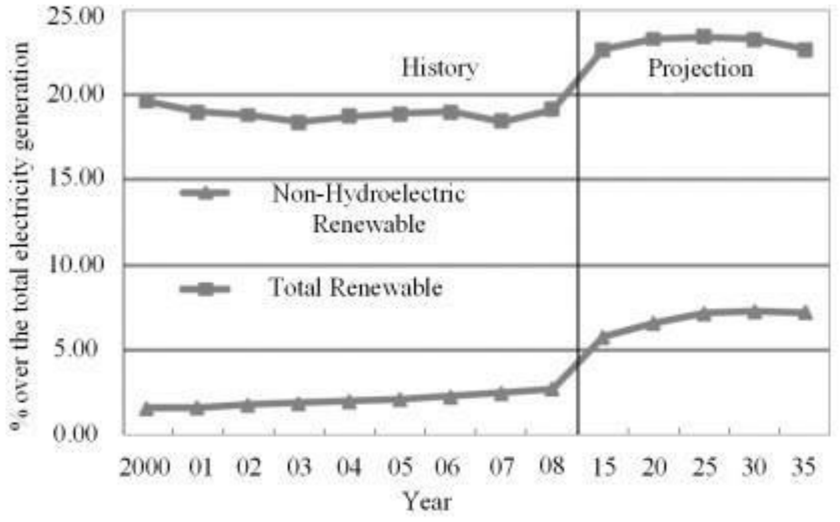


Figure 1.1: Percentage of world renewable electricity generation over the total electricity generation .

By integrating these renewable energy sources into the microgrid system, it is a great opportunity to reduce the fossil fuel consumption as well as the runningcost the system. However, due to the unstable and intermittency nature of renewable energy sources, power reliability and quality problems are more acute . The power quality issues in a microgrid are important since all the renewable sources come with power electronic interfaces which generate undesirable voltage and current harmonics.

It is well known that voltage sags and swells are the most common utility voltage quality problems. These issues will worsen the power quality problems of the microgrid when it is connected to the utility grid. Short circuit, switching on/off of large loads, and faults lead to voltage sag and swell which result in disruption of critical loads in the system, and bring about substantial financial losses .

Further more, the growing use of nonlinear power electronic loads such as static rectifiers, variable speed drives, etc., also increases voltage and current distortions in microgrid operation . This will degrade the power quality and also lower the power factor of the system. The distorted current injected into the microgrid will cause the overheating of power factor correction capacitors motors and transformers,tripping of protective relays, and deterioration in the accuracy of smart meters Reactive power compensation is a very important issue in microgrids . A typical microgrid consists of distribution transformers, distribution lines, motor loads, etc. All of whichare heavy consumers of reactive power. By compensating the reactive power demand at load centers, the system capacity of the microgrid can be utilized more effectively. This will in turn reduce greatly the power drawn from the utility grid as well as the system losses . Therefore, there is an increasing need to monitor and mitigate the power quality issues in the microgrid in order to better serve the customers, to satisfy the operation and regulation requirements, and to enhance telecommunication development and network planning.

1.3.2 Power Quality Compensators Available in Market

The advantages and disadvantages of the available power quality compensators in the market will be introduced in this section. Capacitor banks , static var compensators (SVCs) , dynamic voltage restorers (DVRs) - distribution static compensators (DSTATCOMs) , etc. are the available power quality compensators that can be used to mitigate the aforementioned power quality problems in the microgrids.

1.3.2.1. Capacitor Banks

The schematic of the capacitor banks is presented in Figure 1.2 . The switched capacitor banks are traditionally used to provide reactive power compensation in the network . Even though the switched capacitor is a simple and effective device to supply the reactive power demand of the loads, it has major shortcomings, e.g., switching transient, overcompensation on the power line, resonance with neighbouring loads, aging effect and bulky size .

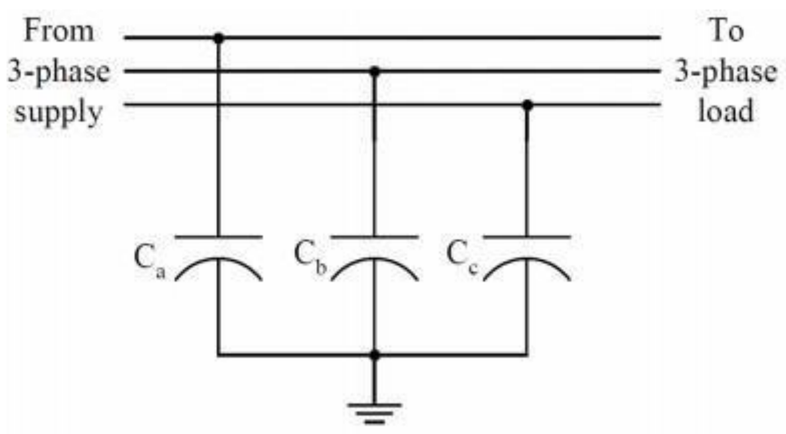


Figure 1.2: Schematic of capacitor banks.

1.3.2.2 SVCs

Figure 1-3 shows the schematic of the SVCs. The SVCs are the combination of a thyristor-switched capacitor, a thyristor-controlled reactor, a mechanical switched reactor and capacitor, and a harmonic filter . The inductive or capacitive characteristic is controlled by adjusting the firing angle of the two parallel, reverse connected thyristors . The SVCs are able to increase the power transmission ability of the transmission lines; improve the systems transient stability; increase the power factor of the load, etc. The major reasons that SVCs are not suitable for their introduction into the microgrids are: 1) limited bandwidth operation; 2) a larger number of passive components that increases the size and losses; and 3) slower responses

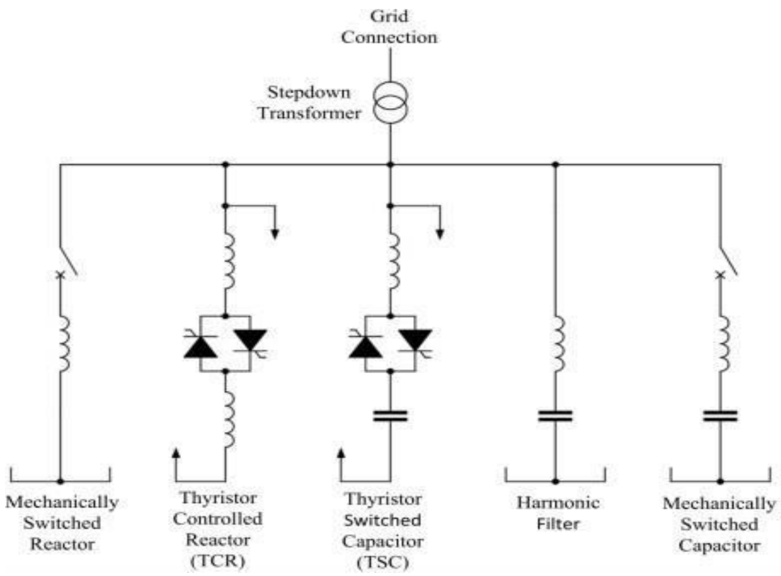


Figure 1.3: Schematic of static var compensators

1.3.2.3 DVRs

The DVR is a cost-effective device to solve the voltage power quality problems

The basic topology of the DVRs is illustrated in Figure 1-4. A typical DVR consists of a voltage source inverter (VSI) to achieve the DC/AC conversion, a DC voltage source to supply the DC link of the VSI, a filter to suppress the switching harmonics of the VSI, and a series transformer to obtain the series voltage injection at the distribution line. The basic principle of the DVR is to inject a voltage of specific phase angle and magnitude in series with the distribution line, so that the load voltage can be maintained at the rated sinusoidal waveform . In the literatures, in addition to its basic function, the DVR can provide other benefits. For example, in the pre-sag operation the DVR can restore the exact amplitude and phase angle of the load voltage when the sag and phase jump happens in the source voltage. In the in-phase method, the DVR can

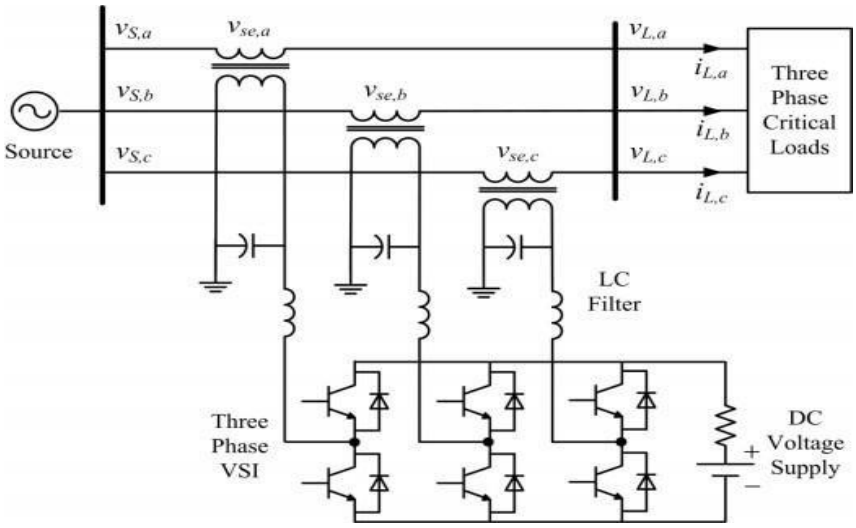


Figure 1.4: Schematic of dynamic voltage restorers

inject the minimum amplitude of the compensation voltage. In the self-supported mode , the DVR does not require external energy storages by utilizing the capacitor connected at the DC link of the VSI. In the energy optimized strategy the energy handled by the DVR can be optimized.

Even though the DVR has shown satisfactory performance in mitigating the voltage sags, swells, and harmonics, it cannot deal with the current related power quality problems. Moreover, the traditional DVR requires external DC voltage sources, e.g., battery energy storage systems, DC power sources, distributed generations (DGs).

1.3.2.4. DSTATCOM

The DSTATCOM is able to solve the current related power quality problems Figure 1.5 illustrates the basic structure of the DSTATCOM. A typical DSTATCOM consists of a VSI to achieve the DC/AC conversion, a capacitor to maintain the DC link voltage of the VSI, and a filter to suppress the switching harmonics of the VSI. The operating principle of the DSTATCOM is to inject a shunt current of specific phase angle and magnitude into the distribution line, so that the source current can be maintained at the desired sinusoidal waveform

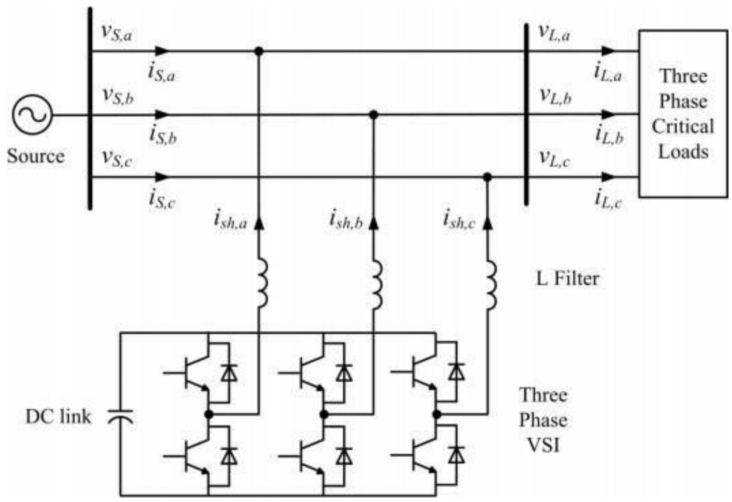


Figure 1.5: Distribution Starcom (DSTATCOM)

By injecting the shunt compensating current, the DSTATCOM can deal with power factor correction, current harmonic elimination, etc. However, it still cannot handle the voltage power quality problems, e.g., sags, swells, and harmonics.

1.4. Motivations of Applying Unified Power Quality Conditioner

It is noted that the capabilities of the aforementioned devices are limited because each device is intended to solve only one or two specific power quality problems. They may work well for traditional power transmission/distribution systems. But for newly developed microgrids where all these power quality issues exist, they lose their efficacy. Under these circumstances, it is required that all these equipment/devices be installed in order to solve the power quality issues in a microgrid, which is obviously cost prohibitive. Additionally managing and maintaining these individual components can be a complex and expensive task.

According to the aforementioned review, the motivation of this thesis is to utilize a highly integrated power quality conditioner in the microgrids. In 1998, Fujita and Akagi proposed the unified power quality conditioner (UPQC) system which has the capability of improving power quality at both the source side and load side as shown in Figure 1.6

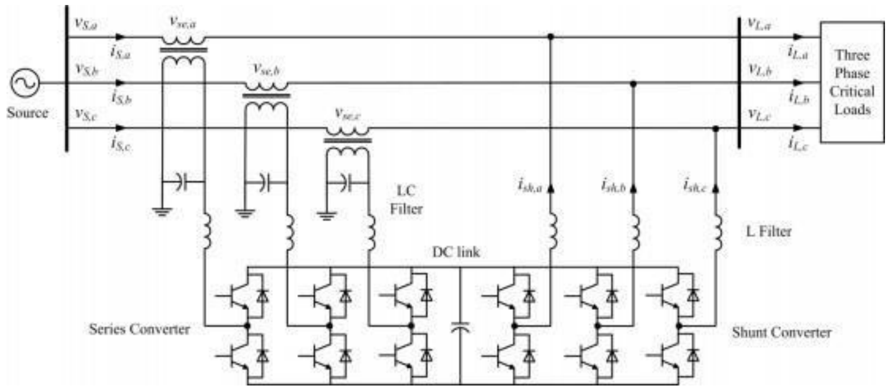


Figure 1.6: Schematic of unified power quality conditioners.

The UPQC system contains two major parts. One is the power electronic converters module where the series and shunt converters are integrated together, and the other one is the series transformer which handles the series injected voltage. Since then, UPQC has become one of the most attractive solutions to improve power quality in the distribution system due to its superior performance in mitigating almost all major power quality problems. However, UPQC is still at the research stage, which has not been widely utilized so far. The reason is that the UPQC system contains two sets of power converters and a transformer. This significantly increases the cost of producing and marketing the system. It is important to reduce the rating of the UPQC system without any compromise of the compensating capabilities. In this manner, it will increase the utilization of the UPQC and reduce the cost of the system, which enhance the competitiveness of the whole system

Based on the review of the existing UPQC topologies and techniques it

is noted that there is no generalized strategy to optimize the rating of a UPQC system. The research works in this thesis focus on optimal design of the UPQC system and the corresponding control implementation of the designed UPQC without compromising its compensating capabilitie

1.5. Objectives Of The Thesis

As discussed previously, the optimization of the ratings of the UPQC system has seldom been studied so far. This thesis mainly works on optimal design and control implementation of the UPQC system.

The objectives of this thesis are summarized as follows

1. The first objective is to review the existing UPQC topologies and techniques. Specifically, the UPQC topologies and techniques should be classified in order to provide a clear understanding of the state-of-the-art techniques in the UPQCs, and to discover the research gaps in this area.

2. As mentioned previously, due to the unstable and intermittency nature of renewable energy sources, power reliability and quality problems are more acute. The power quality issues in a microgrid are important since all the renewable sources come with power electronic interfaces which generate undesirable voltage and current harmonics. The second objective of this thesis is to clarify the most common power quality problems which the UPQC has to mitigate. Furthermore, the standards of the power quality of the grids have to be clarified. They are utilized to evaluate the operating performance of the designed UPQC systems.

3. Before the optimal design and the corresponding control implementation of the UPQC systems, the most popular control algorithm based on the traditional UPQC topology should be introduced. The plant of the UPQC system should be built on the Matlab/Simulink platform. The simulation results are supposed to demonstrate the performance of the UPQC system in mitigating the major power quality problems in the microgrids.

4. Since the UPQC consists of two sets of power converters, i.e., a series converter and a shunt converter, they increase the manufacturing cost of the setup compared with the traditional power quality compensators. This is why the UPQC has not been commercialized so far. The reduction of the ratings of the UPQC without compromising the compensation abilities becomes essential, as it will increase the utilization rate of the converters and reduce the manufacturing cost of the systems. In this way, the whole system will be more competitive. In this thesis, a search strategy should be developed to determine the optimal VA ratings of series and shunt converters in the UPQC. The corresponding controller should also be designed to satisfy the power quality compensating requirement and safeguard the online operation of the UPQC system.

5. The UPQC system contains two major parts. One is the power electronic conversion where the series and shunt converters are integrated together, and the other one is the series transformer which handles the series injected voltage. As the VA ratings of the converters and the transformer will affect each other, both the VA ratings of the converters and that of the series transformer should be taken care of during the optimization process to obtain the optimal capital cost of the whole UPQC

system. A generalized strategy is supposed to be developed to optimize the capital cost of the UPQC system which determines the fundamental VA ratings of the shunt converter, series converter, and series transformer. The corresponding control method has to optimize the online operating VA loadings of the UPQC, which can ensure the safe operation of the whole system

CHAPTER 2

LITERATURE REVIEW OF UNIFIED POWER QUALITY CONDITIONER

Power quality issues are becoming more and more significant in these days because of the increasing number of power electronic devices that behave as nonlinear loads. A wide diversity of solutions to power quality problems is available for both the distribution network operator and the end user. The power processing at supply, load and for reactive and harmonic compensation by means of power electronic devices is becoming more prevalent due to the vast advantages offered by them. The shunt APF is usually connected across the loads to compensate for all current related problems such as the reactive power compensation, power factor improvement, current harmonic compensation and load unbalance compensation, whereas the series active power filter is connected in a series with a line through series transformer. It acts as controlled voltage supply and can compensate all voltage related problems, such as voltage harmonics, voltage sag, voltage swell, flicker, etc. UPQC is a Custom Power device and consists of combined series active power filter that compensates voltage harmonics, voltage unbalance, voltage flicker, voltage sag/swell and shunt active power filter that compensates current harmonics, current unbalance and reactive current as shown in Figure

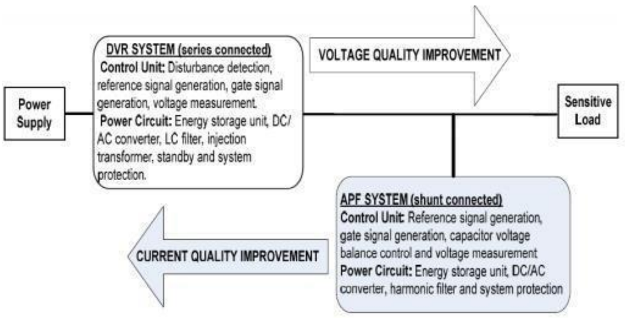


Figure 2.1: Basic representation of UPQC

The Unified Power Quality Conditioner is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and/or critical load. It is a type of hybrid APF and is the only versatile device which can mitigate several power quality problems related with voltage and current simultaneously therefore is multi functioning devices that compensate various voltage disturbances of the power supply, to correct voltage fluctuations and to prevent harmonic load current from entering the power system. Figure shows the system configuration of a single- phase UPQC. Unified Power Quality Conditioner (UPQC) consists of two IGBT based Voltage source converters (VSC), one shunt and one series cascaded by a common DC bus. The shunt converter is connected in parallel to the load. It provides VAR support to the load and supply harmonic currents. Whenever the supply voltage undergoes sag then series converter injects suitable voltage with supply. Thus, UPQC improves the power quality by preventing load current harmonics and by correcting the input power factor**.**

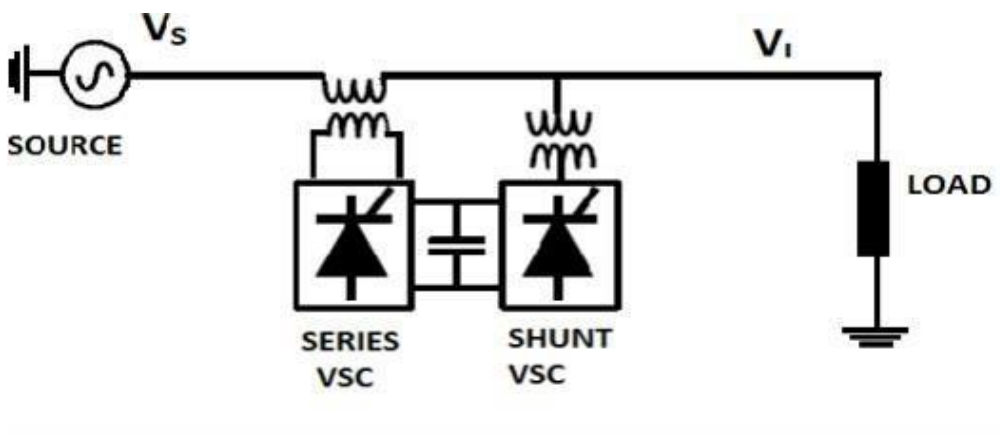


Figure 2.2: Block diagram of UPQC

2.2. Basic configuration of UPQC

The main components of a UPQC are series and shunt power converters, DC capacitors, low-pass and high-pass passive filters, and series and shunt transformers.

2.2.1 Series converter

It is a voltage-source converter connected in series with the AC line and acts as a voltage source to mitigate voltage distortions. It is used to eliminate supply voltage 27flickers or imbalance from the load terminal voltage and forces the shunt branch to absorb current harmonics generated by the nonlinear load. Control of the series converter output voltage is usually performed using sinusoidal pulse-width modulation (SPWM). The gate pulses required for converter are generated by the comparison of a fundamental voltage reference signal with a high-frequency triangular waveform.

2.2.2 Shunt converter

It is a voltage-source converter connected in shunt with the same AC line and acts as a current source to cancel current distortions, compensate reactive current of the load, and improve the power factor. It also performs the DC- link voltage regulation, resulting in a significant reduction of the DC capacitor rating. The output current of the shunt converter is adjusted using a dynamic hysteresis band by controlling the status of semiconductor switches so that output current follows the reference signal and remains in a predetermined hysteresis band.

2.2.3 Midpoint-to-ground DC capacitor bank

It is divided into two groups, which are connected in series. The neutrals of the secondary transformers are directly connected to the DC link midpoint. As the connection of both three-phase transformers is Y/Yo, the zero-sequence voltage appears in the primary winding of the series-connected transformer in order to compensate for the zero-sequence voltage of the supply system. No zero-sequence current flows in the primary side of both transformers. It ensures the system current to be balanced even when the voltage disturbance occurs.

2.2.4 Low-pass filter

It is used to attenuate high frequency components at the output of the series converter that are generated by high-frequency switching

2.2.5 High-pass filter

It is installed at the output of shunt converter to absorb current switching ripples

2.2.6 Series and shunt transformers

These are implemented to inject the compensation voltages and currents, and for the purpose of electrical isolation of UPQC converters. The UPQC is capable of steady state and dynamic series and/or shunt active and reactive power compensations at fundamental and harmonic frequencies. However, the UPQC is only concerned about the quality of the load voltage and the line current at the point of its installation, and it does not improve the power quality of the entire system.

2.3 Equivalent single-phase representation of the UPQC

The equivalent single-phase representation of the UPQC in a power distribution system is shown in Fig. 3.3. The distorted supply voltage vs at the point of common coupling is modelled by the sum of two voltage sources, namely, its fundamental vsf and its harmonics vsh. The nonlinear load is modelled by a distorted current source iL, which is also made up of its fundamental iLf and its harmonics iLh that will change with different loadings. The supply current and the load voltage are denoted by is and vL, respectively.

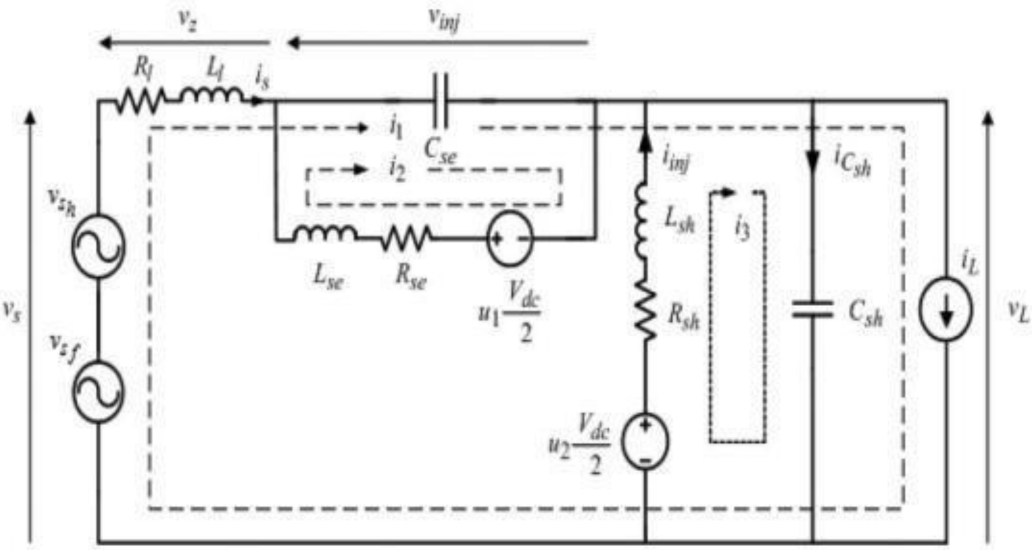


Figure 2.3: Equivalent single-phase representation of the UPQC

Ideally, is and vL should be sine waves of 50 Hz without any harmonic distortions, even though harmonics may exist in vs and iL. As such, this is one of the tasks to be accomplished by the UPQC. vz in Fig.3.3models the voltage drop across the line impedance Rl + jωLl. u1(Vdc/2) and u2(Vdc/2) model the series and shunt active filters of the UPQC, respectively. Their associated low-pass interfacing filters and losses are modelled by Lse, Cse, and Rse, and Lsh, Csh, and Rsh, respectively. iCsh is the leakage capacitor current of the shunt low-pass interfacing filter. u1(Vdc/2) and u2(Vdc/2) represent the switched voltages across the series and shunt VSI outputs of the UPQC, respectively. vinj denotes the injected voltage of the series active filter, while iinj denotes the injected current of the shunt active filter. u1 and U2 will be determined by the ORC to be discussed later; they are supposed to take continuous values between −1 and +1. These continuous values will be modulated by PWM to become the switching signals for the VSIs. Vdc/2 is the desired voltage level of each capacitor unit for the UPQC.

2.4 Functions performed by UPQC

• Convert the feeder (system) current into balanced sinusoids through the shunt compensator.

• Convert the load voltage VL to balanced sinusoids through the series compensator.

• Ensure zero real power injection (and/or absorption) by the compensators.

• Supply reactive power to the load (Q compensation).

UPQC is also known as the universal power quality conditioning system, universal active power line conditioner and universal active. UPQC system can be divided into two sections: The control unit and the power circuit.
Control unit includes disturbance detection, reference signal generation, gate signal generation and voltage/current measurements. Power circuit consists of two voltage source converters, standby and system protection system, harmonic filters and injection transformers. The findings of the comprehensive literature survey summarize the available studies related with control unit and power circuit of UPQC.

2.5 Power Circuit Topologies of UPQC

UPQC is a combination of a shunt (Active Power Filter) and a series compensator (Dynamic Voltage Restorer) connected together via a common DC link capacitor, which facilitates the sharing of the active power. Each Compensator consists of IGBT inverters, which can be operated in current or voltage-controlled mode. Depending upon the location of the shunt compensator with respect to series compensator, UPQC model can be named as right shunt-UPQC or left shunt-UPQC. Typically, the active power generated in one unit is consumed in the other unit maintaining the energy balance overall characteristics of the right shunt-UPQC are superior to those of the left shunt-UPQC. Basic topologies of UPQC are shown in Figure 2.4.

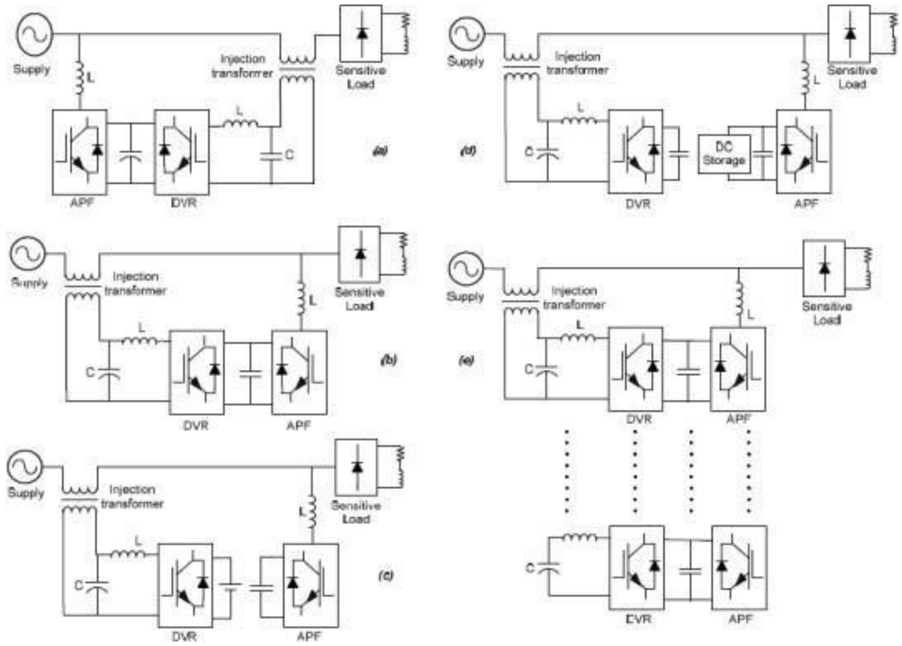


Figure 2.4: Various power circuit topologies: (a) Left shunt-UPQC, (b) Right shunt-UPQC, (c) OPEN UPQC, (d) Interline UPQC and(e) Multilevel UPQC

UPQC can be used for medium voltage and low voltage applications. In case of low power applications, it is not convenient to install a UPQC, since DVR spends most of its time in standby mode. UPQC is generally designed as 3- phase 3-wire (3P3W) systems. 3-phase 4-wire (3P4W) system is also realized from (3P3W) system where the neutral of series transformer used in series part UPQC is considered as the fourth 31wire for 3P4W system. There are Also single-phase UPQC systems. Various topologies such as multilevel topology, single-phase UPQC with two half-bridge converters, H bridge topology and single-phase UPQC with three legs are the examined for UPQC applications. A new topology consists of the DC/DC converter and the super capacitor is presented in. The series and parallel units do not have a common DC link in Advanced renewable generation based distributed power generation system is developed in UPQC is connected between two independent feeders to regulate the bus voltage of one of the feeders while regulating the voltage across a sensitive load in the other feeder in a new configuration, named multi converter unified power quality conditioner (MC- UPQC), for simultaneous compensation of voltage and current in adjacent feeders has been proposed in. Compared to a conventional UPQC, MC-UPQC topology is capable of fully protecting critical and sensitive loads against distortions, sags/swell and interruption in two-feeder systems. The protection of a UPQC against voltage surges and short circuit conditions to prevent its malfunction or destruction is discussed in.

The power circuit of UPQC generally consists of common energy storage unit, DC/AC converter, LC filter and injection transformer. DC link (energy storage unit) supplies required power for compensation of load voltage during voltage sag/swell or current harmonics. UPQC generally consists of two

voltage source inverters (series and shunt) using IGBT which operate from a common DC link storage capacitor. DC link (DC-DC converter) connected to the battery energy storage system is used in. Voltage interruption can also be eliminated by the use of a UPQC with distributed generation. Split capacitor topology is used in. Photovoltaic generation as well as the functions of a unified power quality conditioner is presented in. VSIs are preferred for both shunt and series sides. The series converters are generally composed of 6 Bridges VSI and rarely composed of three single-phase H Bridge VSIs. Shunt converters are generally composed of 6 bridge VSIs for three-phase. There are also some studies using 6 bridge inverters for series converter and three single-phase H bridge inverters for shunt converter. Current source inverters are preferred for both shunt and series sides in. The effect of harmonics generated by the inverter can be minimized using inverter side and line side filtering. Inverter side LC filtering is generally preferred for both series sides and inverter side L filtering is generally preferred for shunt side. Inverter side C filtering is preferred for shunt side in. UPQC incorporating an LCL filter is presented in. Series converter of UPQC is most of time in standby mode and conduction losses will account for the bulk of converter losses during the operation. In this mode, the series injection transformer works like a secondary shorted current transformer using bypass switches delivering utility power directly to the load. A novel configuration of UPQC which can be connected to the distribution system without series injection transformers is presented in.

2.6 Control Techniques of UPQC Topologies

The control unit is the most important part of UPQC system. Rapid detection of disturbance signal with high accuracy, fast processing of the reference signal and high dynamic response of the controller are the prime requirements for desired compensation. The main considerations for the control system of a UPQC include (Figure 2.5):

- Series inverter control: Sag/swell detection, voltage reference generation, voltage injection strategies and methods for generating of gating signals.

- Shunt inverter control: Current reference generation, methods for generating of gating signals and capacitor voltage co

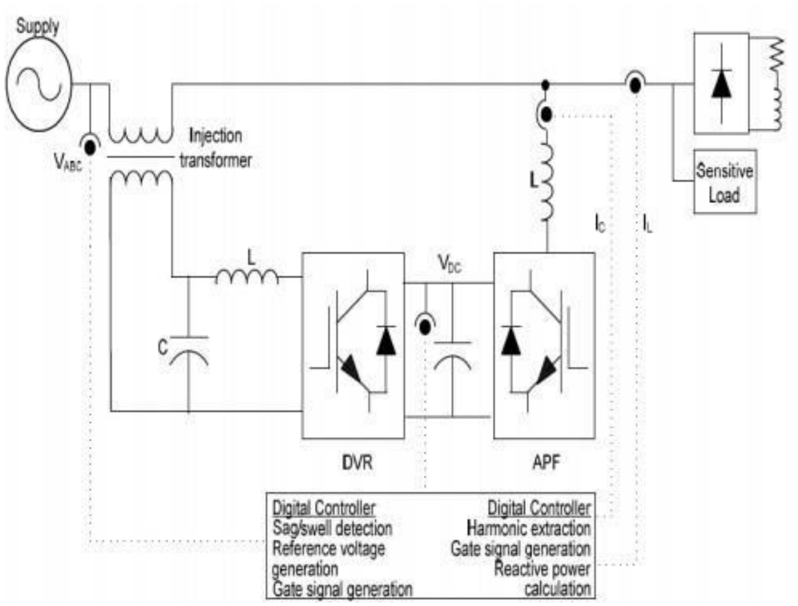


Figure 2.5: Control unit of UPQC with a specified power circuit topology

2.7 UPQC in Service and Future Trends

Digital controller based UPQC has been developed for a laboratory prototype in some of the studies. As a large-scale structure, a 250kVA UPQC is developed at Centre for the Development of Advanced Computing, Trivandrum, India and is under field trial at the centre. Hykon Group Company installs IGBT based UPQC in the range of 10kVA to 250kVA connected to a low voltage level.Most of the proposed or practiced control strategies for power quality conditioners have been reviewed with regard to performance and implementation. The research reveals that there has been a significant increase in interest of UPQC and associated control methods. This can be attributed to the availability of suitable powerswitching devices at affordable price as well as new generation of fast computing devices.

However, deregulation of electricity market may contribute to rising Penetration level of distributed generation from renewable energy sources (e.g. wind, solar, biomass, etc.) in the near future. This can lead to an increase in the number of UPQC studies based on distributed generation.

2.8 Summary

Widespread applications of power electronic based devices/equipment in industry have increased the importance and application of power quality studies. Decrease in the cost of power electronic devices and improvement in the efficiency of both power converters and energy storage components have increased the applicability of new technological solutions such as Custom Power devices. CP devices including DVR, APF and UPQC are showing tremendous development. These devices have become very popular in recent years in both low voltage and medium voltage applications.

The comprehensive reviews of articles concerning CP devices are presented to show the advantages and disadvantages of each possible configuration and control techniques. The literature survey reveals that new control algorithms and topologies for CP devices have been developed to minimize the power losses, increase the system flexibility and efficiency. These reviews will help the researchers to select the optimum control strategy and power circuit configuration for their CP applications.

CHAPTER 3

POWER QUALITY AND ITS PROBLEMS

Electric systems and grids are complex dynamic systems. These systems suffer usually from unexpected or sudden changes of the currents and voltages. These changes are due mainly to the different types of linear and non-linear loads to which they are connected. In addition, to different types of accidents which can intervener into the grid. With the increasing use of power semiconductors in the most of industrial and domestic procedures, the electric grids are polluted with different harmonic currents and voltages. These harmonics affect the normal function of the most of the grid connected devices; in addition to considerable economic losses. Many classic and modern solutions have been proposed in the literary for the harmonic problems. In this chapter, the harmonic problem as one of the most common power quality problems will be presented. The different modern and traditional solutions will then be discussed.

3.1 Definition of Power Quality

Power quality is a term that means different things to different people. Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE1100 defines power quality as "The concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment." As appropriate as this description might seem, the limitation of power quality to "sensitive electronic equipment" might be subject to disagreement.

Electrical equipment susceptible to power quality or more appropriately to lack of power quality would fall within a seemingly boundless domain. All electrical devices are prone to failure or malfunction when exposed to one or more power quality problems. The electrical device might be an electric motor, a transformer, a generator, a computer, a printer, communication equipment or a household appliance. All of these devices and others react adversely to power quality issues, depending on the severity of problems.

A simpler and perhaps more concise definition might state: "Power quality is a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy." This definition embraces two things that we demand from an electrical device: performance and life expectancy. Any power-related problem that compromises either attribute is a power quality concern.

Power quality can also be defined as a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy. Power distribution systems should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in power systems, especially the distribution systems have many nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the pure sinusoidal waveform is lost. This ends up producing many power quality problems.

3.2 Power Systems Distortion and Problems

In power systems, different voltage and current problems can be faced. The main voltage problems can be summarized in short duration variations, voltage interruption, frequency variation, voltage dips and harmonics. Harmonics represent the main problem of currents of power systems.

The main reasons for concern with power quality (PQ) are as following:

• End user devices become more sensitive to PQ due to many microprocessor-based controls

• Large computer systems in many businesses facilities.

• Power electronics equipment used for enhancing system stability, operation and efficiency. These are major sources of bad Power Quality.

• Continuous development of high-performance equipment: Such equipment is more susceptible to power disturbances.

The users always demand higher power quality. Some basic criterions for power quality are

constant rms value, constant frequency, symmetrical three-phases, pure sinusoidal wave

shape and limited THD.

3.2 Responsibilities of the suppliers and users of electricalpower

The realization of quality electrical power is the responsibility of the suppliers and sers of electricity. Suppliers are in the business of selling electricity to widely varying client. The need of one user is usually not the same as the needs of other users. Most electrical equipment is designed to operate within a voltage of ±5% of nominal with marginal decrease in performance. For the most part, utilities are committed to adhering to these limits. At locations remote from substations supplying power from small generating stations, voltages outside of the ±5% limit are occasionally seen. Such variation could have a negative impact on loads such as motors and fluorescent lighting. The overall effects of voltage outside the nominal are not that significant unless the voltage approaches the limits of ±10% of nominal. Also, in urban areas, the utility frequencies are rarely outside ±0.1 Hz of the nominal frequency. This is well within the operating tolerance of most sensitive.[1

3.3 Sources of Poor Power Quality

Sources of poor Power Quality are listed as follows:

- Adjustable –speed drives
- Switching Power supplies
- Arc furnaces
- Electronic Fluorescent lamp ballasts
- Lightning Strike
- L-G fault
- Non- linear load
- Starting of large motors
- Power electronic devices

3.4 Need of Power Quality

There is an increased concern of power quality due to the following reasons:

1. New-generation loads that use microprocessor and microcontroller-based

controls and power electronic devices, are more sensitive to power quality variations than that equipment used in the past.

2. The demand for increased overall power system efficiency resulted in continued growth of devices such as high-efficiency adjustable-speed motor drives and shunt capacitors for power factor correction to reduce losses. This is resulting in increasing harmonic level on power systems and has many people concerned about the future impact on system capabilities.

3. End users have an increased awareness of power quality issues. Utility customers are becoming better informed about such issues as interruptions, sags, and switching transients and are challenging the utilities to improve the quality of power delivered.

4. Most of the networks are interconnected these days. Integrated processes mean that the failure of any component has much more important consequences

3.5 Classification of Power Quality Problems

3.5.1 Short Duration Voltage Variation

Depending on the fault location and the system conditions, the fault can cause either temporary voltage drops (sags), voltage rises (swells), or a complete loss of voltage (interruptions). The duration of short voltage variations is less than 1minute. These variations are caused by fault conditions, the energization of large loads which require high starting currents, or intermittent loose connections in power wiring.

3.5.1.1 Voltage Sag

Voltage sag (also called a "dip") is a brief decrease in the rms line voltage of 10 to 90 percent of the nominal line-voltage. The duration of a sag is 0.5 cycle to 1 minute. Common sources that contribute to voltage sags are the starting of large induction motors and utility faults.

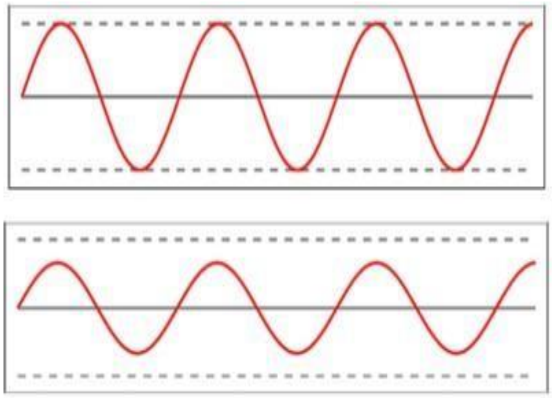


Figure 3.1: Voltage Sag

3.5.1.2 Voltage Swell

A swell is a brief increase in the rms line-voltage of 110 to 180 percent of the nominal line-voltage for duration of 0.5 cycle to 1 minute. The main sources of voltage swells are line faults and incorrect tap settings in tap changers in substations.InterruptionAn interruption is defined as a reduction in line-voltage or current to less than 10 percent of the nominal, not exceeding 60 seconds in length. Interruptions can occur due to power system faults, equipment failures and control malfunctions.

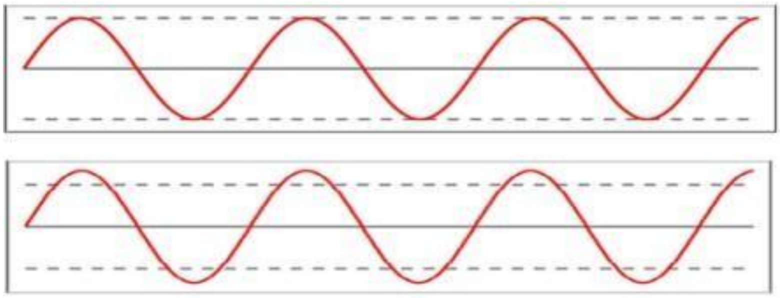


Figure 3.2: Voltage Swell

3.5.1.3 Interruption

An interruption is defined as a reduction in line-voltage or current to less than 10 percent of the nominal, not exceeding 60 seconds in length. Interruptions can occur due to power system faults, equipment failures and control malfunction

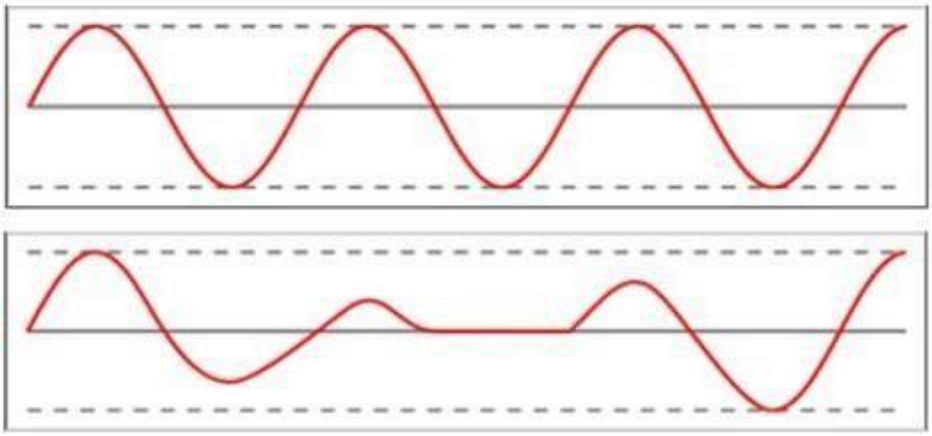


Figure 3.3: Interruption

3.5.2 Long-Duration Voltage Variation

Long-duration variations can be categorized as over voltages, under voltages or sustained interruptions.

3.5.2.1 Overvoltage

An overvoltage is an increase in the rms ac voltage greater than 110 percent at the power frequency for duration longer than 1 min. Over voltages are usually the results of load switching or incorrect tap settings on transformers.

3.5.2.2 Under voltage

An under voltage is decreases in the rms ac voltage to less than 90 percent at the power frequency for duration longer than 1 min. A load switching on or a capacitor bank switching off can cause an under voltage until voltage regulation equipment on the system can restore the voltage back to within tolerance limits. Also overloaded circuits can result in under voltage

3.5.2 Sustained Interruptions

When the supply voltage has been zero for a period of time in excess of 1 min the long- duration voltage variation is considered a sustained interruption.

3.5.3 Transients

3.5.3.1 Impulsive Transient

An impulsive transient is a brief, unidirectional variation in voltage, current, or bothon a power line. Lightning strikes, switching of inductive loads, or switching in the power distribution system are the most common causes of impulsive transients. The effects of transients can be mitigated by the use of transient voltage suppressors such as Zener diodes.

Figure 3.4: Impulsive Transients[2]

3.5.3.2 Oscillatory Transient

An oscillatory transient is a brief, bidirectional variation in voltage, current, or both on a power line. These are caused due to the switching of power factor correction capacitors.

Figure 3.5: Oscillatory Transients[2]

3.5.4 Voltage Fluctuations

Voltage fluctuations are relatively small (less than 5 percent) variations in the rms line voltage.

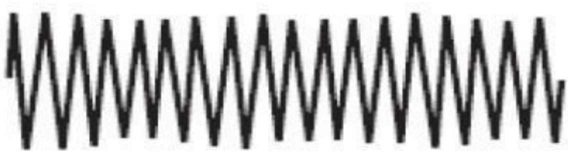


Figure 3.6: Voltage Fluctuations or Flicker

Cyclo-converters, arc furnaces, and other systems that draw current not in synchronization with the line frequency are the main contributors of these variations.

3.5.5 Voltage Imbalance

A voltage imbalance is a variation in the amplitudes of three-phase voltages, relative to one another. Voltage imbalance can be the result of different loads on the phases, resulting in different voltage drops through the phase-line impedances.

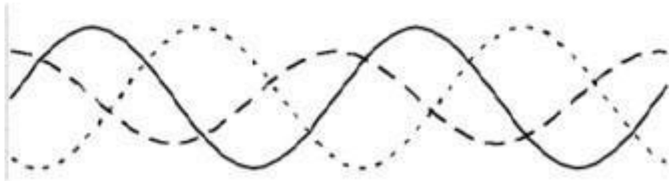


Figure 3.7: Voltage imbalance [2]

3.5.6 Waveform Distortion

Waveform distortion is defined as a steady-state deviation from an ideal sine wave of power frequency principally characterized by the spectral content of the deviation.

(i) DC offset: The presence of a dc voltage or current in an ac power system is termed dc offset.

3.5.7 Harmonics

Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the frequency at which the supply system is designed to operate, and that is known as the fundamental frequency which is usually 50 or 60 Hz. The harmonic distortion originates in the nonlinear characteristics of devices and also on loads connected to the power system

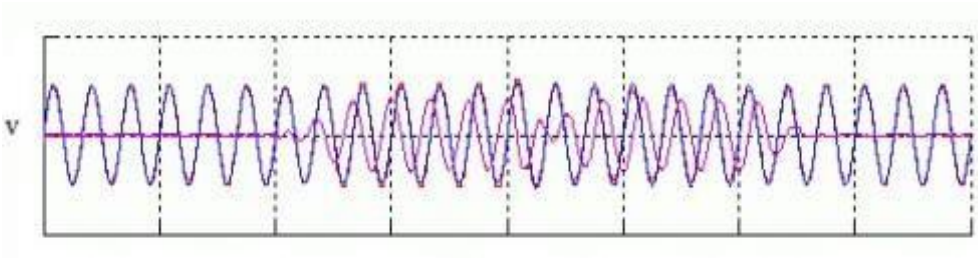


Figure 3.8: Harmonics [2]

Harmonic distortion levels can be described by the calculating total harmonic distortion (THD) which measures the complete harmonic spectrum with magnitudes and phase angles of each individual harmonic component. THD is represented as the square-root of the sum of the squares of each individual harmonic. Voltage THD is

$$V_{THD} = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{V1}$$

Where V1 is the rms magnitude of the fundamental component, and Vn is the rms magnitude of component n where n = 2,....., .∞ The problem with this approach is that THD become infinity if no fundamental is present. A way to avoid this ambiguity is to use an alternate definition that represents the harmonic distortion. This is called the distortion index (DIN) and is defined as

$$DIN = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{\sqrt{\sum_{n=1}^{\infty} V_n^2}}$$

THD and DIN are interrelated by the following equations

$$\mathrm{DIN} = \frac{THD}{\sqrt{1+THD^2}}$$

$$\mathrm{THD} = \frac{DIN}{\sqrt{1-DIN^2}}$$

3.5.7.1 Sub-harmonics

Sub harmonics can be defined as frequency components in voltage and current waveforms less than the power system frequency. Cyclo-converters, adjustable speed drives, arc furnaces, wind generators and other loads inject low frequency currents that produce sub harmonic distortion in voltage supply

3.5.7.2 Inter-harmonics

Voltages or currents having frequency components that are not integer multiples of the frequency at which the supply system is designed to operate (50 or 60 Hz) are called inter- harmonics. Inter-harmonics can appear as discrete frequencies or as a wideband spectrum. The main sources of inter-harmonic waveform distortion are static frequency converters, induction furnaces, cyclo-converters and arcing devices. Power line carrier signals can also be considered as inter-harmonics.

3.5.8 Electrical Noise

Noise is a high frequency distortion of the voltage waveform. Caused by disturbances on the utility system or by equipment such as welders, switchgear and transmitters, noise can frequently go unnoticed. Frequent or high levels of noise can cause equipment malfunction, overheating and premature wear.

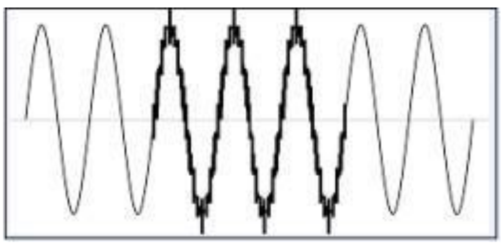


Figure 3.9: Electrical Noise Waveform

3.5.9 Notching

Notching is a disturbance of opposite polarity to the normal voltage waveform (which is subtracted from the normal waveform) lasting for less than one-half cycle.Notching is usually caused by malfunctioning of electronic switches or power conditioners. While it is generally not a major problem, notching can cause equipment, especially electronics, to operate improperly.

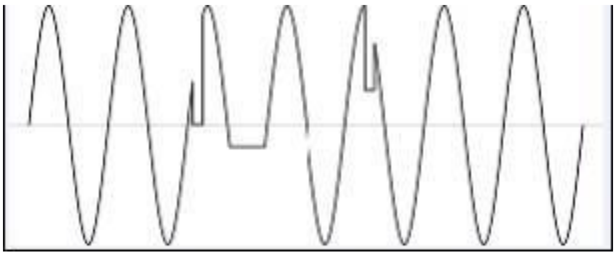


Figure 3.10: Notching Waveform[3]

3.6 Effects of Harmonics

Harmonic currents will flow into the utility feeder and may create a number of problems in so doing. They may be trapped by power factor correction capacitors and overload them or cause resonant over-voltages. They can distort the feeder voltage enough to cause problems in computers, telephone lines, motors, and power supplies, and may even cause transformer failures from eddy current losses. The harmonic currents may be trapped by installing series LC filters resonant at the offending frequencies. These filters should be designed to offer low impedance at the resonant frequency compared to the source impedance at that frequency. But, again, there is a hidden “gotcha.” If a filter is installed that has a series resonance at the 7th harmonic, it will also have a parallel resonance with the utility at a lower frequency when the source inductance is added to the filter inductance. If this parallel resonance should lie on or near the 5th harmonic, there is the possibility of the resonant over-currents described earlier. The installation of series resonant traps will always introduce parallel resonances at frequencies below the trap frequencies. Good practice dictates that multiple resonant traps be installed first at the lowest harmonic frequency of concern and then in sequence at the higher-frequency harmonics. If switched, they should be switched on in sequence starting with the lowest frequency trap and switched out in sequence starting from the highest frequency trap.

The voltage or current distortion limit is determined by the sensitivity of loads (also of power sources), which are influenced by the distorted quantities. The least sensitive is heating equipment of any kind. The most sensitive kind of equipment's is those electronic devices which have been designed assuming an ideal (almost) sinusoidal fundamental frequency voltage or current waveforms. Electric motors are the most popular loads which are situated between these two categories.

3.6.1 Power Factor

Power factor is defined as the ratio of real power to volt-amperes and is the cosine of the phase angle between the voltage and the current in an AC circuit. These are neatly defined quantities with sinusoidal voltages and currents. Power factor can be improved by adding capacitors on the power line to draw a leading current and supply lagging VArs to the system. Power factor correction capacitors can be switched in and out as necessary to maintain VAr and voltage control.For a sinusoidal signal, the power factor is given by the ratio between the active and the apparent power. Electrical equipment's' parameters are normally given under nominal voltage and current. A low power factor can indicate bad use of this equipment's. The apparent power can be defined by:

$$S=V_{rms}.I_{rms}=V_{rms}.\sqrt{\frac{1}{T}\int_0^T i_L^2\,dt} \qquad (2.5)$$

The active power P can be given by the relation:

$$P=V_{rms}.I_{rms}.\cos(\propto 1) \qquad (2.6)$$

The reactive power Q is defined by:

$$Q=V_{rms}.I_{rms}.\sin(\propto 1) \qquad (2.7)$$

The power factor in this case can be given by Equation 2.8.

$$P.F=P/S=P/\sqrt{P^2+Q^2} \qquad (2.8)$$

In the case where there is harmonics, a supplementary power called the distorted power D appears. This power can be given by the relation.

$$D=V_{rms}.\sqrt{\sum_{n=2}^{\alpha} I_{Ln}^2} \quad (2.9)$$

The apparent power can then be expressed as:

$$S=\sqrt{P^2+Q^2+D^2} \quad (2.10)$$

The power factor is then given by:

$$P.F=\frac{P}{\sqrt{P^2+Q^2+D^2}} \quad (2.11)$$

From equation (2.11), we can notice that the power factor decreases because of the existence of harmonics in addition to the reactive power consumption. The Fresnel diagram of the power is given in Fig. 3.2.

3.6.2 Distortion Factor

The distortion factor Fd is defined as the ratio between the fundamental and the signal in RMS values. It is given by:

$$F_d = \frac{I_{L1}}{I_{rms}} \quad (2.3)$$

It is then equal to unity when the current is purely sinusoidal and decreases when the distortion appears.

3.6.3 Crest Factor

The crest factor of a signal Fc is defined by Equation (2.4):

$$F_c=\frac{\text{crest value}}{\text{effectivevalue}} \quad (2.4)$$

For sinusoidal waves, the crest factor is 1.41. It can achieve the value of 5 in the case of highly distorted waves.equipment, especially electronics, to operate improperly.

3.7 Solutions to Power Quality Problems

The mitigation of power quality problems can be achieved in two ways. It can be done from either customer side or utility side. First approach used is load conditioning and the other is line conditioning. Load conditioning ensures that the equipment is less sensitive to power disturbances. They are based on PWM converters and connected in shunt or in series to low and medium voltage

distribution system. Series active power filters operate in conjunction with shunt passive filters in order to compensate load current harmonics. Series active power filters operates as a controllable voltage source whereas shunt active power filters operate as a controllable current source. Both of these schemes are implemented preferable with voltage source PWM inverters, with a dc bus having a reactive element such as a capacitor. However, with the restructuring of power sector, the line conditioning systems or utility side solutions will play a vital role in improving the inherent supply quality. Some of the effective and economic measures can be identified as following: [3]

3.7.1 Lightening and Surge Arresters

Arresters are designed for lightening protection of transformers, but are not sufficient for limiting voltage fluctuations to protect sensitive electronic control circuits.

3.7.2 Thyristor Based Static Switches

The static switch is a device for switching a new element into the circuit when the voltage support is needed. It has a dynamic response time of about one cycle. It can be used in the alternate power line applications. To correct quickly for voltage spikes, sags or interruptions, the static switch can be used to switch one or more of devices such as filter, capacitor, alternate power line, energy storage systems etc.

3.7.3 Energy Storage Systems

Storage systems can be used to protect sensitive equipment from shutdowns caused by voltage sags or momentary interruptions. Energy is fed to the system to compensate for the energy that would be lost by the voltage sag or interruption. The systems used are usually DC storage systems such as batteries, UPS, superconducting magnet energy storage (SMES), storage capacitors or even fly wheels driving DC generators. The output of these devices can be supplied to the system through an inverter on a momentary basis

3.7.4 Electronic Tap Changing Transformer

A voltage-regulating transformer with an electronic load tap changer can be used with a single line from the utility. It can regulate the voltage drops up to 50% and requires a stiff system (short circuit power to load ratio of 10:1 or better).

3.7.5 Harmonic Filters

Filter are used where effective reduction or elimination of certain harmonics is required. If possible, it is always preferable to use a 12-pulse or higher transformer connection, rather than a filter. Usually, multiple filters are needed, each tuned to a separate harmonic. Each filter causes a parallel resonance as well as a series resonance, and each filter slightly changes the resonances of other filters. [3]

3.8 Custom power devices

3.8.1 Introduction

For improving the system performance for distribution system and with the growing development of the power semiconductor technology, the concepts of custom power were introduced to distribution systems. The concept describes the value-added power that electric utilities will offer their customers in the future, focusing on the quality of power flow and reliability. Due to this increasing demand and the rapid development of the high- power semiconductor technology, the custom power solutions are taking place rapidly. In a custom power system customer receives specified power quality from a utility or a service provider or at-the-fence equipment installed by the customer in coordination with the utility, which includes an acceptable combination of the following features:

- No (or rare) power interruptions
- Magnitude and duration of voltage reductions within specified limits.
- Low harmonic voltage.
- Low phase unbalance

This can be done on the basis of an individual, large customer, industry or a supply for a high-tech community on a wide area basis.

3.8.2 Need of Custom Power

The increased use of automated equipment, like adjustable speed drives, programmable logic controllers, switching power supplies, arc furnaces, electronic fluorescent lamp ballasts, automated production lines are far more vulnerable to disturbances than were the previous generation equipment and less automated production and information systems.Even though the power generation in most advanced country is fairly reliable, the distribution is not always so. It is however not only reliability that the consumers want these days, quality too is very important for them. With the deregulation of the electric power energy market, the awareness regarding the quality of power is increasing day by day among customers. Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage.In the several processes such as semiconductor manufacturing or food processing plants, a batch of product can be ruined by a voltage dip of very short duration. Even short dips are sufficient to cause contactors on motor drives to drop out. There are other loads which are very sensitive such as hospitals, processing plants, air traffic control and numerous other data processing and service providers that require clean and uninterrupted power. Thus, in this scenario in which customers increasingly demand power quality, the term power quality attains increased significance.The factors mentioned point out the problems faced by the industry and awareness of consumers about quality of power due to which it has increasingly become important to provide the consumers with the reliable as well as superior power quality. Thus,the development of custom power has gained so much of widespread attention nowadays. [4]

3.8.3 Custom Power Devices

There are many types of Custom Power devices. Some of these devices include Active Power Filters (APF), Surge Arresters (SA). Battery Energy Storage Systems(BESS), Super conducting Magnetic Energy Systems (SMES), Static Electronic Tap Changers (SETC), Solid State Fault Current Limiter (SSFCL), Solid-State Transfer Switches (SSTS), Static VAR Compensator (SVC), Distribution Series Capacitors (DSC), Dynamic Voltage Restorer (DVR), Distribution Static synchronous Compensators (DSTATCOM) and Uninterruptible Power Supplies (UPS) , Unified power quality conditioner(UPQC).The classification of custom power devices can be done into two major categories, one is network configuring type and the other is compensating type. The network configuring type devices changes the configuration of the power system network for power quality enhancement. SSCL (Solid State Current Limiter), SSCB (Solid State Circuit Breaker) and SSTS (Solid State Transfer Switch) are the most representative in this category.The compensating type devices are used for active filtering; load balancing, power factor correction and voltage regulation. The family of compensating devices includes DSTATCOM (Distribution Static compensator), DVR (Dynamic voltage restorer) and Unified power quality conditioner (UPQC). DSTATCOM is connected in shunt with the power system while DVR is a series connected device that injects a rapid series voltage to compensate the supply voltage. UPQC is the combination of DSTATCOM and DVR. It injects series voltage and shunt currents to the system.Though there are many different methods to mitigate voltage sags and swells, but the use of a custom power device is considered to be the most efficient method to serve for different purposes. The term Custom Power pertains to the use of power electronic controllers in a distribution system to deal with various power quality problems. It makes sure that customers get pre-specified quality and reliability of power supply that may include a single or the combination of the specifications like no power interruptions, low phase unbalance, low harmonic distortion in load voltage, low flicker at the load voltage, acceptance of fluctuations, magnitude and duration of overvoltage and under voltages within specified limits and poor factor loads without significant effect on the terminal voltage.

3.8.4 Solid State Current Limiter

The most widely used solution for limitation of the fault currents is to use a transformer with a split secondary winding (or a three windings transformer) and current limiting reactors. The basic configuration of Solid-State Current Limiter is shown in Figure 3.1. However, the usage of fault current limiting reactors with powerful motor loads has a negative impact on the stability of motors, for example

when short-term voltage sags occur. It would be worthwhile to directly control transients, resulting from faults, at primary circuits, thus alleviating effects of the faults.Series fault current limiters used to limit the fault current by disconnecting solid-state switch and increasing the impedance. However, such scheme has a disadvantage: the system should be operating in continuous mode, and malfunction of the static switch could lead to interruption of power supply for the customer.Parallel fault current limiters are activated only at the moment of fault and have the following functions:

- limit the peak fault current
- decrease the motors feeding into the fault
- shunt the consumer switches while disconnecting

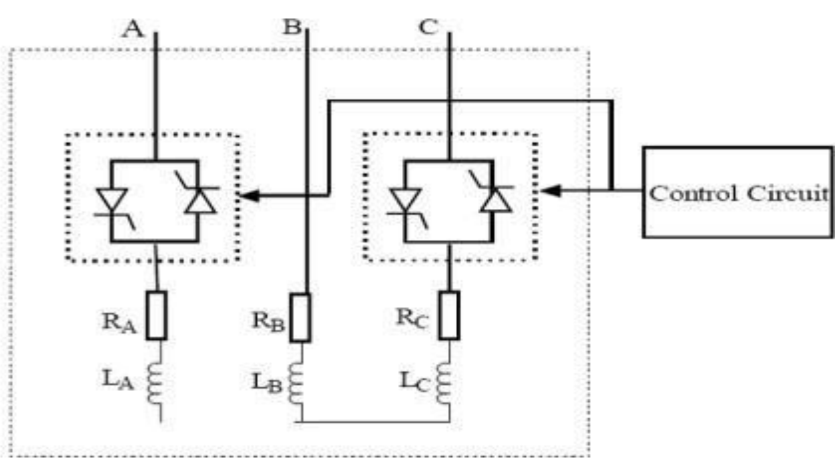


Figure 3.11: Solid state current limiter[5]19

3.9 Solutions for the Harmonics

The filtering of the grid currents and voltage is a priory problem for the distributer as like as the client. Because the limits on harmonic emission are not equally applied in the low of the different countries, the producers of the different electrical devices try to construct devices that satisfy for the conditions and limits of the international standards. The electric companies, from its side, use different filtering equipment's and encourage the researches toward finding new efficient solutions for the power quality problems.

The clients install also sometimes reactive power and harmonic compensation batteries to operate the power factor and reduce the energy consumption bill.

Many traditional and modern solutions for harmonics mitigation and power quality improvement were proposed in literary. Some of these solutions investigate in the load to minimize the harmonic emission while the others propose the use of external filtering equipment's that prevent the spread of harmonics into the grid.

3.9.1 In-Line Reactors

In-line reactor or choke is a simple solution to control harmonic distortion generated by adjustable speed drives. The solution is come up with inserting a relatively small reactor, or choke, at the input of the drive. The inductance prevents the capacitor to be charged in a short time and forces the drive to draw current over a longer time and reduces the magnitude of the current with much less harmonic content while still delivering the same energy.

3.9.2 Transformers with Passive Coupling

Some types of triangle zigzag coupling of transformers allow the elimination of the harmonics of order 3 and its multiples. The cost of these coupling types is the augmentation of the source impedance, and then the augmentation of voltage harmonic distortion.

3.9.3 Passive Filters

Passive filter, which is relatively inexpensive in comparison with the other harmonic reduction methods, is the most used method. Inductance, capacitor and the load as a resistance are tuned in a way to control the harmonics. However, they suffer from interfering with the power systems. Actually, passive filters are designed to shunt harmonics from the lines or block their flow through some parts of the systems by tuning the elements to create a resonance at the selected frequency. These filters are tuned and fixed according to the impedance of the point at which they will be connected and hence cannot be adjusted instantaneously in accordance to the load. As a result their cutoff frequency changes unexpectedly after any change in the load impedance resulting in producing a resonance with other elements installed in the system.

3.10 Modern Solutions for Harmonic Problems

Modern solutions were proposed as efficient solutions for the elimination of electric grid harmonics in order to defeat the disadvantages of the traditional methods like passive filters. Between these solutions we find two categories which are the most used:

Active filters (series, parallel, or a combination of both of them in Unified Power Quality Conditioner (UPQC)).

Hybrid filters composed of active and passive filters at once.Active Power Filters

The increasing use of power electronics-based loads (adjustable speed drives, switch mode power supplies, etc.) to improve system efficiency and controllability is increasing the concern for harmonic distortion levels in end use facilities and on the overall power system. The application of passive tuned filters creates new system resonances which are dependent on specific system conditions.Passive filters often need to be significantly overrated to account for possible harmonic absorption from the power system. Passive filter ratings must coordinate with reactive power requirements of the loads and it is often difficult to design the filters to avoid leading power factor operation for some load conditions.Active filters have the advantage of being able to compensate for harmonics without fundamental frequency reactive power concerns. Currently they are based on PWM converters and connect to low and medium voltage distribution system in shunt or in series. Series active power filters must operate in conjunction with shunt passive filters in order to compensate load current harmonics. Shunt active power filters operate as a controllable current source and series active power filters operates as a controllable voltage source. Both schemes are implemented preferable with voltage source PWM inverters, with a dc bus having a reactive element such as a capacitor.Active power filters can perform one or more of the functions required to compensate power systems and improving power quality. The rating of the active power can be less than a conquerable passive filter for the same nonlinear load and the active filter will not introduce system resonances that can move a harmonic problem from one frequency to another. [6]

3.10.1 Series Active Power Filter (Series APF)

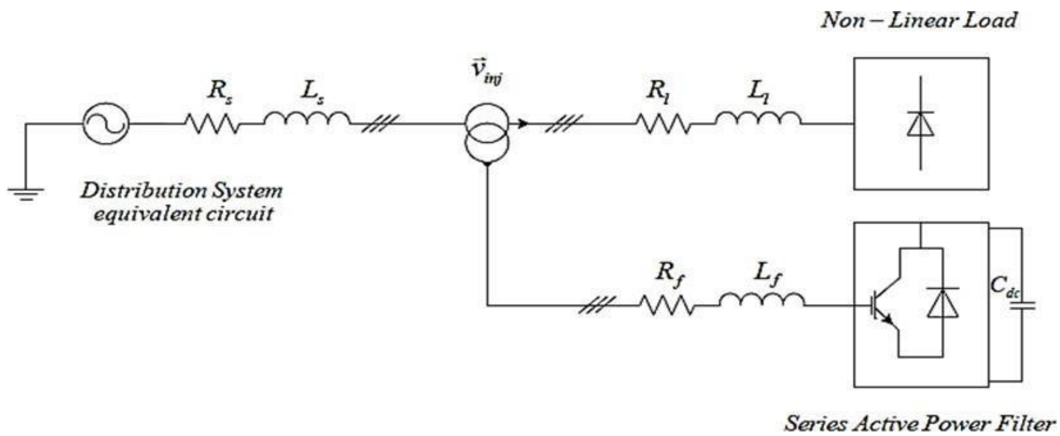


Fig 3.12: Series Active Power Filter

The aim of the series APF is to locally modify the impedance of the grid. It is considered as harmonic voltage source which cancel the voltage perturbations which come from the grid or these created by the circulation of the harmonic currents into the grid impedance. However, series APFs can't compensate the harmonic currents produced by the loads.

3.10.2 SHUNT ACTIVE POWER FILTER

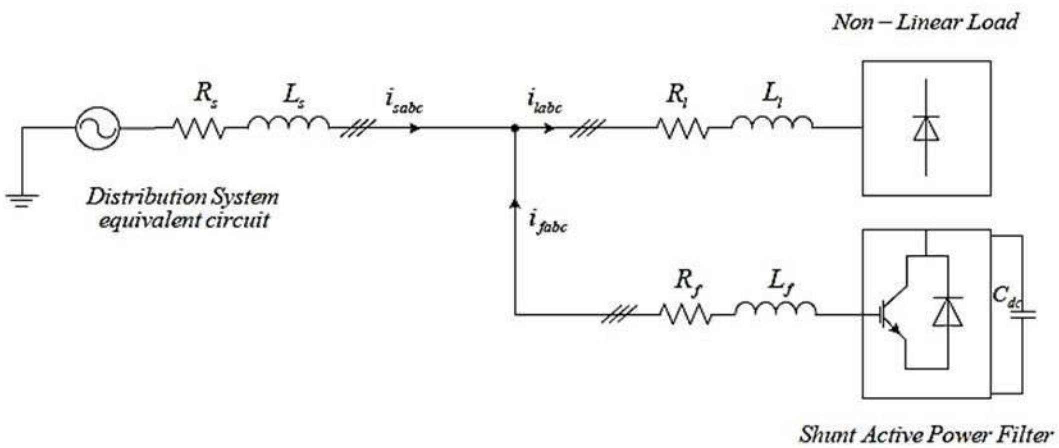
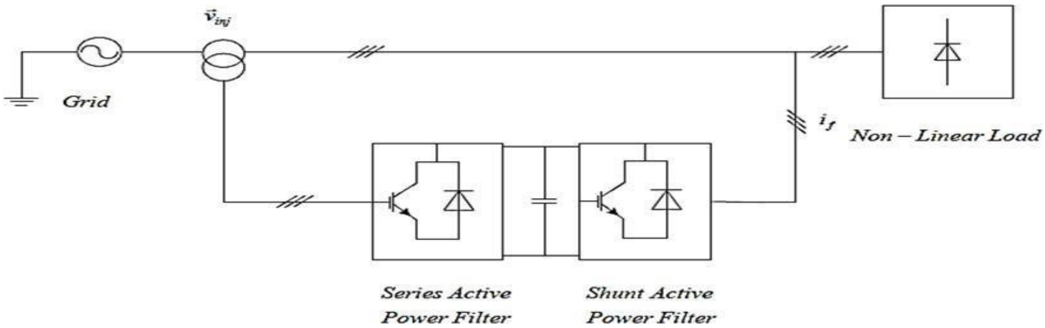


Fig 3.13: Shunt Active Power Filter

The SAPFs are connected in parallel with the harmonic producing loads. They are expected to inject in real time the harmonic currents absorbed by the pollutant loads. Thus, the grid current will become sinusoidal.Fig. 3.13 Shunt APF Connected in Parallel with Non-Linear Load



3.15 Combination of Parallel and Series APF (UPQC)

Fig. 3.15 explains the combination of two APFs parallel and series, called also (Unified Power Quality Conditioner). This structure combines the advantages of the two APF type’s series and parallel. So it allows simultaneously achieving sinusoidal source current and voltage

3.10.3 Hybrid Filters

Hybrid filter is a filter topology which combines the advantages of the passive and active filters. For this reason, it is considered as the best solution to eliminate the harmonic currents from the grid. The principal reason for the use of hybrid filters is the development of the power semiconductors like MOSFETs and IGBTs. Over more, from an economical point of view, the hybrid power filters allow reducing the cost of APF.

Hybrid power filters can be classified according to the number of elements used in the topology, the treated system (single phase, three phase three legs or four legs) and the used inverter type (current source inverter or voltage source inverter).

3.10.4 Non-Linear Loads

When the input current into the electrical equipment does not follow the impressed voltage across the equipment, then the equipment is said to have a nonlinear relationship between the input voltage and input current. All equipment's that employ some sort of rectification are examples of nonlinear loads. Nonlinear loads generate voltage and current harmonics that can have adverse effects on equipment designed for operation as linear loads. Transformers that bring power into an industrial environment are subject to higher heating losses due to harmonic generating sources (nonlinear loads) to which they are connected.

3.10.5 Shunt Active Power Filter

The concept of using active power filters to mitigate harmonic problems and to compensate reactive power was proposed more than two decades ago. It has proven its ability to control the grid current and to ameliorate the power quality. The theories and applications of active power filters have become more popular and have attracted great attention. Without the drawbacks of passive harmonic filters, such as component aging and resonant problems, the active power filter appears to be a viable solution for reactive power compensation as well as for eliminating harmonic currents. As we mentioned earlier, the SAPF is connected in parallel with the non-linear load to behave as another controlled non-linear load. The system of the non-linear load and the SAPF will be seen by the grid as a linear load connected to the PCC. In the case of compensation of reactive

power this load will be resistive. Otherwise it will be either inductive or capacitive linear load.

3.10.6 Distribution Static Compensator (DSTATCOM)

The purpose of the DSTATCOM is to cancel load harmonics fed to the supply. The coupling of DSTATCOM is three phases, in parallel to network and load. It works as current sources, connected in parallel with the nonlinear load, generating the harmonic currents the load requires also balance them in addition to providing reactive power. In order to compensate undesirable components of the load current the DSTATCOM injects currents into the point of common coupling. With an appropriated control strategy, it is also possible to correct power factor and unbalanced loads. This principle is applicable to any type of load considered a harmonic source.

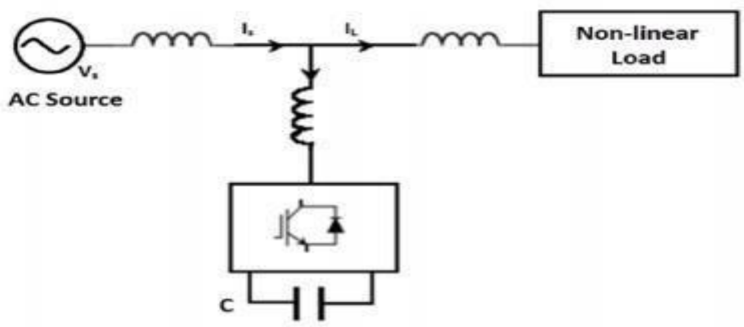


Figure 3.16: Distribution Starcom (DSTATCOM)

Its advantage is that it of carries only the compensation current plus a small amount of active fundamental current supplied to compensate for system losses. Shunt Active Power Filter in current control mode is also called as DSTATCOM.

3.10.7 Dynamic Voltage Restorer (DVR):

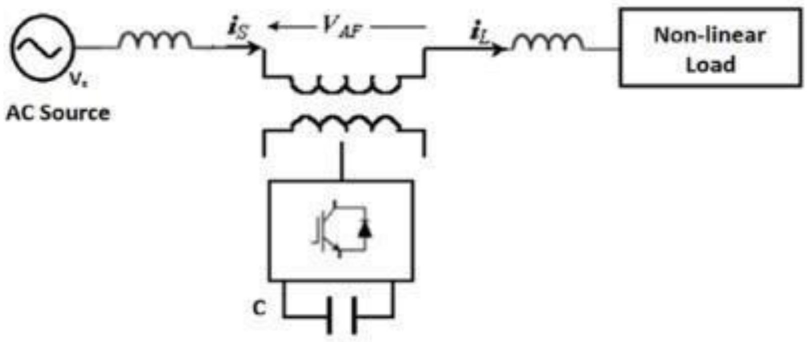


Figure 3.17: Dynamic Voltage Restorer (DVR) [6

DVR injects a voltage component in series with the supply voltage, thus compensating voltage sags and swells on the load side. Control response is on the order of 3msec, ensuring a secure voltage supply under transient network conditions. Voltage injection of arbitrary phase with respect to the load current implies active power transfer capability. This active power is transferred via the dc link, and is supplied either by a diode bridge connected to the ac network, a shunt connected PWM converter or by an energy storage device. It works as a harmonic isolator to prevent the harmonics in the source voltage reaching the load in addition to balancing the voltages and providing voltage regulation.

3.10.8 Unified Power Quality Conditioner (UPQC)

The best protection for sensitive loads from sources with inadequate quality, is shuntseries connection i.e. unified power quality conditioner (UPQC) .Recent research efforts have been made towards utilizing unified power quality conditioner (UPQC) to solve almost all power quality problems for example voltage sag, voltage swell, voltage outage and over correction of power factor and unacceptable levels of harmonics in the current and voltage The basic configuration of UPQC is shown in fig

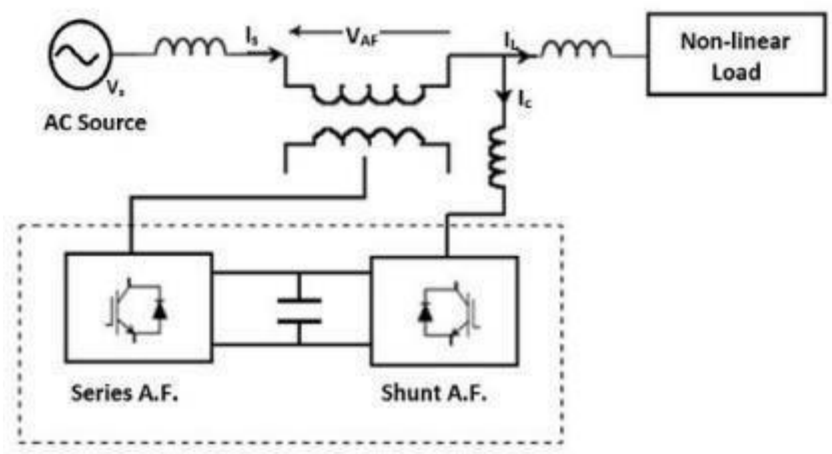


Figure 3.18: Unified Power Quality Conditioner (UPQC)

The main purpose of a UPQC is to compensate for supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics. In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. The UPQC, therefore, is expected as one of the most powerful solutions to large capacity sensitive loads to voltage flicker/imbalance.Unified Power Quality Conditioner (UPQC) for non-linear and a voltage sensitive load has following facilities:

• It eliminates the harmonics in the supply current, thus improves utility current quality for nonlinear loads.

• UPQC provides the VAR requirement of the load, so that the supply voltage and current are always in phase, therefore, no additional power factor correction equipment is necessary.

• UPQC maintains load end voltage at the rated value even in the presence of supply voltage sag.

• The voltage injected by UPQC to maintain the load end voltage at the desired value is taken from the same dc link, thus no additional dc link voltage support is required for the series compensator.

The UPQC consists of two three phase inverters connected in cascade in such a manner that Inverter I is connected in series with the supply voltage through a transformer inverter II is connected in parallel with the load. The main purpose of the shunt compensator is to compensate for the reactive power demanded by the load, to eliminate the harmonics and to regulate the common dc link voltage. The series compensator is operated in PWM voltage-controlled mode. It injects voltage in quadrature advance to the supply voltage (current) such that the load end voltage is always maintained at the desired value. The two inverters operate in a coordinated manner

There are three principle elements to the custom power concept; these are:

• The Dynamic Voltage Restorer (DVR), it provides series compensationby voltage injection for power system sag and swell

• The Distribution Static Compensator (D-STATCOM), it providescontinuously variable shunt compensation by current injection foreliminating voltage fluctuations and obtaining correct power factor in three phase systems. An ideal

- application of it is to prevent disturbing from polluting the rest of the distribution system.
- Unified Power Quality Conditioner (UPQC), it provides series and shunt compensation i.e. inject voltage in sag and swell condition and injectcurrent for elimination of voltage fluctuations, correct power factor,avoid pollution to restof the distribution system.
- The proper selection of necessary custom power strategies in addition toaccurate system modeling and appropriate protection devices will increase the power quality.

3.11 Superiority of UPQC over Other Devices

Each of Custom Power devices has its own benefits and limitations. The UPQC is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage and load current disturbances /imbalance. The most effective type of these devices is considered to be the Unified Power Quality Conditioner (UPQC). There are numerous reasons why the UPQC is preferred over the others. UPQC is much flexible than any single inverter-based device. It can simultaneously correct for the unbalance and distortion in the source voltage and load current whereas all other devices either correct current or voltage distortion. Therefore, the purpose of two devices is served by UPQC only. [6]

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CHAPTER 4

PROJECT DESIGN

4.1 Overview

Shunt active power filter compensates current harmonics by injecting equal-but- opposite harmonic compensating currents into the grid. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180°. This principle is applicable to any type of load considered as harmonic source. Moreover, with an appropriate control scheme, the active power filter can also compensate the load power factor. In this way, the power distribution system sees the non-linear load and the active power filter as an ideal resistor. The current compensation characteristics of the shunt active power filter is shown in Fig. 3.1

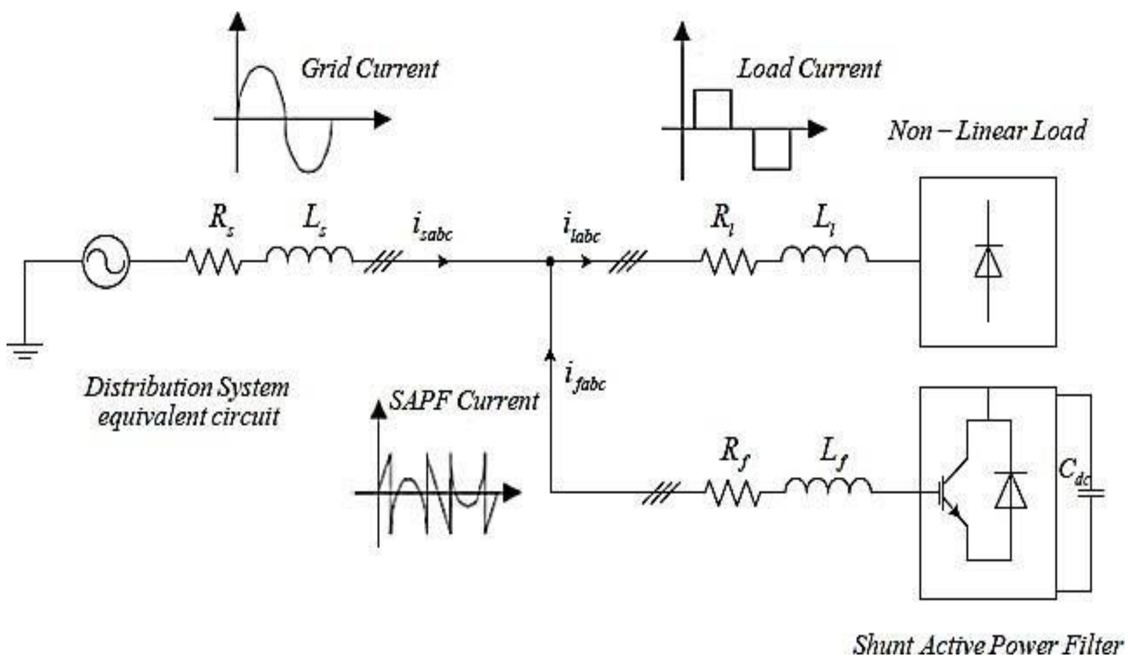

Fig. 4.1 Compensation Characteristic of Shunt Active Power Filter

4.2 Harmonic Current Extraction Methods

The aim of active power filtering is to compensate the harmonic currents produced by the non-linear loads, and to ensure the sinusoidal form of grid currents and voltages. The first step in active filtering is the harmonic currents extraction to be injected into the grid. The good extraction of harmonics is a keyword for a good active power filtering. Many extraction methods were proposed in literary. They can be divided into two families: the first family uses the Fast Fourier Transform (FFT) in the frequency domain to extract the current harmonics. The main disadvantages of this method are the bad results in transient, the heavy amount of calculations, and the use of considerable memory. In addition to a delay in the extraction of harmonics which can be at least one period.

The second family is based on the time domain calculations in the extraction of harmonics. Some of its methods are based on the instantaneous active and reactive power. Others are based on the calculation of direct and indirect current components. Recently, the neural networks and the adaptive linear neural networks have been used in the extraction of harmonic components of current and voltage.

4.2.1 Instantaneous Active and Reactive Power Theory

Most APFs have been designed on the basis of instantaneous active and reactive power theory (p-q), first proposed by Akagi et al in 1983. Initially, it was developed only for three-phase systems without neutral wire, being later worked by *Watanabe* and *Aredes* for three-phase four wires power systems. The method uses the transformation of distorted currents from three phase frame *abc* into bi-phase stationary frame $\alpha\beta$. The basic idea is that the harmonic currents caused by nonlinear loads in the power system can be compensated with other nonlinear controlled loads. The p-q theory is based on a set of 31 instantaneous powers defined in the time domain. The three-phase supply voltages (u_a, u_b, u_c) and currents (i_a, i_b, i_c) are transformed using the Clarke (or α-β) transformation into a different coordinate system yielding instantaneous active and reactive power components. This transformation may be viewed as a projection of the three-phase quantities onto a stationary two-axis reference frame. The Clarke transformation for the voltage variables is given by

$$\begin{bmatrix} u_{\propto} \\ u_{\beta} \\ u_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \tag{3.1}$$

Similarly, this transform can be applied on the distorted load currents to give:

$$\begin{bmatrix} i_{l\propto} \\ i_{l\beta} \\ i_{l0} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \tag{3.2}$$

The instantaneous active power *p(t)* is defined by:

$$p(t)= u_a i_{la} + u_b i_{lb} + u_c i_{lc} \tag{3.3}$$

This expression can be given in the stationary frame by:

$$\begin{cases} p(t) = u_{\propto} i_{l\propto} + u_{\beta} i_{l\beta} \\ p_o(t) = u_o i_{lo} \end{cases} \tag{3.4}$$

Where, *p(t)* is the instantaneous active power, *p0(t)* is the instantaneous homo-polar sequence power. Similarly the instantaneous reactive power can be given by:

$$q(t) = -\frac{1}{\sqrt{3}}[(u_a - u_b) i_{lc} + (u_b - u_c) i_{la} + (u_c - u_a) i_{lb}] = u_{\propto} i_{l\beta} - u_{\beta} i_{l\propto} \tag{3.5}$$

It is important to notice that the instantaneous reactive power *q(t)* signify more than the simple reactive power. The instantaneous reactive power take in consideration all the current and voltage harmonics, where as the habitual reactive power consider just the fundamentals of current and voltage.

From equations (3.4) and (3.5) the instantaneous active and reactive power can be given in matrix form by:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} u_\propto & u_\beta \\ -u_\beta & u_\alpha \end{bmatrix} \begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} \tag{3.6}$$

In general, each one of the active and reactive instantaneous power contains a direct component and an alternating component. The direct component of each presents the power of the fundamentals of current and voltage. The alternating term is the power of the harmonics of currents and voltages.

In order to separate the harmonics from the fundamentals of the load currents, it is enough to separate the direct term of the instantaneous power from the alternating one. A Low Pass Filter (LPF) with feed-forward effect can be used to accomplish this task. Fig. 4.2 shows the principle of this extraction filter.

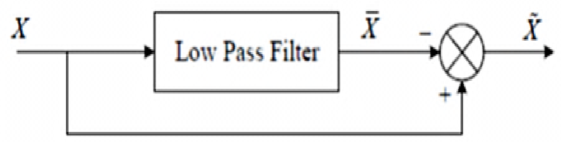

Fig. 4.2 Diagram of the Low Pass Filter with Feed-Forward.

After the separation of the direct and alternating terms of instantaneous power, the harmonic components of the load currents can be given using the inverse of equation (3.6) which gives:

$$\begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} = \frac{1}{v_{s\propto}^2 + v_{s\beta}^2} \begin{bmatrix} v_{s\propto} & -v_{s\beta} \\ v_{s\beta} & v_{s\alpha} \end{bmatrix} \begin{bmatrix} \tilde{p}_l \\ \tilde{q}_l \end{bmatrix} \tag{3.7}$$

Where, the "$\sim$ "sign points to the alternating.

The APF reference current can be then given by:

$$\begin{bmatrix} i_{fa}^* \\ i_{fb}^* \\ i_{fc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \tilde{i}_{l\alpha} \\ \tilde{i}_{l\beta} \end{bmatrix} \tag{3.8}$$

Fig. 3.3 presents the principle of the active and reactive instantaneous power.

This method offers the advantage of the possibility of harmonic compensation and/or reactive power compensation. In the case of reactive power compensation it is enough to send the reactive power q(t) directly to the reference current calculation bloc without the use of any extraction filter.

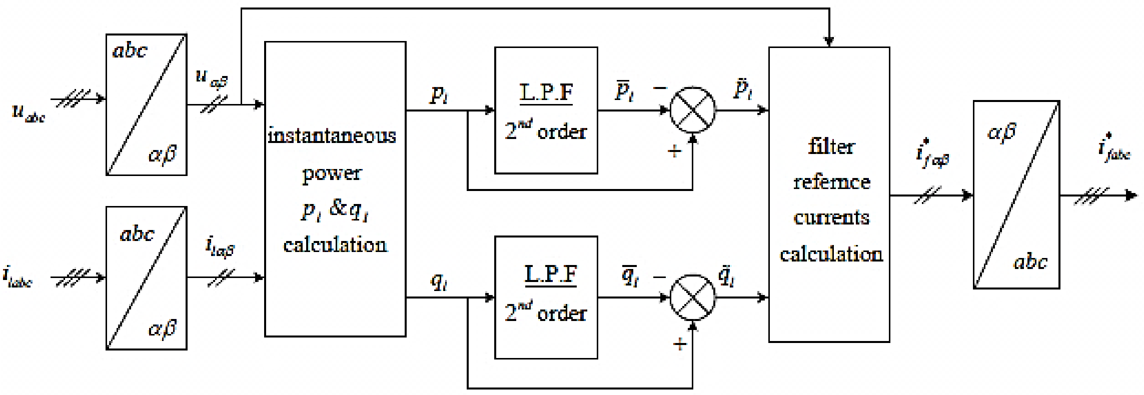

Fig. 4.3 Principle of Instantaneous Active and Reactive Power Theory.

4.3 Voltage Source Inverter

Voltage source inverters (VSI) are one of the most important applications of power electronics. The main purpose of these devices is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable. The important development of VSI is a result, from the one hand to the development of fast, controllable, powerful, and robust semi-conductors, from the other hand to the use of the so-called pulse width modulation (PWM) techniques. In the high power applications, the three level VSIs are the most adopted in comparison with two levels ones. Because the THD of the output voltage and current of the three levels VSI is clearly lower.

The standard three-phase VSI topology is shown in Fig. 4.4. It is composed of three legs with current reversible switches, controlled for the open and close. These switches are realized by controlled switches (GTO or IGBT) with anti-parallel diodes to allow the flow of the free-wheeling currents.

The switches of any leg of the inverter (T1 and T4, T2 and T5, T3 and T6) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity.

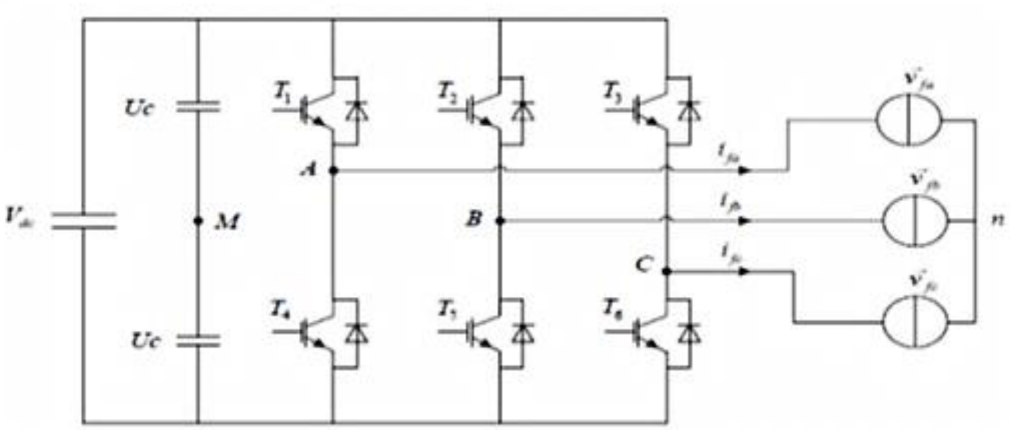

Fig. 4.4 Three-phase Two Levels VSI Topology

4.3.1 Modeling of Voltage Source Inverter

The output of the VSI which is shown in Fig. 4.4 can take two levels of voltage ($+V_{dc}$, $- V_{dc}$) dependent on the dc source voltage and the switches states. Actually, the control of the two switches on the same leg is complementary: the conduction of one of them implies the blocking of the other.

The state of each one of the switches is defined by the control signals (S_a, S_b and S_c) as follow:

$$S_a = \begin{cases} 1 \; if \; T_1 close \; , T_4 open \\ 0 \; if \; T_1 open \; , T_4 close \end{cases}$$

$$S_b = \begin{cases} 1 \; if \; T_2 close \; , T_5 open \\ 0 \; if \; T_2 open \; , T_5 close \end{cases}$$

$$S_c = \begin{cases} 1 \; if \; T_3 close \;, T_6 open \\ 0 \; if \; T_3 open \;, T_6 close \end{cases}$$

4.3.2 Modeling of Active Power Filter

The connection of the shunt active power filter to the point of common coupling of the grid is done mostly by the mean of a RL low pass filter as shown in Fig. 4.1. The voltage equation for each phase can be given by:

$$v_{sk} = v_{fk} - v_{L_{fk}} - v_{R_{fk}}$$

$$v_{fk} - L_f \frac{di_{fk}}{dt} - R_f i_{fk} \text{ , k=a,b,c} \tag{3.9}$$

The three phase equations are then given by:

$$L_f \frac{d}{dt} \begin{bmatrix} i_{fa} \\ i_{fb} \\ i_{fc} \end{bmatrix} = -R_f \begin{bmatrix} i_{fa} \\ i_{fb} \\ i_{fc} \end{bmatrix} + \begin{bmatrix} v_{fa} \\ v_{fb} \\ v_{fc} \end{bmatrix} - \begin{bmatrix} s_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \tag{3.10}$$

And for the dc side:

$$C_{dc}. \frac{dV_{dc}}{dt} = S_a i_{fa} + S_b i_b + S_c i_f \tag{3.11}$$

The equation system defining the SAPF in the three phase frame is then given by:

$$\begin{cases} L_f \frac{di_{fa}}{dt} = -R_f i_{fa} + v_{fa} - v_{sa} \\ L_f \frac{di_{fb}}{dt} = -R_f i_{fb} + v_{fb} - v_{sb} \\ L_f \frac{di_{fc}}{dt} = -R_f i_{fc} + v_{fc} - v_{sc} \end{cases} \tag{3.12}$$

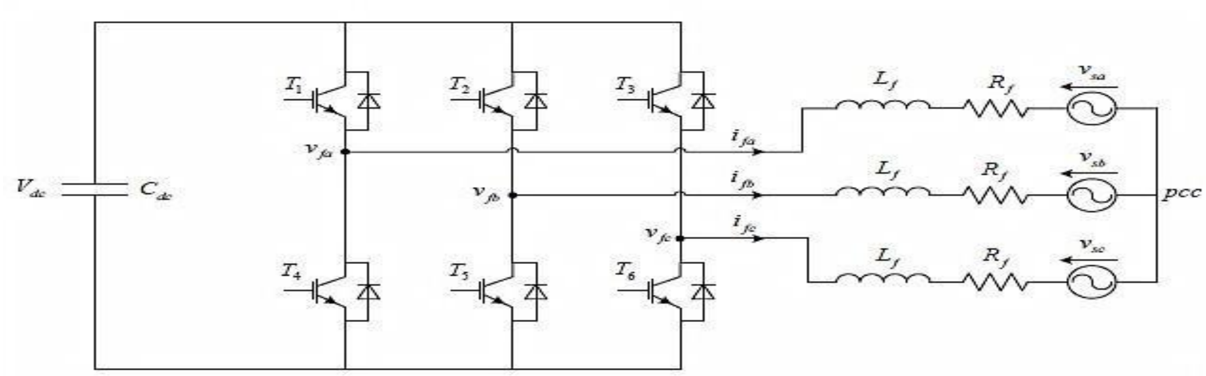

Fig.4.5 SAPF Connection to the PCC

4.3.3 Control Methods of VSI

The aim of the control of the VSC is to force the output currents of the inverter to follow their predefined reference currents. The main principle is based on the comparison between the actual current of the filter with the reference currents generated by the different extraction methods. In the next section, we are going to discuss some different methods in VSC control.

4.3.3.1 Hysteresis Control Method

The current control strategy plays an important role in fast response current controlled inverters such as the active power filters. The hysteresis current control method is the most commonly proposed control method in time domain. This method provides instantaneous current corrective response, good accuracy and unconditioned stability to the system. Besides that, this technique is said to be the most suitable solution for current controlled inverters.
Hysteresis current control is a method of controlling a voltage source inverter so that an output current is generated which follows a reference current waveform.

The basic structure of PWM voltage source inverter with hysteresis controller is shown in Fig. 4.6. The hysteresis control strategy aims to keep the controlled current inside a defined rejoin around the desired reference current. The status of the switches is determined according to the error. When the current is increasing and the error exceeds a certain positive value, the status of the switches changes and the current begins to decrease until the error reaches a certain negative value, then the switches status changes again.

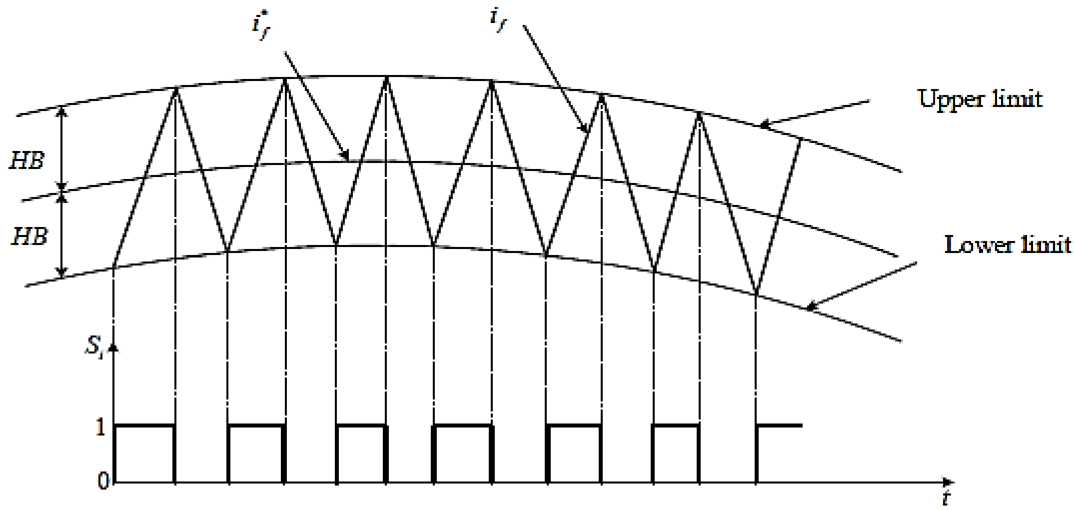

Fig. 4.6 Hysteresis Control Principle

In the fix hysteresis band control of the VSI, the switching frequency is a function of the derivative of the output current. This one depends on the value of the inductance of the decoupling filter and the voltage drop around it. It is important to notice that the coupling filter affects the switching frequency and the dynamic behavior of the active filter. The simple implementation procedure is the main advantage of this control method. However, the variable switching frequency is the major draw-back of this method. This variable frequency affects mainly the function of power electronic elements which can't support high switching frequency in high power applications. In order to solve the problem of variable switching frequency, a new hysteresis control strategies like "modulated hysteresis control" and "variable hysteresis band" were proposed. In the modulated hysteresis control it is difficult to define the hysteresis band width. Over more, the fix switching frequency achieved using this method affects the rapidity obtained by hysteresis control.

4.3.3.2 Sinusoidal Pulse Width Modulation (SPWM) Control

The control techniques based on the PWM solve the problem of switching frequency of the VSI. They use a fix switching frequency which makes it easier to cancel the switching harmonics. The PWM can be realized using different techniques such as carrier based PWM, PWM with harmonics minimization, and space vector PWM. The carrier PWM can be natural PWM, symmetric PWM, and asymmetric PWM.

The most simple and well known PWM technique is the sinusoidal PWM. This technique uses a controller which determines the voltage reference of the inverter from the error between the measured current and its reference. This reference voltage is then compared with a triangular carrier signal (with high frequency defining the switching frequency). The output of this comparison gives the switching function of the VSI. The choice of the ratio between the frequency of the reference signal and the frequency of the carrier signal is very important in the case of symmetric and periodic reference. As a consequence, in the case of sinusoidal reference, the ratio between the two frequencies must be integer to synchronize the carrier with the reference. Over more, it is preferable that the carrier frequency be odd to conserve the reference symmetry. In all cases this ratio must be sufficiently high to ensure the fast switching and to take the switching harmonics away from the fundamental produced by the inverter.

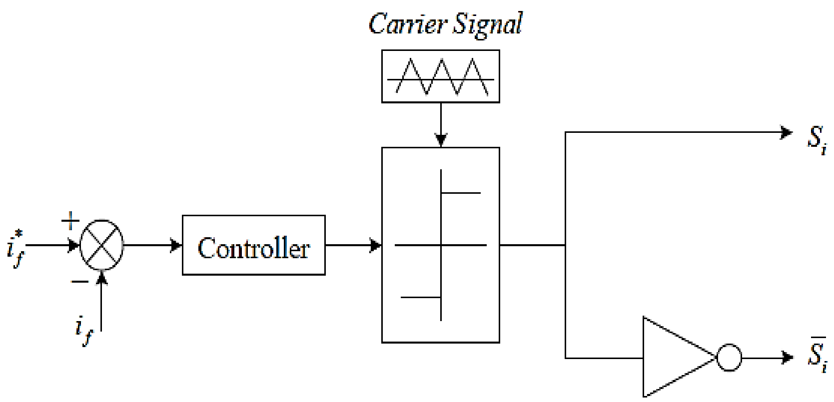

Fig. 4.7 The Principle of Sinusoidal PWM Control Method

Recently, new control techniques called space vector PWM were implemented. The difference between this technique and the sinusoidal technique is that it doesn’t use carrier signal to define switching orders.

4.3.3.3 Space Vector PWM Control (SVPWM)

Space vector modulation technique was first introduced by German researchers in the mid of 1980s. This technique showed several advantages over the traditional PWM technique and has been proven to inherently generate superior PWM waveforms. By implementing the SVM technique, the number of switching is reduced to about 30% at the same carrier frequency of the sinusoidal pulse width modulation (SPWM) method. It offers better DC bus utilizations with lower THD in the AC current and reduces of switching losses too. The maximum modulation index for the SPWM method is 0.785 with the sinusoidal waveform between the phase and the neutral current of the system. However, the modulation index can be increased to 0.907 for the SVPWM.

The basic principle of the SVM technique is that it treats the inverter as a whole unit, which is different when compared to PWM technique. This technique is based on the decomposition of a reference voltage vector into voltage vector realizable on a six pulse inverter.

The SVPWM technique is widely used in inverter and rectifier controls. Compared to the sinusoidal pulse width modulation (SPWM), SVPWM is more suitable for digital implementation and can increase the obtainable maximum output voltage with maximum line voltage approaching 70.7% of the DC link voltage (compared to SPWM's 61.2%) in the linear modulation range. Moreover, it can obtain a better voltage total harmonic distortion factor. There are different algorithms for using SVPWM to modulate the inverter or rectifier. Many SVPWM schemes have been investigated extensively in literatures. The goal in each modulation strategy is to lower the switching losses, maximize bus utilization, reduce harmonic content, and still achieve precise control.

In the SVPWM scheme, the 3-phase output voltage is represented by a reference vector which rotates at an angular speed of $\omega = 2\pi f$. The task of SVM is to use the combinations of switching states to approximate the reference vector. To approximate the locus of this vector, the eight possible switching states of the inverter are represented as 2 null vectors and 6 active vectors.

4.4 Control of the Active Power Filter

The researchers are always at the point of the research to ameliorate the control methods of the SAPF to achieve better results either from the point of view of better perturbation extraction methods, the amelioration of the dynamic regimes, decreasing the value of the THD,…etc., or the development of new control methods to ameliorate the performance of the APF with the different non-linear loads. There are principally two methods for the compensation of the harmonic currents dependent on the measured current.

4.4.1 Direct Control Method

In this method the load currents are measured and the harmonic currents are extracted from the load currents. Fig. 3.8 shows the diagram of the direct control method. Using this method, the SAPF injects the harmonic currents without any information about the grid currents. All the errors in the system like the parameters uncertainty, the measurement or control errors will appear in the grid current as unfiltered harmonic contents. The main advantage of this method is the system stability. However, this method needs an expanded control algorithm with large number of sensors.

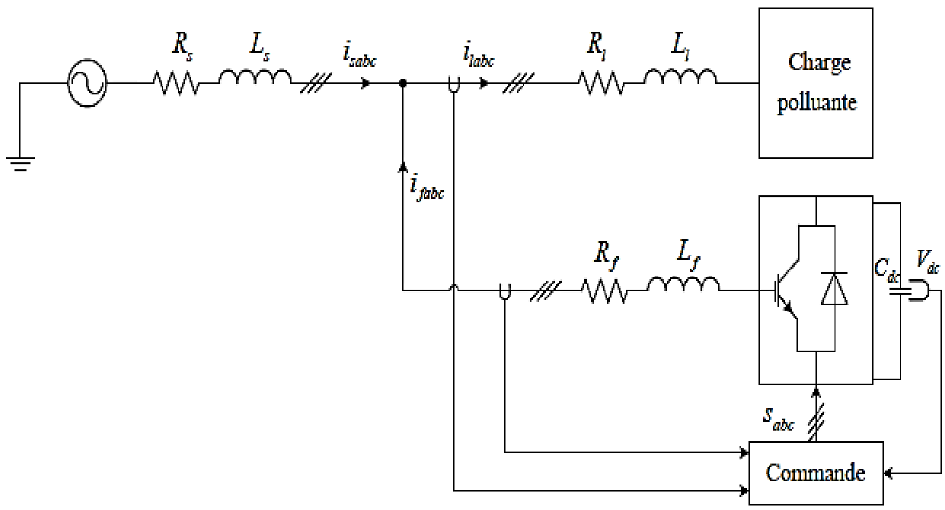

Fig. 4.8 Direct Control Method Diagram

4.4.2 Indirect Control Method

This method based on the measurement of the source currents, and then to impose the sinusoidal form on these currents. The control algorithm is less complicated and needs fewer sensors than the direct control. Fig. 3.9 shows the diagram of the indirect control method of the SAPF.

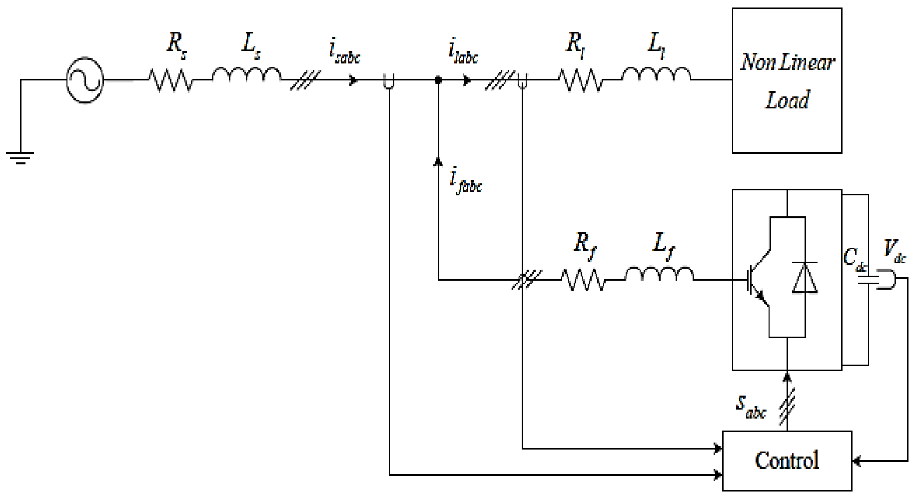

Fig. 4.9 Indirect Control Method Diagram

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

4.5 Development Environment

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

4.6 The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

4.7 The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

4.8 Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two- dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

4.9 The MATLAB Application Program Interface (API)

This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT- files.

4.10 MATLAB Documentation

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task- oriented and reference information about

MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

4.11 Three phase source block

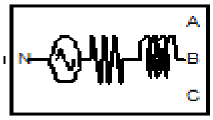

Fig 4.10 Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

4.12 VI measurement block

The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents

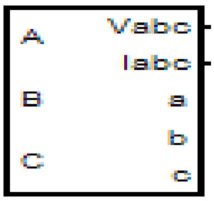

Fig .4.11 Three Phase V-I Measurement

4.13 Scope

Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes. The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation

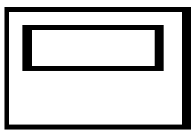

Fig . 4.12 Scope

4.14 Three-Phase Series RLC Load

The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

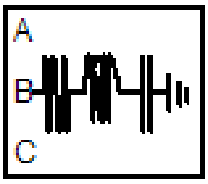

Fig . 4.13 Three-Phase Series RLC Load

4.15 Three-Phase Breaker block

The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.

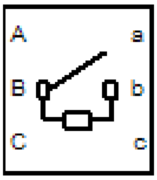

Fig.4.14 Three-Phase Breaker Block

4.16 Integrator Library:

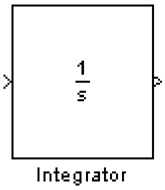

Fig.4.15 Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

4.17 Breaker

Implement circuit breaker opening at current zero crossing.

Library: Elements

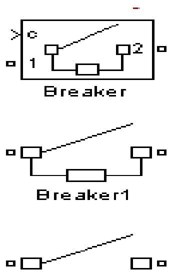

Fig.4.16 Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it).

When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

4.18 Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources

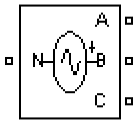

Fig.4.17 Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

4.19 Trigonometric Function

Specified trigonometric function on input

Library: Math Operations

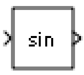

Fig.4.18 Trigonometric Function

Purpose: The Trigonometric Function block performs common trigonometric functions

4.20 Three-Phase Transformer (Two Windings)

Implement three-phase transformer with configurable winding connections Library:

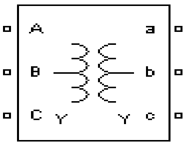

Fig.4.19 Three Phase Transformer

Purpose:

The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

4.21 Three-Phase Transformer 12 Terminals

Implement three single-phase, two-winding transformers where all terminals are accessible

Library: Elements

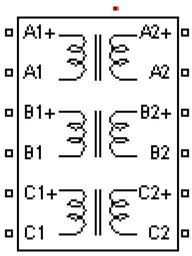

Fig.4.20 Two winding Transformer

Purpose: The Three-Phase Transformer 12 Terminals block implements three single- phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

4.22 IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode Library: **Power**

Electronics

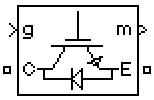

Fig. 4.21 IGBT

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

CHAPTER 5

IMPLEMENTATION OF PROJECT

5.1 INTRODUCTION

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real- world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.

Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor. The model depicts the time-dependent mathematical relationships among the system's inputs, states, and outputs. Then, we use Simulink to simulate the behavior of the system over a specified time span. Simulink uses information that you entered into the model to perform the simulation.

5.2 BLOCK DIAGRAM

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block). The lines represent connections of block inputs to block outputs. Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time. A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate. A block comprises one or more of the following:

1) A set of inputs,
2) A set of states, and
3) A set of outputs.

A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance. Continuous Versus discrete Blocks Simulink's standard block set includes continuous blocks and discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only at integral multiples of a fixed interval called the block's sample time. Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, depending on whether they are driven by continuous or discrete blocks. A block that can be either discrete or continuous is said to have an implicit sample rate. The implicit sample time is continuous if any of the block's inputs are continuous. The implicit sample time is equal to the shortest input sample time if all the input sample times are integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times. Simulink can optionally color code a

Block diagram to indicate the sample times of the blocks it contains, e.g., black (continuous), magenta (constant), yellow (hybrid), red (fastest discrete), and so on. The block contains block name, icon, and block library that contain the block, the purpose of the block

5.3 SIMULINK BLOCK LIBRARIES

Simulink organizes its blocks into block libraries according to their behavior.

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-time components.
4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.
6) The Functions & Tables library contains blocks that describe general functions and table look-up

operations.

7) The Nonlinear library contains blocks that describe nonlinear functions.
8) The Signal & Systems library contains blocks that allow multiplexing and demultiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types of subsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

5.4 SUB SYSTEMS

Simulink allows to model a complex system as a set of interconnected subsystems each of which is represented by a block diagram. We create a subsystem using Simulink's Subsystem block and the Simulink model editor. We can embed subsystems with subsystems to any depth to create hierarchical models. We can create conditionally executed subsystems that are executed only when a transition occurs on a triggering or enabling input.

5.4 SOLVERS

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model. The process of computing the successive states of a system from its model is known as solving the model. No single method of solving a model suffices for all systems. Accordingly, Simulink provides a set of programs, known as solvers, that each embody a particular approach to solving a model. The Simulation Parameters dialog box allows us to choose the solver most suitable for our model.

5.5 Fixed-Step and Variable-Step Solvers

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size. Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly and increasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time, required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

5.6 Continuous and Discrete Solvers

Continuous solvers use numerical integration to compute a model's continuous states at the current time step from the states at previous time steps and the state derivatives. Continuous solvers rely on the model's blocks to compute the values of the model's discrete states at each time step. Mathematicians have developed a wide variety of numerical integration techniques for solving the ordinary differential equations (ODEs) that represent the continuous states of dynamic systems. Simulink provides an extensive set of fixed-step and variable-step continuous solvers, each implementing a specific ODE solution method. Some continuous solvers subdivide the simulation time span into major and minor steps, where a minor time step represents a subdivision of the major time step.

The solver produces a result at each major time step. It use results at the minor time steps to improve the accuracy of the result at the major time step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time-step for a model and nothing else. They do not compute continuous states and they rely on the model's blocks to update the model's discrete states. We can use a continuous solver, but not a discrete solver, to solve a model that contains both continuous and discrete states. This is because a discrete solver does not handle continuous states. If you select a discrete solver for a continuous model, Simulink disregards your selection and uses a continuous solver instead when solving the model.

Simulink provides two discrete solvers, a fixed-step discrete solver and a variable- step discrete solver. The fixed-step solver by default chooses a step size and hence simulation rate fast enough to track state changes in the fastest block in our model. The variable-step solver adjusts the simulation step size to keep pace with the actual rate of discrete state changes in our model. This can avoid unnecessary steps and hence shorten simulation time for multirate models.

5.7 MODEL EXECUTION PHASE

In the simulation model execution phase, Simulink successively computes the states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps. The length of time between steps is called the step size. The step size depends on the type of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states have discontinuities (Zero Crossing Detection). At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated. At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

1) Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and states to the output function as it may require these arguments to compute the block's output. Simulink updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.
2) Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's continuous states by numerically integrating the time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.
3) Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.
4) Computes the time for the next time step.

Simulink repeats steps 1 through 4 until the simulation stop time is reached.

5.8 Block Sorting Rules

Simulink uses the following basic update rules to sort the blocks:

1) Each block must be updated before any of the direct-feed through blocks that it drives. This rule ensures that the inputs to direct-feed through blocks will be valid when they are updated.
2) Non direct-feed through blocks can be updated in any order as long as they are updated before any direct-feed through blocks that they drive. This rule can be met by putting all non direct-feed through blocks at the head of the update list in any order. It thus allows Simulink to ignore non direct-feed through blocks during the sorting process.

The result of applying these rules is an update list in which non direct-feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct-feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output. However, an algebraic loop can represent a set of simultaneous algebraic equations (hence the name) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step. Accordingly, Simulink assumes that loops involving direct-feed through blocks do, in fact, represent a solvable set of algebraic equations and attempts to solve them each time the block is updated during a simulation.

5.9 DETERMINING BLOCK UPDATE ORDER

During a simulation, Simulink updates the states and outputs of a model's blocks once per time step. The order in which the blocks are updated is therefore critical to the validity of the results. In particular, if a block's outputs are a function of its inputs at the current time step, the block must be updated after the blocks that drive its inputs. Otherwise, the block's outputs will be invalid. The order in which blocks are stored in a model file is not necessarily the order in which they need to be updated during a simulation. Consequently, Simulink sorts the blocks into the correct order during the model initialization phase.

In order to create a valid update ordering, Simulink categorizes blocks according to the relationship of outputs to inputs. Blocks whose current outputs depend on their current inputs are called direct feed through blocks. All other blocks are called non direct-feed through blocks. Examples of direct-feed through blocks include the Gain, Product, and Sum blocks. Examples of non direct-feed through blocks include the Integrator block (its output is a function purely of its state), the Constant block (it does not have an input), and the Memory block (its output is dependent on its input in the previous time step). Simulink allows you to assign update priorities to blocks. Simulink updates higher priority blocks before lower priority blocks. Simulink honors the priorities only if they are consistent with its block sorting rules.

5.10 Simulation Result Analysis

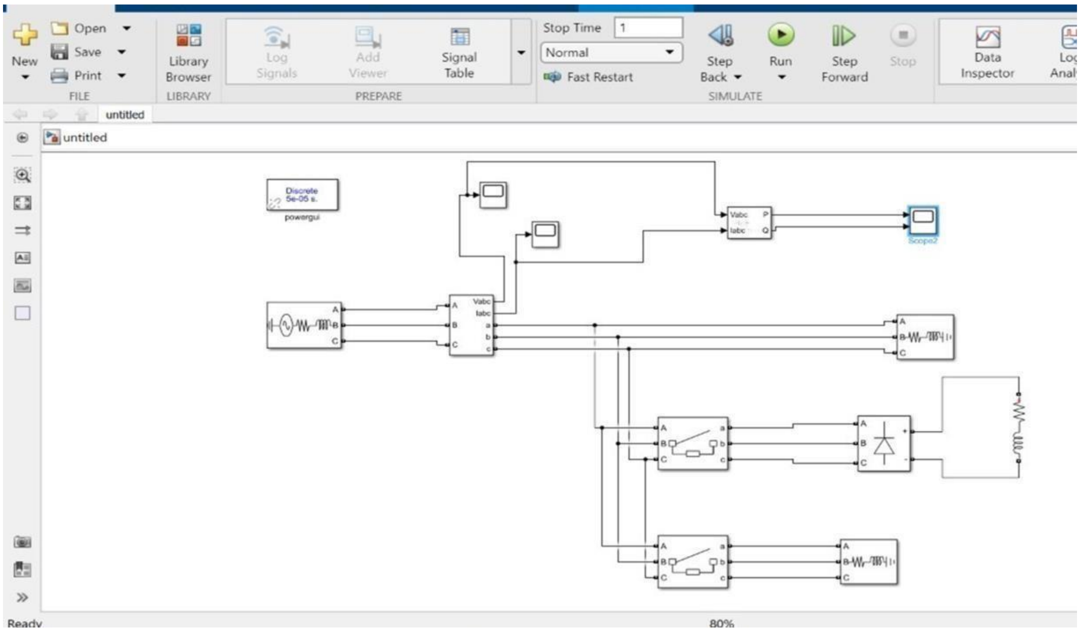

Fig 5.1 proposed circuit with out upqc

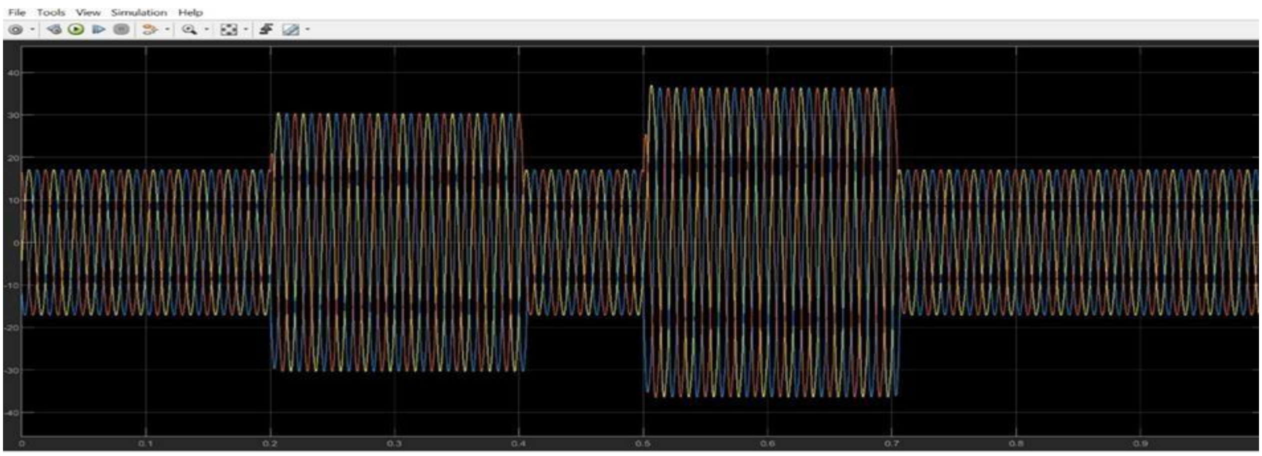

Fig 5.2 Output voltage without UPQC

The system without UPQC experiences a voltage disturbance when a LLLG fault occurred this effects the system power quality.

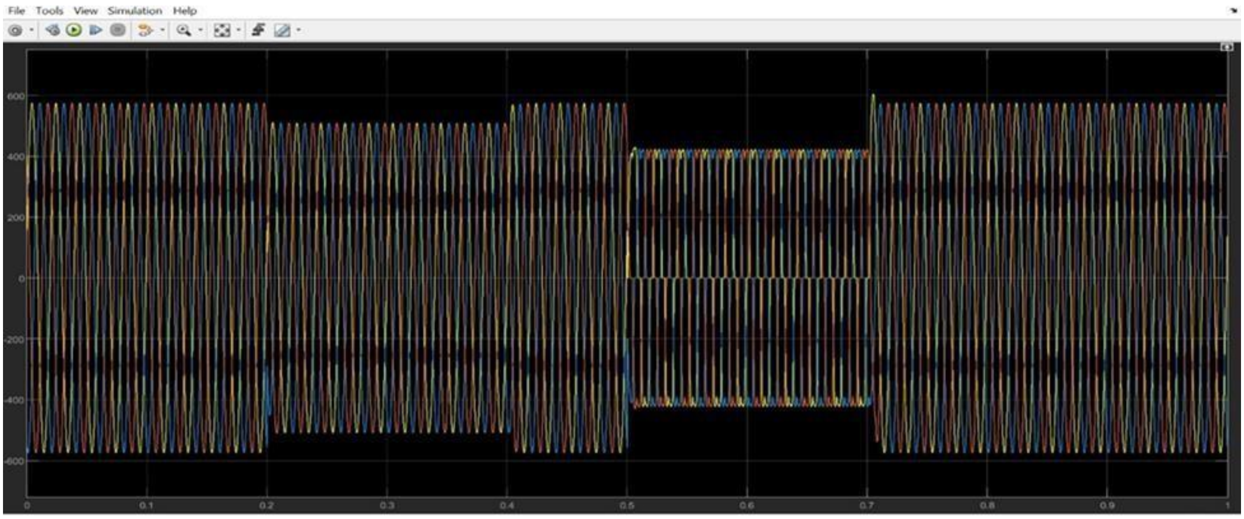

Fig 5.3 Output current waveform

A high current is observed under LLLG fault condition to the circuit with PI controller. This increases the system loses and effects the quality of power supply.

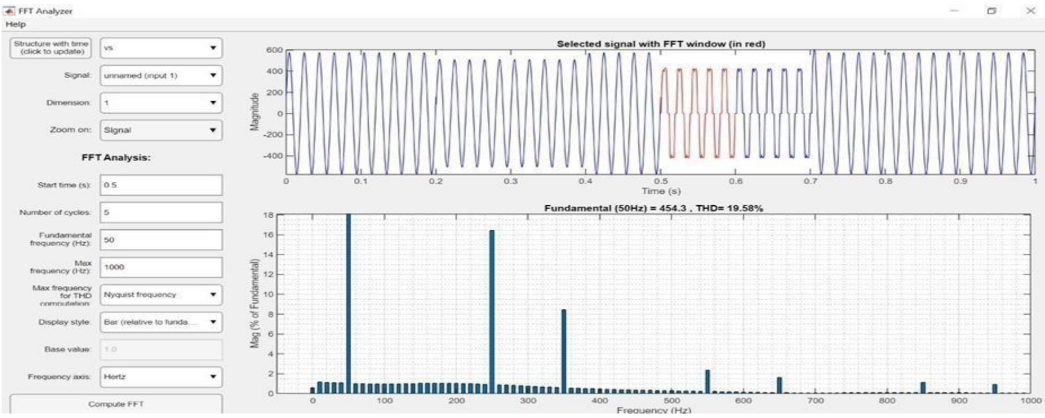

Fig 5.4 Total Harmonic Disortion

The above graph clearly describes the THD of the system with PI controller. It is observed a total harmonic distortion of 19.42%.

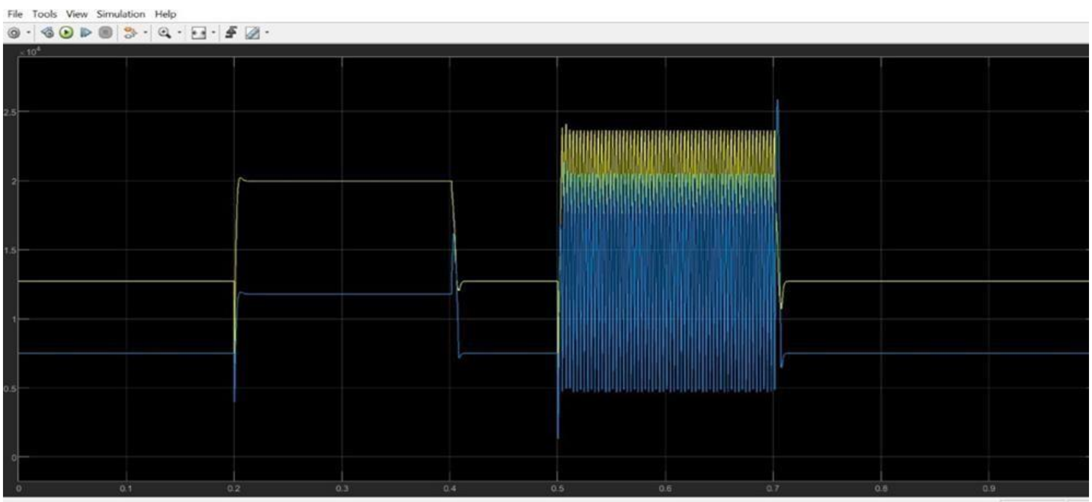

Fig 5.5 Active and Reactive Power Variations

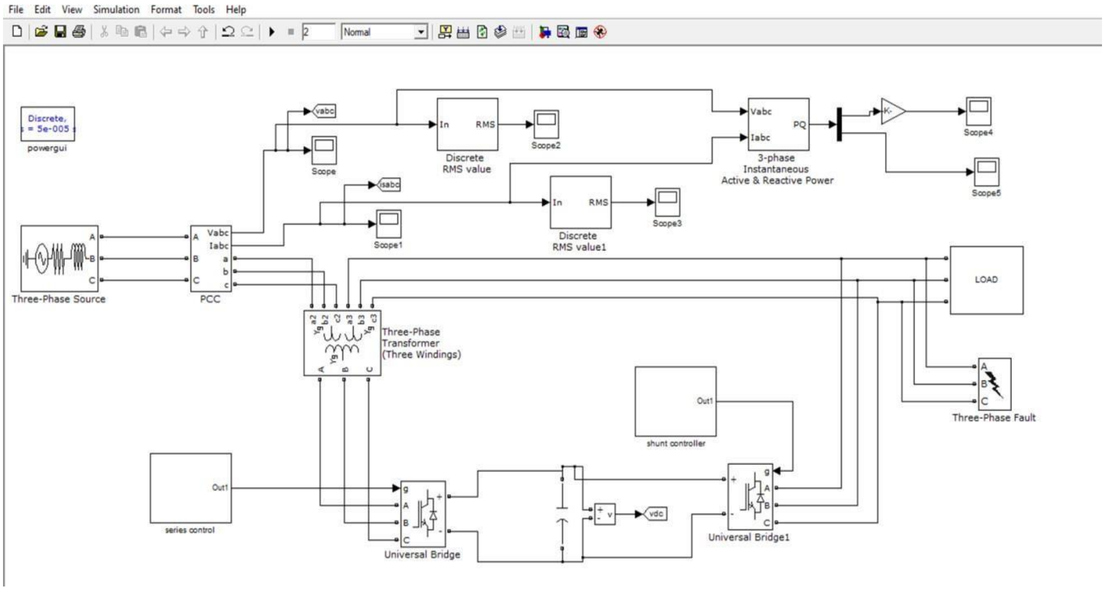

Fig 5.6 Simulation circuit with UPQC

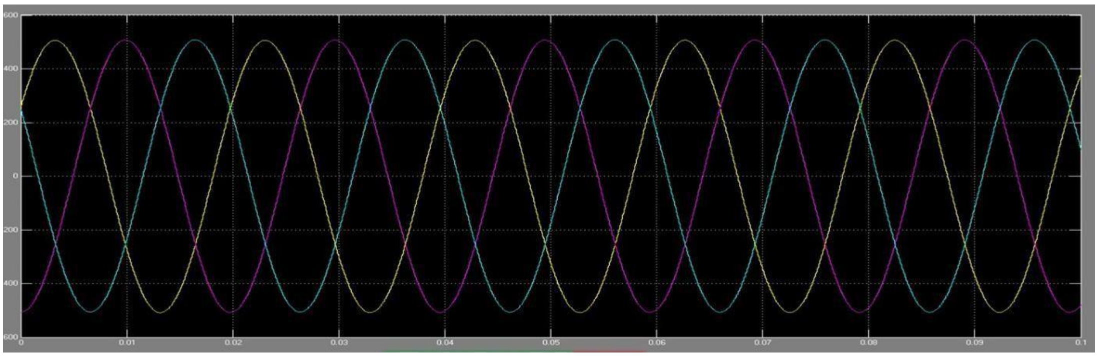

Fig 5.7 Output voltage waveform

The system with UPQC has generated a stabilized output voltage waveform without any distortions maintained during the LLLG fault condition

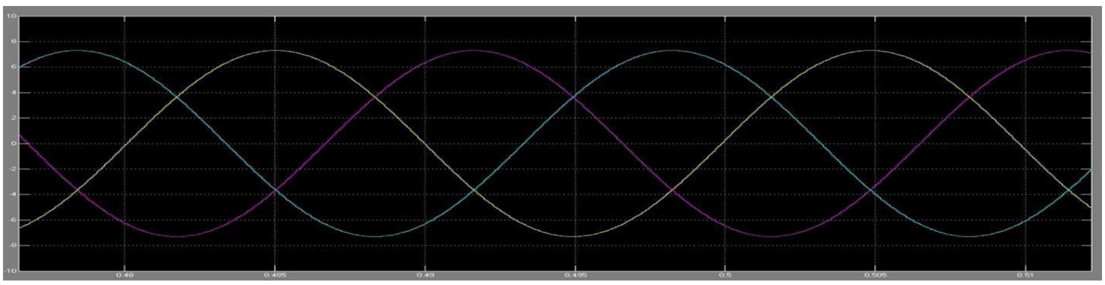

Fig 5.8 Output current waveform

The current waveform is still have some distortions under LLLG fault condition with UPQC Controller. This effects the system parameters.

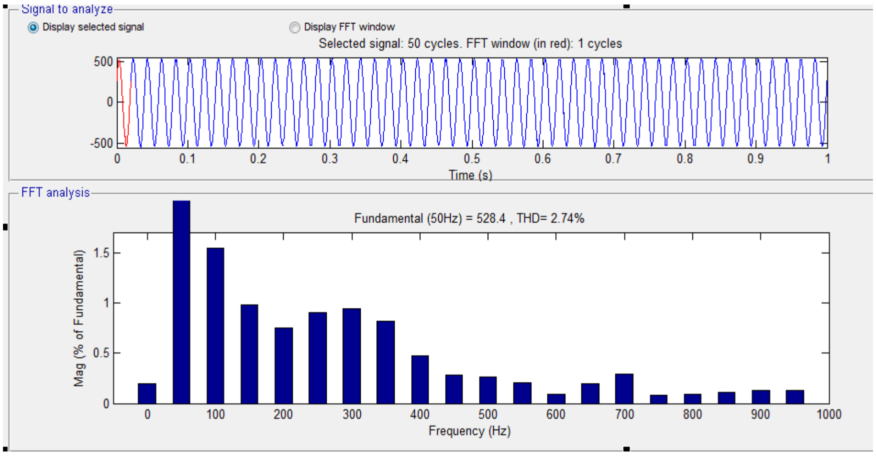

Fig 5.9 THD with UPQC

The THD of the system with UPQC controller has reduced the THD of 19.42% to 2.74%. this clearly shows that UPQC has achieved high efficiency when compared to the PI controller.

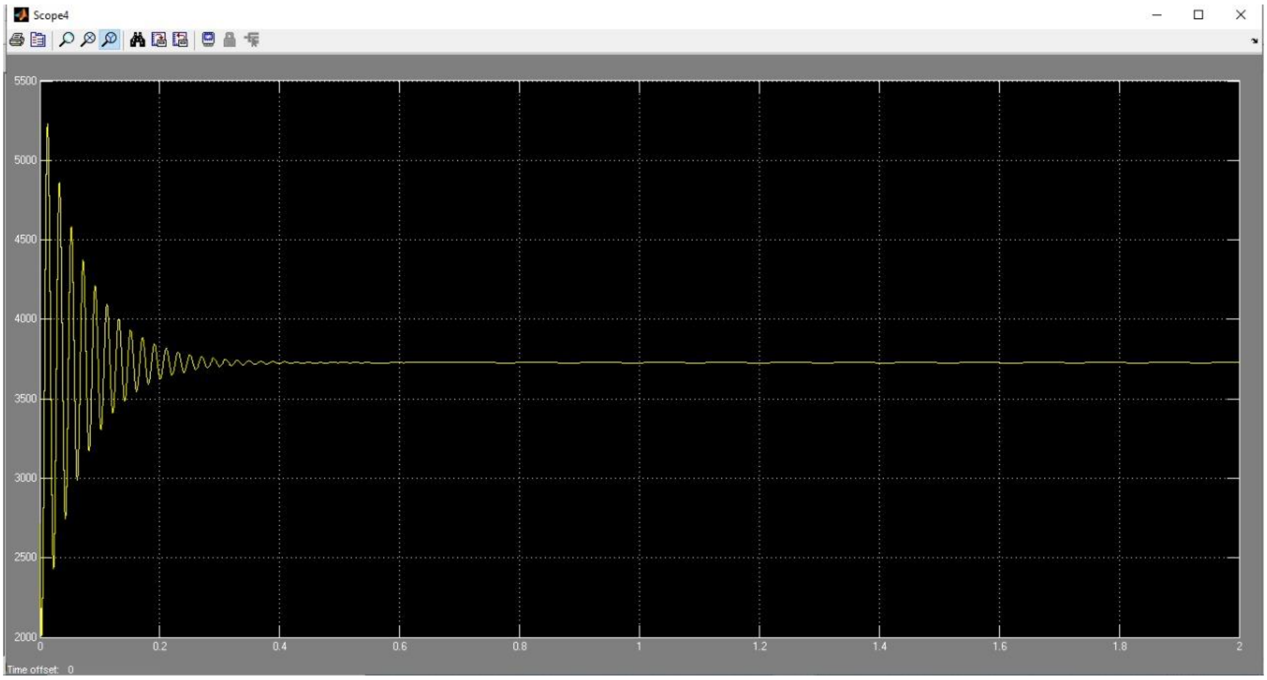

Fig 5.10 Active and Reactive Power Variations

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

CONCLUSION

A noticeable trend in distribution systems is the emergence of distributed harmonic producing loads. These loads typically have comparable sizes and are distributed all over an electric network. There is a need to develop new techniques to assess harmonic distortions for systems with distributred harmonic sources. The objective of the project is to minimize the power quality problems with the implementation of power quality enhancement device UPQC. This device has the capacity to improve the power quality at the point of installation. Without UPQC the system voltage and currents are unbalanced undar fault condition with THD of 6.02%. When we applied UPQC with PI controller the vooutput voltage is balanced and still some distortions observed in current waveforms under fault conditions the THD isss reduced to 2.74%. By using the proposed Hybrid controller with UPQC the system output voltage and currents are balanced without any distortion and the THD is reduced finally to 0.08%. Hence the analysis proves that the proposed Hybrid controller with UPQC achieved better results when compared to the existing models.

FUTURE SCOPE

Now a day's power quality has become the most essential factor for both power suppliers and consumers due to the degradation of the electric power energy market. Efforts are being made to improve power quality. Today in this modern world power quality has become a great issue. As many industries and for domestics use we need a voltage and current free from all types of harmonics and unbalances. Due to problems in power quality there is development of many methods to improve power quality by using active power filters. The concept of power was introduced by the N.G. Hingrani. Power electronics devices consists of a diode, thyristors, IGBT, diodes. The active power filters are used to remove harmonics from current of load side and make supply current completely sinusoidal, and it also mitigate the problems of supply voltage imbalance i.e. voltage rise/dip and make voltages at load side balanced of equal magnitude. The active power filters can be combined together and made to remove both problems due to voltage and current harmonics. There are wide range of controlling techniques for active power filters The reactive power theory was used to do simulation of three phase three wire line which is valid for both of the transient and steady state. The physical meaning of instantaneous reactive power theory was described in . The instantaneous reactive power theory with the non-linear loads is described in . The DVR model is discussed in for removal of all kinds of voltage related problems. Here the operating system consist of PLL and Park's transformation is used for simulation. In three phase simulation of series active power filter is done for removal of voltage unbalances in supply side and make load voltage balanced and regulated. In chapter the operation of DSTATCOM is explained. In the operation of three phase four wire shunt APF is explained which is used to suppress load current harmonics which is due to non- linear loads. As the power quality is the most important factor so to get improved power quality and removal of all type of harmonics from voltage and current we study UPQC which is a very versatile device and can be used for both mitigate the problems due to current harmonics and voltage disturbances. The voltage source inverter active filters are used for removal of power quality problems. The shunt active power filer is used to remove all the problems related to current harmonics and reactive power compensation so that the power quality will improve.

PUBLICATIONS

We have submitted our project to the international conference on "Recent Developments in Power Engineering (ICRDPE-21)" conducted on 9^{th} & 10^{th} July 2021.

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A

PROJECT REPORT

On

SMART GRID POWER QUALITY IMPROVEMENT USING MODIFIED UPQC

Submitted by

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2)Mr. G.NAGARAJU (18K85A0213)

3)Mr. P.SAI PAVAN (18K85A0219)

4)Mr. R.ASHISH (18K85A0220)

in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

Mr. K.V.GOVARDHAN RAO M.TECH.,(Ph.D)

ASSISTANT PROFESSOR

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ST.MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled **SMART GRID POWER QUALITY IMPROVEMENT USING MODIFIED UPQC,** is being submitted by **1. N.Pallavi (17K81A0233), 2. G.Nagaraju (18K85A0213), 3. P.Sai Pavan (18K85A0219), 4. R.Ashish (18K85A0220)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY** in Electrical and Electronics Engineering is a record of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

	Head of the Department
Mr.K.V.Govardhan Rao	**Dr.N.Ramchandra**
Department of EEE	Department of EEE

Internal Examiner External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in Department of Electrical and Electronics Engineering, session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled **SMART GRID POWER QUALITY IMPROVEMENT USING MODIFIED UPQC** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

The Smart Grid system typically deals with different issues involving security and Power Quality (PQ) improvement. With massive usage of power electronic devices and growth of nonlinear loads, harmonics are inserted into the system. So, it is important to maintain the quality of the power for the efficient functioning of the end user equipment. The well-known Flexible AC Transmission System (FACTS) devices like Unified Power Quality Conditioners (UPQC) are usually employed to resolve the issues related to voltage sag, swell, flicker, PQ, and neutral current reduction of distribution systems. UPQC is a custom powered device which is considered as the grouping of DVR and D-STATCOM which performs series, shunt compensating and phase shifting at the same time. An UPQC itself inserts harmonics into the system that affects the system stability for sensitive loads. This paper describes biogeography based optimization (BBO) with harmonics elimination techniques for modified UPQC connected with Smart Grid. At fault condition UPQC mitigate the fault with simultaneous or individual operation of series-shunt converters. The excitation of Modified UPQC converters with DC link capacitor are obtained from PV (Photo-Voltaic) panel.

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LIST OF OUTPUT SCREENS

NOMENCLATURE

UPQC	:	Unified Power Quality Conditioner
DVR	:	Dynamic Voltage Restorer
D-STATCOM	:	Distribution Static Compensator
PQ	:	Power Quality
THD	:	Total Harmonic Distortion
APF	:	Active Power Filter
VSI	:	Voltage Source Inverter
PWM	:	Pulse Width Modulation
PV	:	Photo Voltaic
FACTS	:	Flexible AC Transmission Systems
IEEE	:	Institute of Electrical & Electronics Engineering

CHAPTER 1
INTRODUCTION

Electric systems and grids are complex dynamic systems. These systems suffer usually from unexpected or sudden changes of the currents and voltages. These changes are due mainly to the different types of linear and non-linear loads to which they are connected. In addition, to different types of accidents which can intervener into the grid. With the increasing use of power semiconductors in the most of industrial and domestic procedures, the electric grids are polluted with different harmonic currents and voltages. These harmonics affect the normal function of the most of the grid connected devices; in addition to considerable economic losses. Many classic and modern solutions have been proposed in the literary for the harmonic problems. In this chapter, the harmonic problem as one of the most common power quality problems will be presented. The different modern and traditional solutions will then be discussed.

1.1 DEFINITION OF POWER QUALITY:

Power quality is a term that means different things to different people. Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE1100 defines power quality as "The concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment." As appropriate as this description might seem, the limitation of power quality to "sensitive electronic equipment" might be subject to disagreement. Electrical equipment susceptible to power quality or more appropriately to lack of power quality would fall within a seemingly boundless domain. All electrical devices are prone to failure or malfunction when exposed to one or more power quality problems. The electrical device might be an electric motor, a transformer, a generator, a computer, a printer, communication equipment or a household appliance. All of these devices and others react adversely to power quality issues, depending on the severity of problems.

A simpler and perhaps more concise definition might state: "Power quality is a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy." This definition embraces two things that we demand from an electrical device: performance and life expectancy. Any power-related problem that compromises either attribute is a power quality concern.

Power quality can also be defined as a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy. Power distribution systems should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in power systems, especially the distribution systems have many nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the pure sinusoidal waveform is lost. This ends up producing many power quality problems.

1.2 POWER SYSTEMS DISTORTION AND PROBLEMS:

In power systems, different voltage and current problems can be faced. The main voltage problems can be summarized in short duration variations, voltage interruption, frequency variation, voltage dips and harmonics. Harmonics represent the main problem of currents of power systems.

1.2.1 Voltage Variation For Short Duration:

The short duration voltage variation is the result of the problems in the function of some systems or the start of many electric loads at the same time. The defaults can increase or decrease the amplitude of the voltage or even cancel it during a short period of time. The increase of voltage is a variation between 10-90% of the nominal voltage. It can hold from half of a period to 1 minute according to the IEEE 1159-1995. According to the same reference, the increase in voltage is defined when the amplitude of the voltage is about 110-180% of its nominal value.

1.2.2 Voltage Interruption:

The cutoff of the voltage happens when the load voltage decreases until less than 10% of its nominal value for a short period of time less than 1 minute. The voltage interruption can be the effect of defaults in the electrical system, defaults in the connected equipment’s or bad control systems. The main characteristic of the voltage interruption is the period over which it happens.

1.2.3 Frequency Variations:

In the normal conditions the frequency of the distribution grid must be within the interval 50±1 Hz. The variations of the frequency of the grid can appears to the clients who are using auxiliary electric source (solar system, thermal station…etc.). These variations are rare and happen in the case of exceptional conditions like the defaults in the turbines.

1.2.4 Unbalance in Three Phase Systems:

The three phase system is unbalanced when the currents and voltages are not identical in amplitude; or when the phase angle between each two phases is not 120°. In the ideal conditions, the three phase system is balanced with identical loads. In reality, the loads are not identical, in addition to the problems of the distribution grids which can interfere.

1.2.5 Voltage Dips:

The voltage dips are periodic perturbations. They appear as a natural effect of the switching of the transistors. They are due also to the start of big loads like motors. Lifts, lights, heaters…etc. this phenomena causes bad functioning of the protection equipment's.

1.3 HARMONICS:

Harmonics are described by IEEE as sinusoidal voltages or currents having frequencies that are integer multiples of the fundamental frequency at which the power system is designed to operate. This means that for a 60-Hz system, the harmonic frequencies are 120 Hz (2nd harmonic), 180 Hz (3rd harmonic) and so on. Harmonics combine with the fundamental voltage or current producing a non-sinusoidal shape, thus, a waveform distortion power quality problem. The non-sinusoidal shape corresponds to the sum of different sine waves with different magnitudes and phase angles, having frequencies that are multiples of the system frequency.

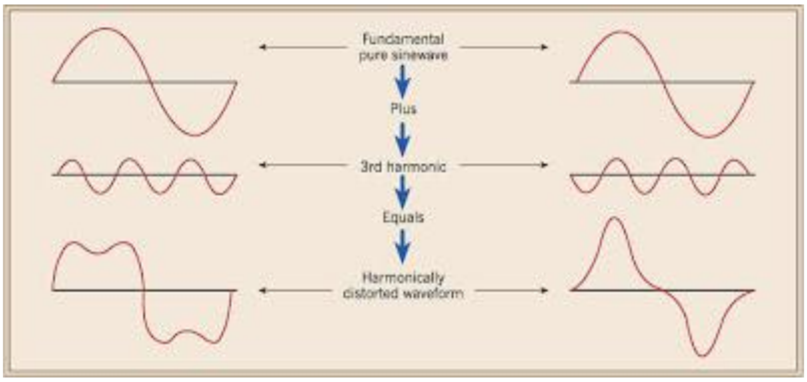

Fig. 1.1 Harmonic Waveform Distortion

Harmonic distortion levels can be characterized by the complete harmonic spectrum with magnitudes and phase angles of each individual harmonic component. It is also common to use the Total Harmonic Distortion (THD), as a measure of the effective value of harmonic distortion. It has become an increasing concern for many end-users and for the overall power system because of the growing application of power electronics equipment. Protection from high levels of harmonics includes isolation or modification of the source, phase multiplication, pulse width modulator (PWM) and application of passive or active harmonic filters.

Power systems are designed to operate at frequencies of 50 or 60 Hz. However, certain types of loads produces currents and voltages with frequencies that are integer multiples of the 50 or 60 Hz fundamental frequency. These frequencies components are a form of electrical pollution known as harmonic distortion.

There are two types of harmonics that can be encountered in a power system.

- Synchronous harmonics.
- Asynchronous harmonics.

Synchronous harmonics are sinusoids with frequencies which are multiples of the fundamental frequency. The multiplication factor is often referred to as the harmonic number. The synchronous harmonics can be subdivided into two categories.

- Sub-harmonics: when the harmonic frequency is less than the fundamental frequency.
- Super harmonics: when the harmonic frequency is more than the fundamental frequency.

Harmonics are familiar to the musicians as the overtones from an instrument. They are the integer multiples of the instrument’s fundamental or natural frequency that are produced by a series of standing waves of higher and higher order. Exactly the same thing happens in power circuits when non-linear loads create harmonic currents that are integer multiples of the supply fundamental frequency. The rapid growth of solid-state power electronics has greatly increased the number and size of these loads.

The concept of harmonics was introduced in the beginning of the 19^{th} century by Joseph Fourier. Fourier has demonstrated that all periodic non-sinusoidal signals can be represented by infinitive sum or series of sinusoids with discontinuous frequencies as given by Equation (1.1).

$$i(t) = I_0 + \sum_{h=1}^{\propto} I_h \cos(h\omega t + \varphi_h) \quad \ldots\ldots \quad (1.1)$$

The component I_0 in the Fourier series is the direct component. The first term of the sum with the index h=1 is the fundamental of the signal. The rest of the series components are called the harmonics of the range h. Fig. 1.1 Shows the form of a wave containing the third harmonic (h=3). In the three phase electric grid, the principle harmonic components are the harmonics of ranges (6*h±1).

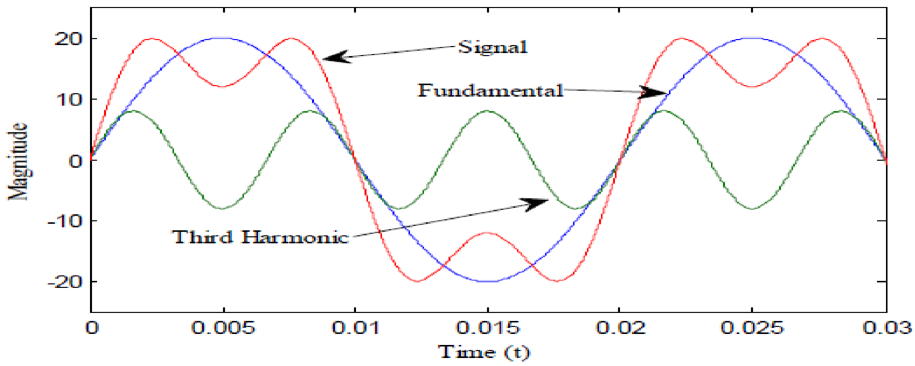

Fig. 1.2 Harmonic Content of a Signal and its Fundamental.

Transformer exciting current, arc furnaces, rectifiers and many other loads will produce harmonics in the utility lines. Most utilities limit the allowable harmonic current levels to the values shown in IEEE 519.

1.3.1 Total Harmonic Distortion (THD):

The total harmonic distortion of a signal is a measurement of the harmonic distortion present in current or voltage. It is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. Harmonic distortion is caused by the introduction of waveforms at frequencies in multiples of the fundamental.

$$THD(\%) = \frac{\sqrt{\sum_{i=2}^{\alpha} x_i^2}}{|x_1|} \quad (1.2)$$

The THD is a very useful quantity for many applications. It is the most commonly used harmonic index. However, it has the limitation that, it is not a good indicator of voltage stress within a capacitor because that is related to the peak value of voltage waveform.

1.3.2 Distortion Factor:

The distortion factor F_d is defined as the ratio between the fundamental and the signal in RMS values. It is given by:

$$F_d = \frac{I_{L1}}{I_{rms}} \quad (1.3)$$

It is then equal to unity when the current is purely sinusoidal and decreases when the distortion appears.

1.3.3 Crest Factor:

The crest factor of a signal Fc is defined by Equation (1.4):

$$F_c = \frac{\text{crest value}}{\text{effectivevalue}} \quad (1.4)$$

For sinusoidal waves, the crest factor is 1.41. It can achieve the value of 5 in the case of highly distorted waves.

1.3.4 Effects of Harmonics:

Harmonic currents will flow into the utility feeder and may create a number of problems in so doing. They may be trapped by power factor correction capacitors and overload them or cause resonant over-voltages. They can distort the feeder voltage enough to cause problems in computers, telephone lines, motors, and power supplies, and may even cause transformer failures from eddy current losses. The harmonic currents may be trapped by installing series LC filters resonant at the offending frequencies.

These filters should be designed to offer low impedance at the resonant frequency compared to the source impedance at that frequency. But, again, there is a hidden “gotcha.” If a filter is installed that has a series resonance at the 7th harmonic, it will also have a parallel resonance with the utility at a lower frequency when the source inductance is added to the filter inductance. If this parallel resonance should lie on or near the 5^{th} harmonic, there is the possibility of the resonant over-currents described earlier. The installation of series resonant traps will always introduce parallel resonances at frequencies below the trap frequencies. Good practice dictates that multiple resonant traps be installed first at the lowest harmonic frequency of concern and then in sequence at the higher-frequency harmonics. If switched, they should be switched on in sequence starting with the lowest frequency trap and switched out in sequence starting from the highest frequency trap.

The voltage or current distortion limit is determined by the sensitivity of loads (also of power sources), which are influenced by the distorted quantities. The least sensitive is heating equipment of any kind.

The most sensitive kind of equipment's is those electronic devices which have been designed assuming an ideal (almost) sinusoidal fundamental frequency voltage or current waveforms. Electric motors are the most popular loads which are situated between these two categories.

1.3.5 Power Factor:

Power factor is defined as the ratio of real power to volt-amperes and is the cosine of the phase angle between the voltage and the current in an AC circuit. These are neatly defined quantities with sinusoidal voltages and currents.

Power factor can be improved by adding capacitors on the power line to draw a leading current and supply lagging V_{Ars} to the system. Power factor correction capacitors can be switched in and out as necessary to maintain V_{Ar} and voltage control.

For a sinusoidal signal, the power factor is given by the ratio between the active and the apparent power. Electrical equipment's' parameters are normally given under nominal voltage and current. A low power factor can indicate bad use of this equipment's. The apparent power can be defined by:

$$S = V_{rms}.I_{rms} = V_{rms}.\sqrt{\frac{1}{T}\int_0^T i_L^2\,dt} \tag{1.5}$$

The active power P can be given by the relation:

$$P = V_{rms}.I_{rms}.\cos(\propto 1) \tag{1.6}$$

The reactive power Q is defined by:

$$Q = V_{rms}.I_{rms}.\sin(\propto 1) \tag{1.7}$$

The power factor in this case can be given by Equation 1.8.

$$P.F = \frac{P}{S} = \frac{P}{\sqrt{P^2+Q^2}} \tag{1.8}$$

In the case where there is harmonics, a supplementary power called the distorted power D appears. This power can be given by the relation.

$$D = V_{rms}.\sqrt{\sum_{n=2}^{\alpha} I_{Ln}^2} \tag{1.9}$$

The apparent power can then be expressed as:

$$S = \sqrt{P^2 + Q^2 + D^2} \tag{1.10}$$

The power factor is then given by:

$$P.F = \frac{P}{\sqrt{P^2+Q^2+D^2}} \tag{1.11}$$

From equation (1.11), we can notice that the power factor decreases because of the existence of harmonics in addition to the reactive power consumption. The Fresnel diagram of the power is given in Fig. 1.3.

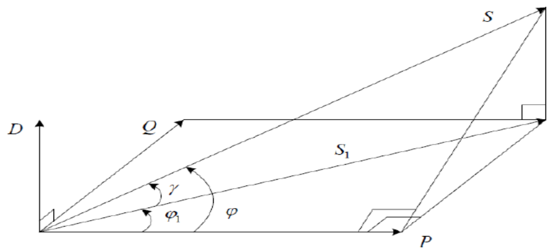

Fig. 1.3 Fresnel Representation of the Power

1.4 HARMONIC CURRENTS SOURCES:

The main cause of harmonics is the injection of harmonic currents by the non-linear loads. The bridges of diodes are the most non-linear loads present in the power applications because they don't need a control and they have long life duration with low cost. There are also many other harmonic producing loads such as:

- Industrial equipment's (welding machines, arc furnaces, induction furnaces, rectifiers).
- Offices equipment's (computers, photocopiers,…etc.).
- Domestic devices (TVs, micro-wave furnaces, neon lightening,…etc.).
- Power inverters.
- Power transformers when working in the saturation zone also are considered as non-linear loads that produce harmonics.

The feeding of non-linear loads generates harmonic currents which spread into the electrical grid. The spread of current harmonics into the feeding impedances (transformers and grid) creates harmonic voltages in these feeders. Remembering that the conductor impedance increases with the frequencies of the currents which pass through it, different impedance will appear for each range of current harmonics. The harmonic current of range h will create through the impedance harmonic voltage. All the loads connected to the same point will be fed with the same perturbed voltages. The equivalent circuit per phase of a non-linear load connected to the grid is given by Fig. 1.4.

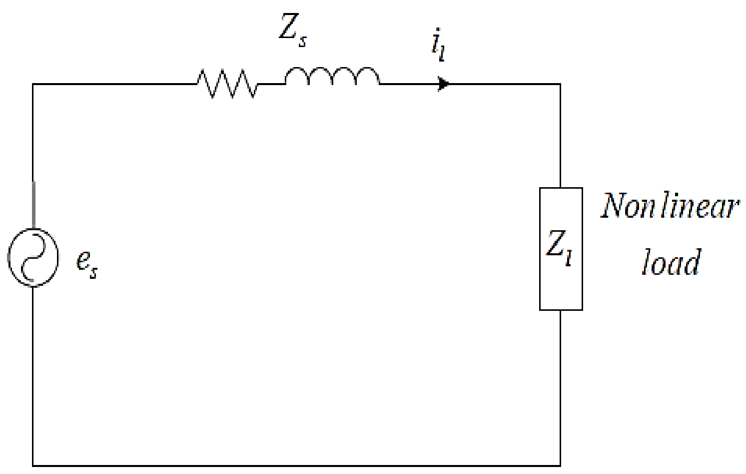

Fig. 1.4 Equivalent Circuit Per Phase of a Non-Linear Load Connected to the Grid.

The spread of harmonic currents from different loads can be represented as in Fig. 1.5

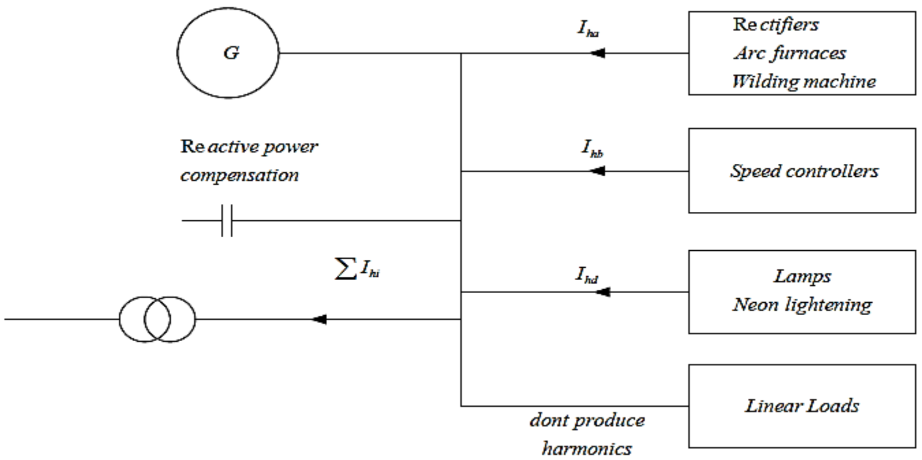

Fig. 1.5 Spread of Harmonic Currents into the Grid

1.5 ECONOMIC EFFECTS OF HARMONICS:

- Premature aging of materials which forces its replacement, in addition to an initial over sizing of these materials.
- The overloading of the grid which implies to increase the nominal power and to oversize the installations, causing more and more losses.
- The current distortions cause sudden triggers and the stop of production equipment's.

These material costs, energetic and production losses affect the competitiveness and the productivity of factories and companies.

1.6 SOLUTIONS FOR THE HARMONICS:

The filtering of the grid currents and voltage is a priory problem for the distributer as like as the client. Because the limits on harmonic emission are not equally applied in the low of the different countries, the producers of the different electrical devices try to construct devices that satisfy for the conditions and limits of the international standards. The electric companies, from its side, use different filtering equipment's and encourage the researches toward finding new efficient solutions for the power quality problems. The clients install also sometimes reactive power and harmonic compensation batteries to ameliorate the power factor and reduce the energy consumption bill.

Many traditional and modern solutions for harmonics mitigation and power quality improvement were proposed in literary. Some of these solutions investigate in the load to minimize the harmonic emission while the others propose the use of external filtering equipment's that prevent the spread of harmonics into the grid.

1.6.1 Inline Reactors:

In-line reactor or choke is a simple solution to control harmonic distortion generated by adjustable speed drives. The solution is come up with inserting a relatively small reactor, or choke, at the input of the drive. The inductance prevents the capacitor to be charged in a short time and forces the drive to draw current over a longer time and reduces the magnitude of the current with much less harmonic content while still delivering the same energy.

1.6.2 Transformers with Passive Coupling:

Some types of triangle zigzag coupling of transformers allow the elimination of the harmonics of order 3 and its multiples. The cost of these coupling types is the augmentation of the source impedance, and then the augmentation of voltage harmonic distortion.

1.6.3 Passive Filters:

Passive filter, which is relatively inexpensive in comparison with the other harmonic reduction methods, is the most used method. Inductance, capacitor and the load as a resistance are tuned in a way to control the harmonics. However, they suffer from interfering with the power systems. Actually, passive filters are designed to shunt harmonics from the lines or block their flow through some parts of the systems by tuning the elements to create a resonance at the selected frequency. These filters are tuned and fixed according to the impedance of the point at which they will be connected and hence cannot be adjusted instantaneously in accordance to the load. As a result their cutoff frequency changes unexpectedly after any change in the load impedance resulting in producing a resonance with other elements installed in the system.

1.6.4 Modern Solutions for Harmonic Problems:

Modern solutions were proposed as efficient solutions for the elimination of electric grid harmonics in order to defeat the disadvantages of the traditional methods like passive filters. Between these solutions we find two categories which are the most used:

- Active filters (series, parallel, or a combination of both of them in Unified Power Quality Conditioner (UPFC)).
- Hybrid filters composed of active and passive filters at once.

1.6.5 Active Power Filters:

The function of the active power filters (APF) is to generate either harmonic currents or voltages in a manner such that the grid current or voltage waves conserve the sinusoidal form. The APFs can be connected to the grid in series (Series APF), shunt (SAPF) to compensate voltage harmonics or current harmonics respectively. Or can be associated with passive filters to construct the hybrid filters (HAPF).

Active filters are relatively new types of devices for eliminating harmonics. This kind of filter is based on power electronic devices and is much more expensive than passive filters. They have the distinct advantage that they do not resonate with the power system and they work independently with respect to the system impedance characteristics. They are used in difficult circumstances where passive filters don't operate successfully because of resonance problems and they don't have any interference with other elements installed anywhere in the power system.

The active filters present many other advantages over the traditional methods for harmonic compensation such as:

- Adaptation with the variation of the loads.
- Possibility of selective harmonics compensation.
- Limitations in the compensation power.
- Possibility of reactive power compensation.

1.6.5.1 Series Active Power Filter (Series APF):

The aim of the series APF is to locally modify the impedance of the grid. It is considered as harmonic voltage source which cancel the voltage perturbations which come from the grid or these created by the circulation of the harmonic currents into the grid impedance. However, series APFs can't compensate the harmonic currents produced by the loads.

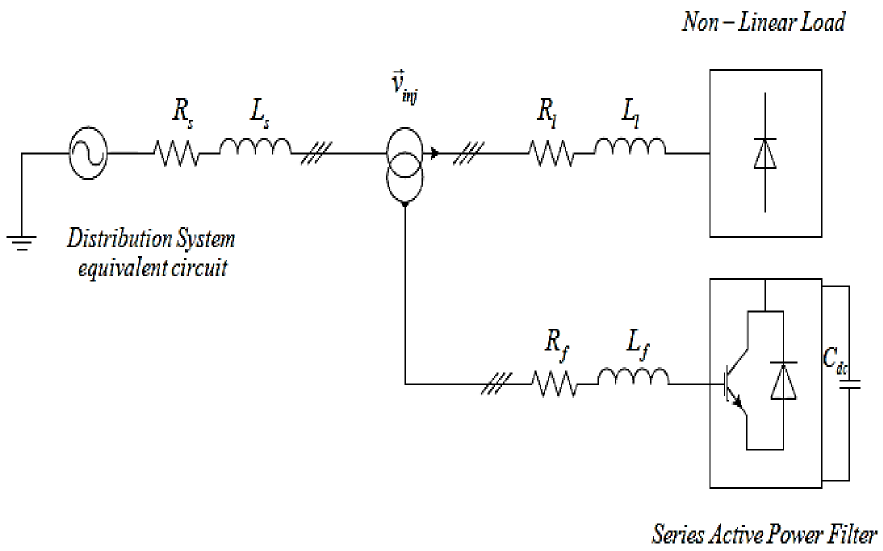

Fig. 1.6 Series Active Power Filter Connected to the Grid

1.6.5.2 Shunt Active Power Filter (SAPF):

The SAPFs are connected in parallel with the harmonic producing loads. They are expected to inject in real time the harmonic currents absorbed by the pollutant loads. Thus, the grid current will become sinusoidal.

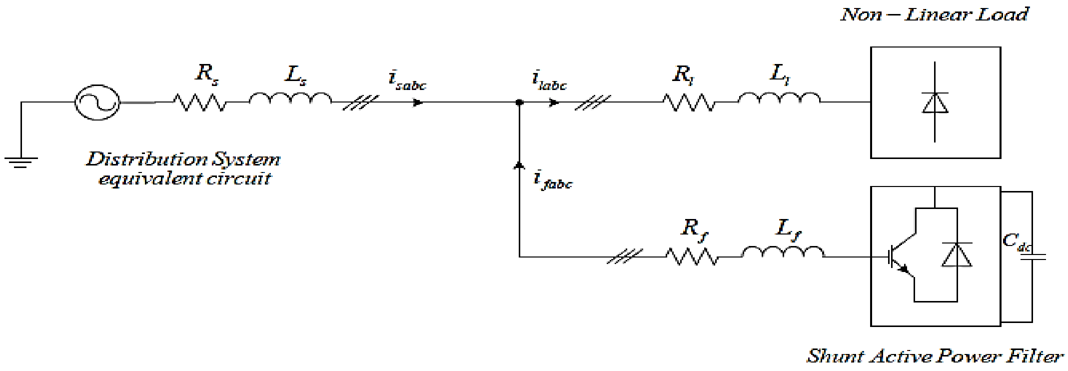

Fig. 1.7 Shunt APF Connected in Parallel with Non-Linear Load

1.6.5.3 Combination of Parallel and Series APF (UPQC):

Fig. 1.8 explains the combination of two APFs parallel and series, called also (Unified Power Quality Conditioner). This structure combines the advantages of the two APF type’s series and parallel. So it allows simultaneously achieving sinusoidal source current and voltage.

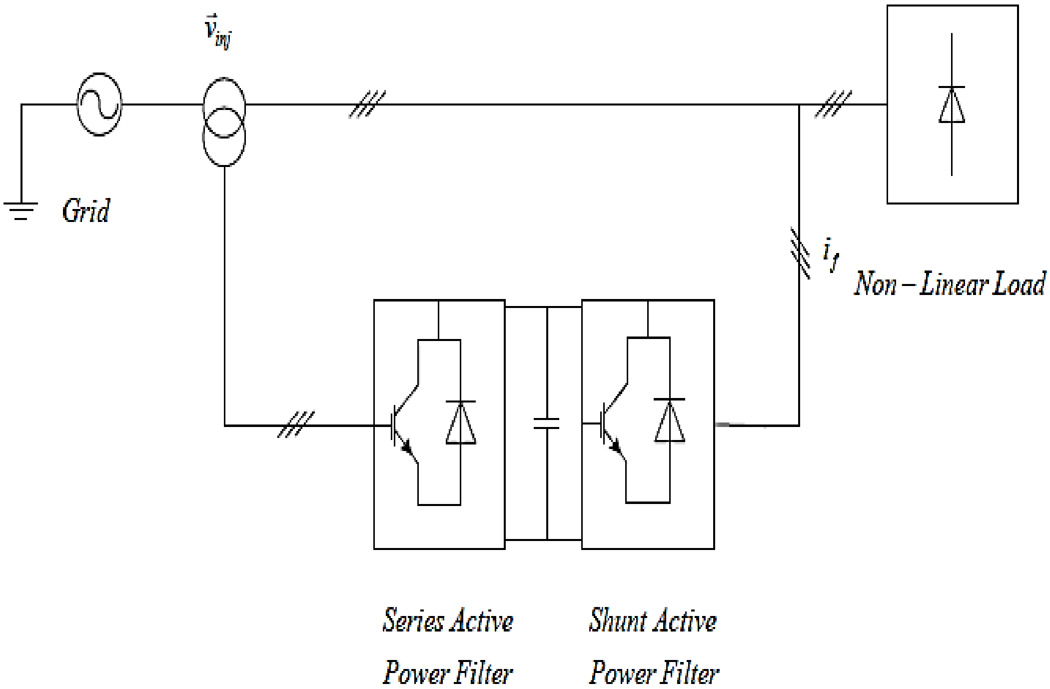

Fig. 1.8 Unified Power Flow Conditioner’s Diagram

1.6.6 Hybrid Filters:

Hybrid filter is a filter topology which combines the advantages of the passive and active filters. For this reason, it is considered as the best solution to eliminate the harmonic currents from the grid. The principal reason for the use of hybrid filters is the development of the power semiconductors like MOSFETs and IGBTs. Over more, from an economical point of view, the hybrid power filters allow reducing the cost of APF.

Hybrid power filters can be classified according to the number of elements used in the topology, the treated system (single phase, three phase three legs or four legs) and the used inverter type (current source inverter or voltage source inverter).

1.7 NON-LINEAR LOADS:

When the input current into the electrical equipment does not follow the impressed voltage across the equipment, then the equipment is said to have a nonlinear relationship between the input voltage and input current. All equipment’s that employ some sort of rectification are examples of nonlinear loads. Nonlinear loads generate voltage and current harmonics that can have adverse effects on equipment designed for operation as linear loads. Transformers that bring power into an industrial environment are subject to higher heating losses due to harmonic generating sources (nonlinear loads) to which they are connected.

1.8 SHUNT ACTIVE POWER FILTER:

The concept of using active power filters to mitigate harmonic problems and to compensate reactive power was proposed more than two decades ago.

It has proven its ability to control the grid current and to ameliorate the power quality. The theories and applications of active power filters have become more popular and have attracted great attention. Without the drawbacks of passive harmonic filters, such as component aging and resonant problems, the active power filter appears to be a viable solution for reactive power compensation as well as for eliminating harmonic currents. As we mentioned earlier, the SAPF is connected in parallel with the non-linear load to behave as another controlled non-linear load. The system of the non-linear load and the SAPF will be seen by the grid as a linear load connected to the PCC.

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION:

The widespread use of non-linear loads is leading to a variety of undesirable phenomena in the operation of power systems. The harmonic components in current and voltage waveforms are the most important among these. Conventionally, passive filters have been used to eliminate line current harmonics. However, they introduce resonance in the power system and tend to be bulky. So, active power line conditioners have become more popular than passive filters as it compensates the harmonics and reactive power simultaneously.

The active power filter topology can be connected in series or shunt and combinations of both. Shunt active filter is more popular than series active filter because most of the industrial applications require current harmonic compensation. Different types of active filters have been proposed to increase the electric system quality. The classification is based on following criteria.

- Power rating and speed of response required in compensated system.
- System parameters to be compensated (e.g. current harmonics, power factor and voltage harmonics)
- Technique used for estimating the reference current/voltage.

Current controlled voltage source inverters can be utilized with an appropriate control strategy to perform active filter functionality. The electrical grid will include a very large number of small producers that use renewable energy sources, like solar panels or wind generators.

2.2 LITERATURE SURVEY:

Johan H. R. Enslin and Peter J. M. Heskes,[1]

"Harmonic interaction between a large number of distributed power inverters and the distribution network,"

In this paper discussed the harmonic interaction between a large number of distributed power inverters and the distribution network. This paper is to analyze the observed phenomena of harmonic interference of large populations of these inverters and to compare the network interaction of different inverter topologies and control options.

Uffe Borup, Frede Blaabjerg and Prasad N. Enjeti ,[2]

"Sharing of nonlinear load in parallel-connected three-phase converters,"

Presented about the sharing of linear and nonlinear loads in three-phase power converters connected in parallel, without communication between the converters. The paper focuses on solving the problem that arises when two converters with harmonic compensation are connected in parallel.

Pichai Jintakosonwit Hideaki Fujita, Hirofumi Akagi and Satoshi Ogasawara, [3]

"Implementation and performance of cooperative control of shunt active filters for harmonic damping throughout a power distribution system,"

This paper proposes cooperative control of multipleactive filters based on voltage detection for harmonic damping throughout a power distribution system. The arrangement of a real distribution system would be changed according to system operation, and/or fault conditions. In addition, shunt capacitors and loads are individually connected to, or disconnected from, the distribution system.

Pedro Rodríguez, JosepPou, Joan Bergas,J. Ignacio Candela , Rolando P. Burgos and DushanBoroyevich ,[4]

"Decoupled double synchronous reference frame PLL for power converters control,"

Presented the detection ofthe fundamental-frequency positive-sequence component of theutility voltage under unbalanced and distorted conditions. Specifically, it proposes a positive-sequence detector based on a new decoupled double synchronous reference frame phase-locked loop (PLL), which completely eliminates the detection errors of conventional synchronous reference frame PLL's. This is achieved by transforming both positive- and negative-sequence components of the utility voltage into the double SRF, from which a decoupling network is developed in order to cleanly extract and separate the positive- and negative-sequence components.

SoerenBaekhoejKjaer, John K. Pedersenand Frede Blaabjerg,[5]

"A review of single-phase grid-connected inverters for photovoltaic modules"

presents a Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules. This paper focuses on inverter technologies forconnecting photovoltaic (PV) modules to a single-phase grid. The inverters are categorized into four classifications: 1) the number of power processing stages in cascade; 2) the type of power decoupling between the PV module(s) and the single-phase grid; 3) whether they utilizes a transformer (either line or high frequency) or not; and 4) the type of grid-connected power stage.

F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus,[6]

"Overview of control and grid synchronization for distributed power generation systems,"

This paper gives an overview of the structures for the DPGS based on fuel cell, photovoltaic, and wind turbines. In addition, control structures of the grid-side converter are presented, and the possibility of compensation for low-order harmonics is also discussed. Moreover, control strategies when running on grid faults are treated. This paper ends up with an overview of synchronization methods and a discussion about their importance in the control.

J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galván, R. C. P. Guisado, M. Á. M. Prats, J. I. León, and N. M. Alfonso,[7]

"Power electronicsystems for the grid integration of renewable energy sources: A survey,"

This paper proposes about distributed energy resource is increasingly being pursued as a supplement and an alternative to large conventional central power stations.

The specification of a power electronic interface is subject to requirements related not only to the renewable energy source itself but also to its effects on the power-system operation, especially where the intermittent energy source constitutes a significant part of the total system capacity.

2.3 PROBLEM FORMULATION:

One of the most common problems when connecting small renewable energy systems to the electric grid concerns the interface unit between the power sources and the grid, because it can inject harmonic components that may detoriate the power quality.

The increasing use in the industry of non-linear loads based on the power electronic elements also introduced serious perturbation problems in the electric power distribution grids. Also, regular increase in the harmonic emissions and current unbalance in addition to high consumption of reactive power can be noticed. The flow of harmonic currents in the electric grids can also cause voltage harmonics and disturbance. These harmonic currents can interact adversely with a wide range of power system equipment's, control systems, protection circuits and other harmonic sensible loads. The energy distributers like consumers were concerned by imposing some regulation protection against the expansion of harmonic problem.

In order to face the problem of harmonics, many solutions have been proposed. These solutions included modifications on the load itself for less harmonic emissions like the case of special structure single phase and three phase rectifier and PWM rectifiers or the connection on the polluted power grids of other traditional or modern compensation systems.

In order to face the problem of harmonics, many researches were encouraged to develop modern, flexible and more efficient solutions for power quality problems including harmonics problem. These modern solutions have been given the name of active compensators or active power filters. The objective of these active power filter abbreviated mostly APF is to compensate harmonic currents and voltages in addition to selective reactive power compensation.

Many types of APF have been proposed and used in harmonic compensation. Series APF is used for voltage harmonics compensation. Shunt APF was proposed for current harmonics and reactive power compensation.

The Unified Power Quality Filter or Conditioner combines the two types Shunt and Series APF in one device responsible for the simultaneous compensation of voltage, current harmonics and reactive power. Although there are different types of APF, the Shunt APF is still the most famous and used type APF.

The main function of Shunt Active Power Filter is to cancel harmonic currents occurring in power grids. The principle of SAPF is to generate harmonic currents equal in magnitude and opposite in phase to those harmonics that circulate in the grid. The non-linear loads absorb non-sinusoidal currents from the grid. Whereas, the SAPF current is generated in a manner that grid current keeps the sinusoidal form. SAPF is controlled to be seen with the non-linear load by the grid either as linear resistive load.

There are two main structures for the control of Shunt Active Power Filter; these are the direct control and the indirect control of APF. In the direct control the main idea is to generate filter current references using the appropriate methods. The generated reference currents are then to be compared with the measured APF currents. The error is then used to produce control signals of the filter. The indirect control interests in controlling the grid currents instead of filter currents. It compares the measured grid currents with their generated references. The error is then sent to the control circuit which determines the control signal of the APF.

CHAPTER 3

PROPOSED UPQC

3.1 OVERVIEW:

Shunt active power filter compensates current harmonics by injecting equal-but-opposite harmonic compensating currents into the grid. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180°. This principle is applicable to any type of load considered as harmonic source. Moreover, with an appropriate control scheme, the active power filter can also compensate the load power factor. In this way, the power distribution system sees the non-linear load and the active power filter as an ideal resistor. The current compensation characteristics of the shunt active power filter is shown in Fig. 3.1

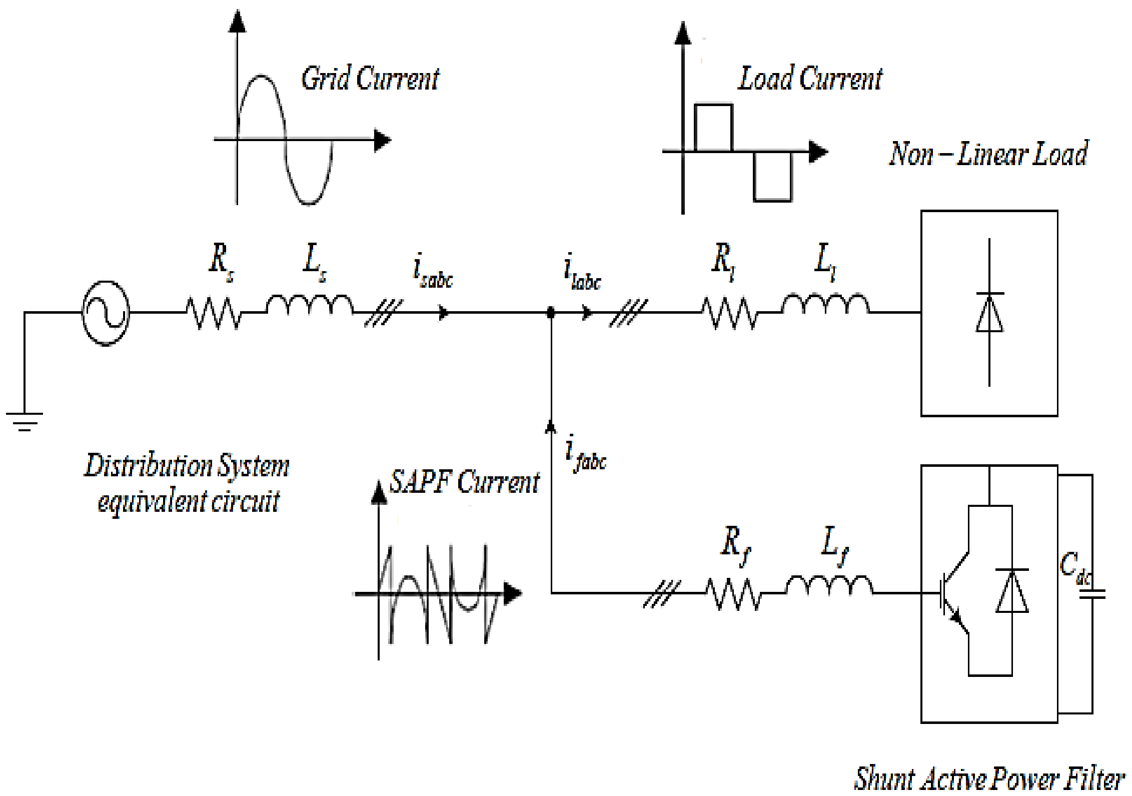

Fig. 3.1 Compensation Characteristic of Shunt Active Power Filter

3.2 HARMONIC CURRENT EXTRACTION METHODS:

The aim of active power filtering is to compensate the harmonic currents produced by the non-linear loads, and to ensure the sinusoidal form of grid currents and voltages.

The first step in active filtering is the harmonic currents extraction to be injected into the grid. The good extraction of harmonics is a keyword for a good active power filtering. Many extraction methods were proposed in literary.

They can be divided into two families: the first family uses the Fast Fourier Transform (FFT) in the frequency domain to extract the current harmonics. The main disadvantages of this method are the bad results in transient, the heavy amount of calculations, and the use of considerable memory. In addition to a delay in the extraction of harmonics which can be at least one period.

The second family is based on the time domain calculations in the extraction of harmonics. Some of its methods are based on the instantaneous active and reactive power. Others are based on the calculation of direct and indirect current components. Recently, the neural networks and the adaptive linear neural networks have been used in the extraction of harmonic components of current and voltage.

3.2.1 Instantaneous Active and Reactive Power Theory:

Most APFs have been designed on the basis of instantaneous active and reactive power theory (p-q), first proposed by Akagi et al in 1983. Initially, it was developed only for three-phase systems without neutral wire, being later worked by *Watanabe* and *Aredes* for three-phase four wires power systems. The method uses the transformation of distorted currents from three phase frame *abc* into bi-phase stationary frame $\alpha\beta$. The basic idea is that the harmonic currents caused by nonlinear loads in the power system can be compensated with other nonlinear controlled loads. The p-q theory is based on a set of 31 instantaneous powers defined in the time domain. The three-phase supply voltages (u_a, u_b, u_c) and currents (i_a, i_b, i_c) are transformed using the Clarke (or α-β) transformation into a different coordinate system yielding instantaneous active and reactive power components. This transformation may be viewed as a projection of the three-phase quantities onto a stationary two-axis reference frame. The Clarke transformation for the voltage variables is given by

$$\begin{bmatrix} u_\propto \\ u_\beta \\ u_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \tag{3.1}$$

Similarly, this transform can be applied on the distorted load currents to give:

$$\begin{bmatrix} i_{l\propto} \\ i_{l\beta} \\ i_{l0} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \tag{3.2}$$

The instantaneous active power *p(t)* is defined by:

$$p(t) = u_a i_{la} + u_b i_{lb} + u_c i_{lc} \tag{3.3}$$

This expression can be given in the stationary frame by:

$$\begin{cases} p(t) = u_\propto i_{l\propto} + u_\beta i_{l\beta} \\ p_o(t) = u_o i_{lo} \end{cases} \tag{3.4}$$

Where, *p(t)* is the instantaneous active power, *p0(t)* is the instantaneous homo-polar sequence power. Similarly the instantaneous reactive power can be given by:

$$q(t) = -\frac{1}{\sqrt{3}}[(u_a - u_b)i_{lc} + (u_b - u_c)i_{la} + (u_c - u_a)i_{lb}] = u_\propto i_{l\beta} - u_\beta i_{l\propto} \tag{3.5}$$

It is important to notice that the instantaneous reactive power *q(t)* signify more than the simple reactive power. The instantaneous reactive power take in consideration all the current and voltage harmonics, where as the habitual reactive power consider just the fundamentals of current and voltage.

From equations (3.4) and (3.5) the instantaneous active and reactive power can be given in matrix form by:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} u_\propto & u_\beta \\ -u_\beta & u_\alpha \end{bmatrix} \begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} \tag{3.6}$$

In general, each one of the active and reactive instantaneous power contains a direct component and an alternating component. The direct component of each presents the power of the fundamentals of current and voltage. The alternating term is the power of the harmonics of currents and voltages.

In order to separate the harmonics from the fundamentals of the load currents, it is enough to separate the direct term of the instantaneous power from the alternating one. A Low Pass Filter (LPF) with feed-forward effect can be used to accomplish this task. Fig. 3.2 shows the principle of this extraction filter.

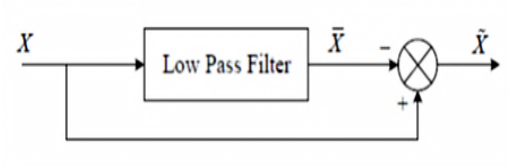

Fig. 3.2 Diagram of the Low Pass Filter with Feed-Forward.

After the separation of the direct and alternating terms of instantaneous power, the harmonic components of the load currents can be given using the inverse of equation (3.6) which gives:

$$\begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} = \frac{1}{v_{s\propto}^2 + v_{s\beta}^2} \begin{bmatrix} v_{s\propto} & -v_{s\beta} \\ v_{s\beta} & v_{s\alpha} \end{bmatrix} \begin{bmatrix} \tilde{p}_l \\ \tilde{q}_l \end{bmatrix} \tag{3.7}$$

Where, the "∼ "sign points to the alternating.

The APF reference current can be then given by:

$$\begin{bmatrix} i_{fa}^* \\ i_{fb}^* \\ i_{fc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \tilde{i}_{l\alpha} \\ \tilde{i}_{l\beta} \end{bmatrix} \tag{3.8}$$

Fig. 3.3 presents the principle of the active and reactive instantaneous power. This method offers the advantage of the possibility of harmonic compensation and/or reactive power compensation. In the case of reactive power compensation it is enough to send the reactive power q(t) directly to the reference current calculation bloc without the use of any extraction filter.

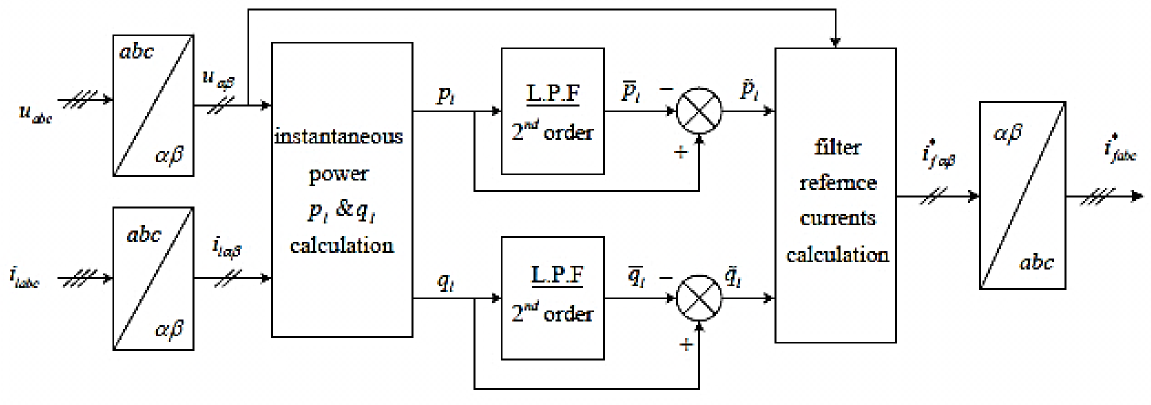

Fig. 3.3 Principle of Instantaneous Active and Reactive Power Theory.

3.3 VOLTAGE SOURCE INVERTER:

Voltage source inverters (VSI) are one of the most important applications of power electronics. The main purpose of these devices is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable.

The important development of VSI is a result, from the one hand to the development of fast, controllable, powerful, and robust semi-conductors, from the other hand to the use of the so-called pulse width modulation (PWM) techniques.

In the high power applications, the three level VSIs are the most adopted in comparison with two levels ones. Because the THD of the output voltage and current of the three levels VSI is clearly lower.

The standard three-phase VSI topology is shown in Fig. 3.4. It is composed of three legs with current reversible switches, controlled for the open and close. These switches are realized by controlled switches (GTO or IGBT) with anti-parallel diodes to allow the flow of the free-wheeling currents.

The switches of any leg of the inverter (T1 and T4, T2 and T5, T3 and T6) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity.

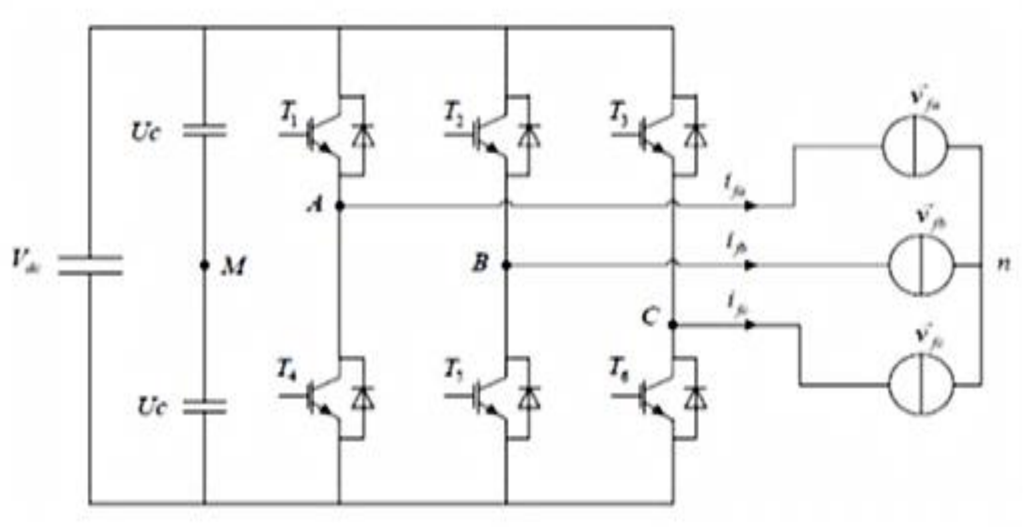

Fig. 3.4 Three-phase Two Levels VSI Topology

3.3.1 Modeling of Voltage Source Inverter:

The output of the VSI which is shown in Fig. 3.4 can take two levels of voltage ($+V_{dc}$, $-V_{dc}$) dependent on the dc source voltage and the switches states. Actually, the control of the two switches on the same leg is complementary: the conduction of one of them implies the blocking of the other.

The state of each one of the switches is defined by the control signals (S_a, S_b and S_c) as follow:

$$S_a = \begin{cases} 1\ if\ T_1 close\ , T_4 open \\ 0\ if\ T_1 open\ , T_4 close \end{cases}$$

$$S_b = \begin{cases} 1\ if\ T_2 close\ , T_5 open \\ 0\ if\ T_2 open\ , T_5 close \end{cases}$$

$$S_c = \begin{cases} 1\ if\ T_3 close\ , T_6 open \\ 0\ if\ T_3 open\ , T_6 close \end{cases}$$

3.3.2 Modeling of Active Power Filter:

The connection of the shunt active power filter to the point of common coupling of the grid is done mostly by the mean of a RL low pass filter as shown in Fig. 3.1. The voltage equation for each phase can be given by:

$$v_{sk} = v_{fk} - v_{L_{fk}} - v_{R_{fk}}$$

$$v_{fk} - L_f \frac{di_{fk}}{dt} - R_f i_{fk}\ , \text{k=a,b,c} \qquad (3.9)$$

The three phase equations are then given by:

$$L_f \frac{d}{dt}\begin{bmatrix} i_{fa} \\ i_{fb} \\ i_{fc} \end{bmatrix} = -R_f \begin{bmatrix} i_{fa} \\ i_{fb} \\ i_{fc} \end{bmatrix} + \begin{bmatrix} v_{fa} \\ v_{fb} \\ v_{fc} \end{bmatrix} - \begin{bmatrix} s_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \quad (3.10)$$

And for the dc side:

$$C_{dc}.\frac{dV_{dc}}{dt} = S_a i_{fa} + S_b i_b + S_c i_f \quad (3.11)$$

The equation system defining the SAPF in the three phase frame is then given by:

$$\begin{cases} L_f \frac{di_{fa}}{dt} = -R_f i_{fa} + v_{fa} - v_{sa} \\ L_f \frac{di_{fb}}{dt} = -R_f i_{fb} + v_{fb} - v_{sb} \\ L_f \frac{di_{fc}}{dt} = -R_f i_{fc} + v_{fc} - v_{sc} \end{cases} \quad (3.12)$$

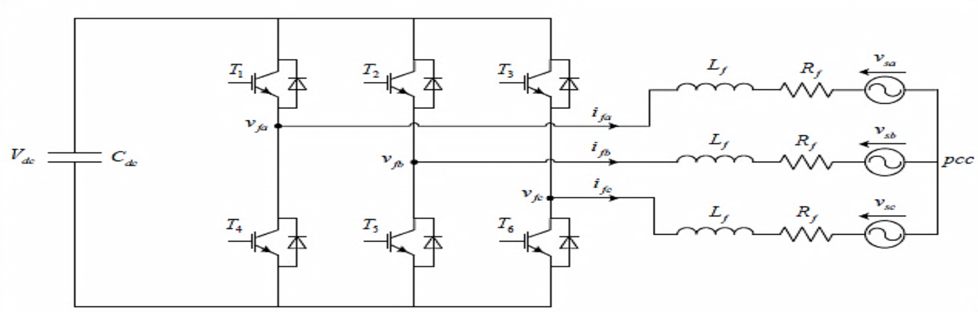

Fig. 3.5 SAPF Connection to the PCC

3.3.3 Control Methods of VSI:

The aim of the control of the VSC is to force the output currents of the inverter to follow their predefined reference currents. The main principle is based on the comparison between the actual current of the filter with the reference currents generated by the different extraction methods. In the next section, we are going to discuss some different methods in VSC control.

3.3.3.1 Hysteresis Control Method:

The current control strategy plays an important role in fast response current controlled inverters such as the active power filters. The hysteresis current control method is the most commonly proposed control method in time domain. This method provides instantaneous current corrective response, good accuracy and unconditioned stability to the system. Besides that, this technique is said to be the most suitable solution for current controlled inverters.

Hysteresis current control is a method of controlling a voltage source inverter so that an output current is generated which follows a reference current waveform.

The basic structure of PWM voltage source inverter with hysteresis controller is shown in Fig. 3.6. The hysteresis control strategy aims to keep the controlled current inside a defined rejoin around the desired reference current. The status of the switches is determined according to the error. When the current is increasing and the error exceeds a certain positive value, the status of the switches changes and the current begins to decrease until the error reaches a certain negative value, then the switches status changes again.

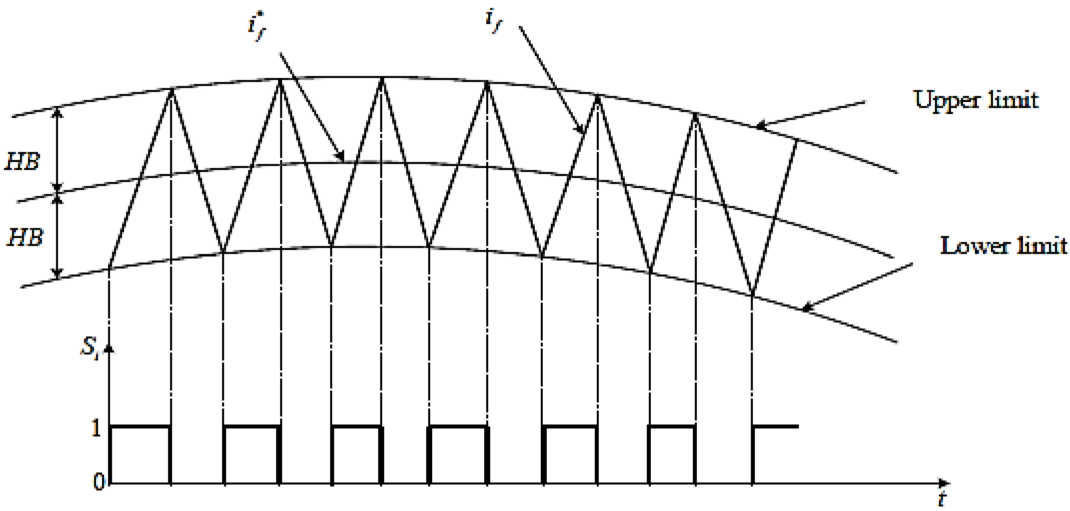

Fig. 3.6 Hysteresis Control Principle

In the fix hysteresis band control of the VSI, the switching frequency is a function of the derivative of the output current.

This one depends on the value of the inductance of the decoupling filter and the voltage drop around it. It is important to notice that the coupling filter affects the switching frequency and the dynamic behavior of the active filter. The simple implementation procedure is the main advantage of this control method. However, the variable switching frequency is the major draw-back of this method. This variable frequency affects mainly the function of power electronic elements which can't support high switching frequency in high power applications. In order to solve the problem of variable switching frequency, a new hysteresis control strategies like "modulated hysteresis control" and "variable hysteresis band" were proposed. In the modulated hysteresis control it is difficult to define the hysteresis band width. Over more, the fix switching frequency achieved using this method affects the rapidity obtained by hysteresis control.

3.3.3.2 Sinusoidal Pulse Width Modulation (SPWM) Control:

The control techniques based on the PWM solve the problem of switching frequency of the VSI. They use a fix switching frequency which makes it easier to cancel the switching harmonics. The PWM can be realized using different techniques such as carrier based PWM, PWM with harmonics minimization, and space vector PWM. The carrier PWM can be natural PWM, symmetric PWM, and asymmetric PWM.

The most simple and well known PWM technique is the sinusoidal PWM. This technique uses a controller which determines the voltage reference of the inverter from the error between the measured current and its reference. This reference voltage is then compared with a triangular carrier signal (with high frequency defining the switching frequency). The output of this comparison gives the switching function of the VSI.

The choice of the ratio between the frequency of the reference signal and the frequency of the carrier signal is very important in the case of symmetric and periodic reference. As a consequence, in the case of sinusoidal reference, the ratio between the two frequencies must be integer to synchronize the carrier with the reference. Over more, it is preferable that the carrier frequency be odd to conserve the reference symmetry. In all cases this ratio must be sufficiently high to ensure the fast switching and to take the switching harmonics away from the fundamental produced by the inverter.

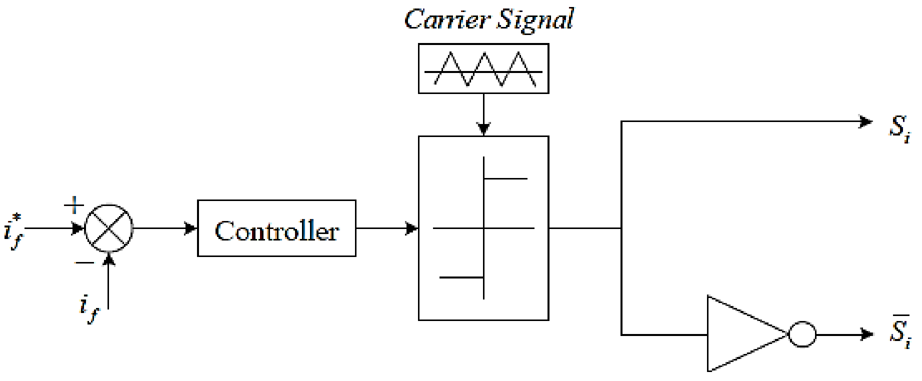

Fig. 3.7 The Principle of Sinusoidal PWM Control Method

Recently, new control techniques called space vector PWM were implemented. The difference between this technique and the sinusoidal technique is that it doesn't use carrier signal to define switching orders.

3.3.3.3 Space Vector PWM Control (SVPWM):

Space vector modulation technique was first introduced by German researchers in the mid of 1980s. This technique showed several advantages over the traditional PWM technique and has been proven to inherently generate superior PWM waveforms. By implementing the SVM technique, the number of switching is reduced to about 30% at the same carrier frequency of the sinusoidal pulse width modulation (SPWM) method. It offers better DC bus utilizations with lower THD in the AC current and reduces of switching losses too. The maximum modulation index for the SPWM method is 0.785 with the sinusoidal waveform between the phase and the neutral current of the system. However, the modulation index can be increased to 0.907 for the SVPWM.

The basic principle of the SVM technique is that it treats the inverter as a whole unit, which is different when compared to PWM technique. This technique is based on the decomposition of a reference voltage vector into voltage vector realizable on a six pulse inverter.

The SVPWM technique is widely used in inverter and rectifier controls. Compared to the sinusoidal pulse width modulation (SPWM), SVPWM is more suitable for digital implementation and can increase the obtainable maximum output voltage with maximum line voltage approaching 70.7% of the DC link voltage (compared to SPWM's 61.2%) in the linear modulation range.

Moreover, it can obtain a better voltage total harmonic distortion factor. There are different algorithms for using SVPWM to modulate the inverter or rectifier. Many SVPWM schemes have been investigated extensively in literatures. The goal in each modulation strategy is to lower the switching losses, maximize bus utilization, reduce harmonic content, and still achieve precise control.

In the SVPWM scheme, the 3-phase output voltage is represented by a reference vector which rotates at an angular speed of $\omega = 2\pi f$. The task of SVM is to use the combinations of switching states to approximate the reference vector. To approximate the locus of this vector, the eight possible switching states of the inverter are represented as 2 null vectors and 6 active vectors.

3.4 CONTROL OF THE ACTIVE POWER FILTER:

The researchers are always at the point of the research to ameliorate the control methods of the SAPF to achieve better results either from the point of view of better perturbation extraction methods, the amelioration of the dynamic regimes, decreasing the value of the THD,…etc.

or the development of new control methods to ameliorate the performance of the APF with the different non-linear loads. There are principally two methods for the compensation of the harmonic currents dependent on the measured current.

3.4.1 Direct Control Method:

In this method the load currents are measured and the harmonic currents are extracted from the load currents. Fig. 3.8 shows the diagram of the direct control method. Using this method, the SAPF injects the harmonic currents without any information about the grid currents. All the errors in the system like the parameters uncertainty, the measurement or control errors will appear in the grid current as unfiltered harmonic contents. The main advantage of this method is the system stability. However, this method needs an expanded control algorithm with large number of sensors.

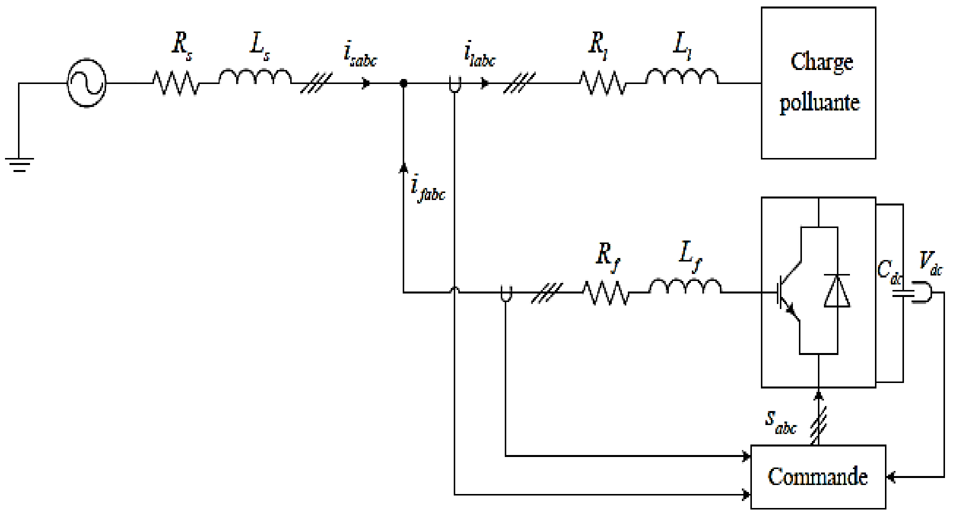

Fig. 3.8 Direct Control Method Diagram

3.4.2 Indirect Control Method:

This method based on the measurement of the source currents, and then to impose the sinusoidal form on these currents. The control algorithm is less complicated and needs fewer sensors than the direct control. Fig. 3.9 shows the diagram of the indirect control method of the SAPF.

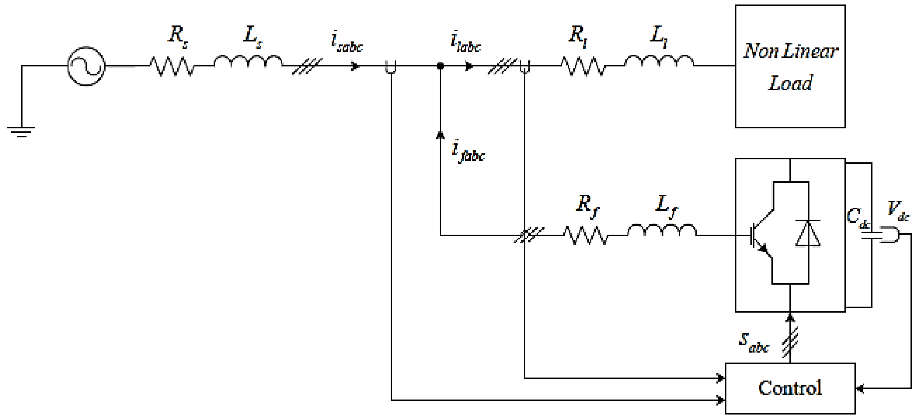

Fig. 3.9 Indirect Control Method Diagram

DC to AC converters produce an AC output waveform from a DC source. Applications include adjustable speed drives (ASD), uninterruptable power supplies (UPS), active filters, Flexible AC transmission systems (FACTS), voltage compensators, and photovoltaic generators. Topologies for these converters can be separated into two distinct categories: voltage source inverters and current source inverters. Voltage source inverters (VSIs) are named so because the independently controlled output is a voltage waveform. Similarly, current source inverters (CSIs) are distinct in that the controlled AC output is a current waveform.

Being static power converters, the DC to AC power conversion is the result of power switching devices, which are commonly fully controllable semiconductor power switches. The output waveforms are therefore made up of discrete values, producing fast transitions rather than smooth ones. The ability to produce near sinusoidal waveforms around the fundamental frequency is dictated by the modulation technique controlling when, and for how long, the power valves are on and off. Common modulation techniques include the carrier-based technique, or pulse width modulation, space-vector technique, and the selective-harmonic technique.

Voltage source inverters have practical uses in both single-phase and three-phase applications. Single-phase VSIs utilize half-bridge and full-bridge configurations, and are widely used for power supplies, single-phase UPSs, and elaborate high-power topologies when used in multicell configurations. Three-phase VSIs are used in applications that require sinusoidal voltage waveforms, such as ASDs, UPSs, and some types of FACTS devices such as the STATCOM. They are also used in applications where arbitrary voltages are required as in the case of active filters and voltage compensators.

Current source inverters are used to produce an AC output current from a DC current supply. This type of inverter is practical for three-phase applications in which high-quality voltage waveforms are required.

A relatively new class of inverters, called multilevel inverters, has gained widespread interest. Normal operation of CSIs and VSIs can be classified as two-level inverters, due to the fact that power switches connect to either the positive or to the negative DC bus. If more than two voltage levels were available to the inverter output terminals, the AC output could better approximate a sine wave. It is for this reason that multilevel inverters, although more complex and costly, offer higher performance.

Each inverter type differs in the DC links used, and in whether or not they require freewheeling diodes. Either can be made to operate in square-wave or pulse-width modulation (PWM) mode, depending on its intended usage. Square-wave mode offers simplicity, while PWM can be implemented several different ways and produces higher quality waveforms.

Voltage Source Inverters (VSI) feed the output inverter section from an approximately constant-voltage source.

The desired quality of the current output waveform determines which modulation technique needs to be selected for a given application. The output of a VSI is composed of discrete values. In order to obtain a smooth current waveform, the loads need to be inductive at the select harmonic frequencies. Without some sort of inductive filtering between the source and load, a capacitive load will cause the load to receive a choppy current waveform, with large and frequent current spikes.

There are three main types of VSIs:

- Single-phase half-bridge inverter
- Single-phase full-bridge inverter
- Three-phase voltage source inverter

Single-phase half-bridge inverter

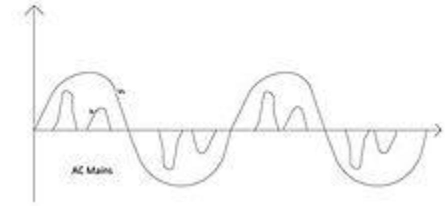

Fig. 3.10 The AC input for an ASD.

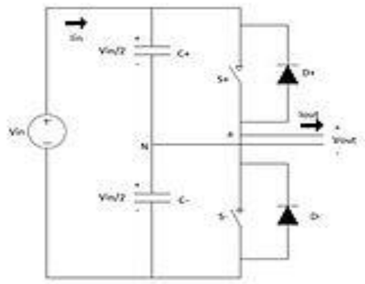

Fig. 3.11 Single-Phase Half-Bridge Voltage Source Inverter

The single-phase voltage source half-bridge inverters, are meant for lower voltage applications and are commonly used in power supplies. Fig. 3.11 shows the circuit schematic of this inverter.

Low-order current harmonics get injected back to the source voltage by the operation of the inverter. This means that two large capacitors are needed for filtering purposes in this design.As Fig. 3.11 illustrates, only one switch can be on at time in each leg of the inverter. If both switches in a leg were on at the same time, the DC source will be shorted out.

Inverters can use several modulation techniques to control their switching schemes. The carrier-based PWM technique compares the AC output waveform, v_c, to a carrier voltage signal, v_Δ. When v_c is greater than v_Δ, S+ is on, and when v_c is less than v_Δ, S- is on.

When the AC output is at frequency fc with its amplitude at v_c, and the triangular carrier signal is at frequency f_Δ with its amplitude at v_Δ, the PWM becomes a special sinusoidal case of the carrier based PWM.[8] This case is dubbed sinusoidal pulse-width modulation (SPWM).For this, the modulation index, or amplitude-modulation ratio, is defined as$m_a = v_c / v_\Delta$.

The normalized carrier frequency, or frequency-modulation ratio, is calculated using the equation $m_f = f_\Delta / f_c$.

If the over-modulation region, ma, exceeds one, a higher fundamental AC output voltage will be observed, but at the cost of saturation. For SPWM, the harmonics of the output waveform are at well-defined frequencies and amplitudes. This simplifies the design of the filtering components needed for the low-order current harmonic injection from the operation of the inverter. The maximum output amplitude in this mode of operation is half of the source voltage. If the maximum output amplitude, m_a, exceeds 3.24, the output waveform of the inverter becomes a square wave.

As was true for PWM, both switches in a leg for square wave modulation cannot be turned on at the same time, as this would cause a short across the voltage source. The switching scheme requires that both S+ and S- be on for a half cycle of the AC output period. The fundamental AC output amplitude is equal to $v_{o1} = v_{aN.}$

Therefore, the AC output voltage is not controlled by the inverter, but rather by the magnitude of the DC input voltage of the inverter.

Using selective harmonic elimination (SHE) as a modulation technique allows the switching of the inverter to selectively eliminate intrinsic harmonics. The fundamental component of the AC output voltage can also be adjusted within a desirable range. Since the AC output voltage obtained from this modulation technique has odd half and odd quarter wave symmetry, even harmonics do not exist. Any undesirable odd (N-1) intrinsic harmonics from the output waveform can be eliminated. Single-phase full-bridge inverter

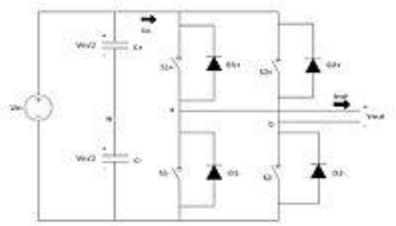

Fig. 3.12 Single-Phase Voltage Source Full-Bridge Inverter

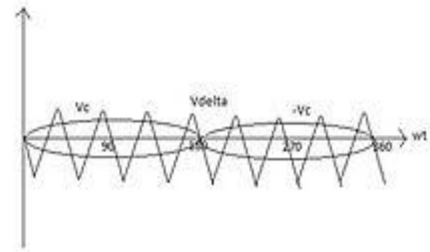

Fig 3.13 Carrier and Modulating Signals for the Bipolar Pulsewidth Modulation Technique

The full-bridge inverter is similar to the half bridge-inverter, but it has an additional leg to connect the neutral point to the load. Figure 3.12 shows the circuit schematic of the single-phase voltage source full-bridge inverter.

To avoid shorting out the voltage source, S1+ and S1- cannot be on at the same time, and S2+ and S2- also cannot be on at the same time. Any modulating technique used for the full-bridge configuration should have either the top or the bottom switch of each leg on at any given time. Due to the extra leg, the maximum amplitude of the output waveform is Vi, and is twice as large as the maximum achievable output amplitude for the half-bridge configuration.

States 1 and 2 from Table 2 are used to generate the AC output voltage with bipolar SPWM. The AC output voltage can take on only two values, either Vi or –Vi. To generate these same states using a half-bridge configuration, a carrier based technique can be used. S+ being on for the half-bridge corresponds to S1+ and S2- being on for the full-bridge.

Similarly, S- being on for the half-bridge corresponds to S1- and S2+ being on for the full bridge. The output voltage for this modulation technique is more or less sinusoidal, with a fundamental component that has an amplitude in the linear region of ma less than or equal to one[8] $v_{o1} = v_{ab1} = v_i \bullet m_a$.

Unlike the bipolar PWM technique, the unipolar approach uses states 1, 2, 3 and 4 from Table 2 to generate its AC output voltage. Therefore, the AC output voltage can take on the values Vi, 0 or –V [1]i. To generate these states, two sinusoidal modulating signals, Vc and –Vc, are needed, as seen in Figure 3.13.

Vc is used to generate VaN, while –Vc is used to generate VbN. The following relationship is called unipolar carrier-based SPWM $v_{o1} = 2 \bullet v_{aN1} = v_i \bullet m_a$.

The phase voltages VaN and VbN are identical, but 180 degrees out of phase with each other. The output voltage is equal to the difference of the two phase voltages, and do not contain any even harmonics. Therefore, if mf is taken, even the AC output voltage harmonics will appear at normalized odd frequencies, fh. These frequencies are centered on double the value of the normalized carrier frequency. This particular feature allowas the case for the half-bridge SHE, the AC output voltage contains no even harmonics due to its odd half and odd quarter wave symmetry.

CHAPTER 4

SIMULATION FOR PV POWERED UPQC

4.1 INTRODUCTION:

The continuous increase in the electrical energy with the clean environment needs the decentralized renewable energy production. The increasing energy consumption may overload the distribution grid as well as power station and may cause the negative impact on power availability, security and quality. The only solution to overcome this problem is integrating the utility grid with the renewable energy systems like solar, wind or hydro. The grid can be connected to the energy system as per the availability of renewable energy sources. Recently the solar power generation systems are getting more attention because solar energy is abundantly available, more efficient and more environment friendly as compared to the conventional power generation systems such as fossil fuel, coal or nuclear. The PV systems are still very expensive because of higher manufacturing cost of the PV panels, but the energy that drives them -the light from the sun- is free, available almost everywhere and will still be present for millions of years, even all non-renewable energy sources might be depleted. One of the major advantages of PV technology is that it has no moving parts. Therefore, the PV system is very robust, it has a long lifetime and low maintenance requirements. And, most importantly, it is one solution that offers environmentally friendly power generation.

The most important issue of all is probably why solar energy is important to you, personally.

- Fossil fuels, like gas and oil, are not renewable energy. Once they are gone they can't be replenished. Someday these fuels will run out and then mankind will either need to come up with a new way to provide power or go back to life as it was prior to man's use of these things.
- Fossil fuels create massive pollution in the environment. This pollution affects waterways, the air you breathe, and even the meat and vegetables that you eat.

- These fuels are expensive to retrieve from the earth and they are expensive to use. Other, more Eco-friendly energy sources like wind and solar energies are relatively inexpensive and easy to produce.

The disadvantage of the PV system is that it can supply the load only in sunny days. Therefore, for improving the performance and supplying the power in all day, it is necessary to hybrid the PV system into another power generation systems or to integrate with the utility grid. The integration of the PV system with the utility grid requires the PWM voltage source converter for interfacing the utility grid and results some interface issues.

A prototype current- controlled power conditioning system has been developed and tested. This prototype sources 20 kW of power from a photovoltaic array with a maximum power point tracking control. The disadvantage of this system is the need of high bandwidth current measurement transducers (dc to several times the switching frequency), and the need for relatively high precision in the reference signal generation. Hence, this increases the cost of the system. The inverters suitable for the PV system are central inverters, string inverters, Module integrated or module oriented inverters, multi string PV inverter with new trends has been described . If these solar inverters are connected with the grid, the control of these inverters can be provided using the phase locked loop . The need and benefits of the distribution technology has been presented . Single-phase Grid connected PV inverters with the control has been described with its advantages and disadvantages. The three-phase Photovoltaic power conditioning system with line connection has been proposed with the disturbance of the line voltage which is detected using a fast sensing technique. The control of the system is provided through the microcontroller. Power electronic systems can also be used for controlling the solar inverter for interfacing the Solar Power Generation system with the grid. The complete design and modeling of the grid connected PV system has been developed to supply the local loads.

4.2 BACKGROUND:

World is moving towards the greener sources of energy to make the planet pollution free and environment friendly. The major utilization of these sources with grid integration is the challenging task. It is therefore Distribution Generation (DGs) particularly single phase rooftop PV system are major research area for grid integration, since these sources have huge opportunity of generation near load terminal. The rooftop application involving single phase DG's fed with PV source can be not only utilized for household use but the excess energy can be transferred to the grid through proper control scheme and adequate hardware. Control scheme based on instantaneous PQ theory has been presented in some literatures for single phase system. Other control scheme such as synchronous reference frame (SRF) is mainly used with three phase system in which sinusoidal varying quantities are being transferred to dc quantities that provides better and precise control than PQ based control even under distorted condition of mains. But SRF based control scheme can be customized for single phase which can't be utilized to get the desired dc quantity to generate required reference command. PV sources are interfaced with the grid through voltage source converters (VSC's). VSC's can be controlled either in PWM based voltage control method or hysteresis based current controlled method (HCC). HCC based controller gives fast response and better regulation but its major drawback lies with Variable frequency. On the other hand the PWM based control gives fixed switching frequency that could be utilized easily for proper design of LC or LCL filters. With PV sources connected at the DC side of the inverter, it is utmost essential to fetch maximum power from the source to make the system efficient.

Out of different algorithm to track maximum power point (MPP) such as perturb and observe (P&O), Incremental Conductance (IC) etc., IC based method provides fast dynamics and control over fast changing insolation condition. In this paper new control scheme based on SRF theory has been proposed for single phase rooftop PV grid connected system. The VSC controller is designed in taking the advantage of both current and voltage controller which is called current driven PWM based voltage controller. Through the VSC the maximum tracked power is pumped into the grid through proper control on DC link voltage. By maintaining the DC link voltage constant during operation, is ensured the total power being generated by PV transferred across the DC bus by the inverter to the grid. Apart from active power transfer the system could be well utilized for providing limited reactive power compensation based on available capacity of the VSC. The detailed system configuration and various control schemes are briefly discussed and explained. The rooftop PV system with proposed scheme is simulated under the MATLAB simulink environment for grid connection to push real power into the grid along with limited power conditioning. The contents are dealt in the following sections: (II) System Configuration (III) PV array modeling and IC MPPT techniques, (IV) Control, (V) MATLAB Simulation, (VI) Performance evaluation.

4.3 HISTORY:

The photovoltaic effect was experimentally demonstrated first by French physicist Edmond Becquerel. In 1839, at age 19, he built the world's first photovoltaic cell in his father's laboratory. Willoughby Smith first described the "Effect of Light on Selenium during the passage of an Electric Current" in a 20 February 1873 issue of Nature. In 1883 Charles Fritts built the first solid state photovoltaic cell by coating the semiconductor selenium with a thin layer of gold to form the junctions; the device was only around 1% efficient. In 1888 Russian physicist Aleksandr Stoletov built the first cell based on the outer photoelectric effect discovered by Heinrich Hertz in 1887.

Albert Einstein explained the underlying mechanism of light instigated carrier excitation—the photoelectric effect—in 1905, for which he received the Nobel Prize in Physics in 1921. Russell Ohl patented the modern junction semiconductor solar cell in 1946 while working on the series of advances that would lead to the transistor.

The first practical photovoltaic cell was publicly demonstrated on 25 April 1954 at Bell Laboratories. The inventors were Daryl Chapin, Calvin Souther Fuller and Gerald Pearson.

Solar cells gained prominence when they were proposed as an addition to the 1958 Vanguard I satellite. By adding cells to the outside of the body, the mission time could be extended with no major changes to the spacecraft or its power systems. In 1959 the United States launched Explorer 6, featuring large wing-shaped solar arrays, which became a common feature in satellites. These arrays consisted of 9600 Hoffman solar cells.

Improvements were gradual over the next two decades. The only significant use was in space applications where they offered the best power-to-weight ratio. However, this success was also the reason that costs remained high, because space users were willing to pay for the best possible cells, leaving no reason to invest in lower-cost, less-efficient solutions. The price was determined largely by the semiconductor industry; their move to integrated circuits in the 1960s led to the availability of larger boules at lower relative prices. As their price fell, the price of the resulting cells did as well. These effects lowered 1971 cell costs to some $100 per watt.

In late 1969, Elliot Berman was investigating organic solar cells, when he joined a team at Exxon SPC who were looking for projects 30 years in the future. The group had concluded that electrical power would be much more expensive by 2000, and felt that this increase in price would make alternative energy sources more attractive, finding solar the most interesting. He conducted a market study and concluded that a price per watt of about $20/watt would create significant demand.

The first improvement was the realization that the standard semiconductor manufacturing process was not ideal. The team eliminated the steps of polishing the wafers and coating them with an anti-reflective layer, relying on the rough-sawn wafer surface. The team also replaced the expensive materials and hand wiring used in space applications with a printed circuit board on the back, acrylic plastic on the front, and silicone glue between the two, "potting" the cells. Solar cells could be made using cast-off material from the electronics market.

4.4 NAVIGATION MARKET:

SPC convinced Tideland Signal to use its panels to power navigational buoys, after finding that Automatic Power, the market leader, had purchased and shelved a solar navigation aid prototype from Hoffman Electronics to protect its battery business. Tideland's solar-powered buoy quickly overtook Automatic.

The rapidly increasing number of offshore oil platforms and loading facilities led Arco to buy Solar Power International (SPI), forming ARCO Solar. ARCO Solar's factory in Camarillo, California was the first dedicated to building solar panels, and was in continual operation from its purchase by ARCO in 1977 until 2011 when it was closed by Solar World.

Following the 1973 oil crisis oil companies used their higher profits to start solar firms, and were for decades the largest producers. Exxon, ARCO, Shell, Amoco (later purchased by BP) and Mobil all had major solar divisions during the 1970s and 1980s. Technology companies also participated, including General Electric, Motorola, IBM, Tyco and RCA.

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.
Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor. The model depicts the time-dependent mathematical relationships among the system’s inputs, states, and outputs. Then, we use Simulink to simulate the behavior of the system over a specified time span. Simulink uses information that you entered into the model to perform the simulation.

4.5 BLOCK DIAGRAM:

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block). The lines represent connections of block inputs to block outputs. Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time. A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate. A block comprises one or more of the following:

1) A set of inputs,
2) A set of states, and
3) A set of outputs.

A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance.

Continuous Versus discrete Blocks Simulink's standard block set includes continuous blocks and discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only at integral multiples of a fixed interval called the block's sample time. Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, depending on whether they are driven by continuous or discrete blocks. A block that can be either discrete or continuous is said to have an implicit sample rate. The implicit sample time is continuous if any of the block's inputs are continuous. The implicit sample time is equal to the shortest input sample time if all the input sample times are integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times.

Simulink can optionally color code a block diagram to indicate the sample times of the blocks it contains, e.g., black (continuous), magenta (constant), yellow (hybrid), red (fastest discrete), and so on. The block contains block name, icon, and block library that contain the block, the purpose of the block.

4.6 SIMULINK BLOCK LIBRARIES:

Simulink organizes its blocks into block libraries according to their behavior.

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-time components.
4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.
6) The Functions & Tables library contains blocks that describe general functions and table look-up operations.

7) The Nonlinear library contains blocks that describe nonlinear functions.
8) The Signal & Systems library contains blocks that allow multiplexing and demultiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types of subsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

4.7 SUB SYSTEMS:

Simulink allows to model a complex system as a set of interconnected subsystems each of which is represented by a block diagram. We create a subsystem using Simulink's Subsystem block and the Simulink model editor. We can embed subsystems with subsystems to any depth to create hierarchical models. We can create conditionally executed subsystems that are executed only when a transition occurs on a triggering or enabling input.

4.8 SOLVERS:

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model. The process of computing the successive states of a system from its model is known as solving the model. No single method of solving a model suffices for all systems. Accordingly, Simulink provides a set of programs, known as solvers, that each embody a particular approach to solving a model. The Simulation Parameters dialog box allows us to choose the solver most suitable for our model.

4.8.1 Fixed-Step and Variable-Step Solvers:

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size.

Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly and increasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time, required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

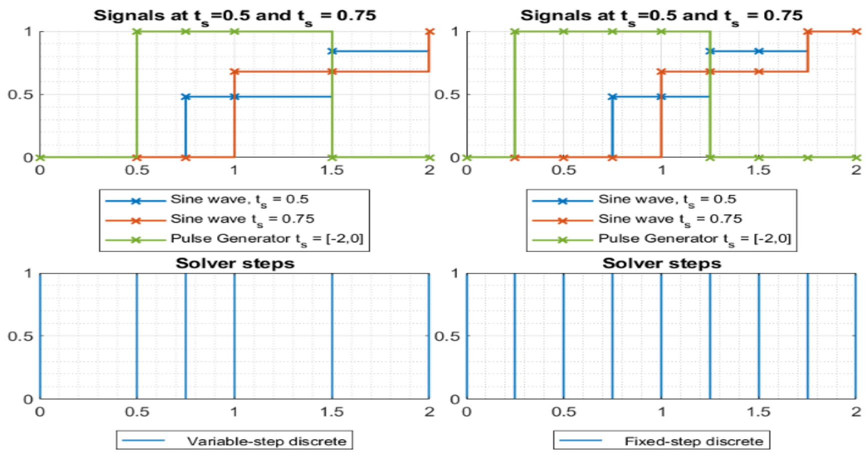

Fig. 4.1 Signals in the model along with the solver steps for the variable-step discrete and the fixed-step discrete solvers

4.8.2 Continuous and Discrete Solvers:

Continuous solvers use numerical integration to compute a model's continuous states at the current time step from the states at previous time steps and the state derivatives. Continuous solvers rely on the model's blocks to compute the values of the model's discrete states at each time step. Mathematicians have developed a wide variety of numerical integration techniques for solving the ordinary differential equations (ODEs) that represent the continuous states of dynamic systems. Simulink provides an extensive set of fixed-step and variable-step continuous solvers, each implementing a specific ODE solution method. Some continuous solvers subdivide the simulation time span into major and minor steps, where a minor time step represents a subdivision of the major time step. The solver produces a result at each major time step. It use results at the minor time steps to improve the accuracy of the result at the major time step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time-step for a model and nothing else. They do not compute continuous states and they rely on the model's blocks to update the model's discrete states. We can use a continuous solver, but not a discrete solver, to solve a model that contains both continuous and discrete states. This is because a discrete solver does not handle continuous states. If you select a discrete solver for a continuous model, Simulink disregards your selection and uses a continuous solver instead when solving the model.

Simulink provides two discrete solvers, a fixed-step discrete solver and a variable-step discrete solver. The fixed-step solver by default chooses a step size and hence simulation rate fast enough to track state changes in the fastest block in our model. The variable-step solver adjusts the simulation step size to keep pace with the actual rate of discrete state changes in our model. This can avoid unnecessary steps and hence shorten simulation time for multirate models.

4.9 MODEL EXECUTION PHASE:

In the simulation model execution phase, Simulink successively computes the states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps. The length of time between steps is called the step size. The step size depends on the type of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states have discontinuities (Zero Crossing Detection). At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated. At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

1) Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and states to the output function as it may require these arguments to compute the block's output. Simulink

updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.

2) Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's continuous states by numerically integrating the time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.
3) Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.
4) Computes the time for the next time step.Simulink repeats steps 1 through 4 until the simulation stop time is reached.

4.10 BLOCK SORTING RULES:

Simulink uses the following basic update rules to sort the blocks:

1) Each block must be updated before any of the direct-feed through blocks that it drives.This rule ensures that the inputs to direct-feed through blocks will be valid when they are updated.
2) Non direct-feed through blocks can be updated in any order as long as they are updated before any direct-feed through blocks that they drive. This rule can be met by putting all non direct-feed through blocks at the head of the update list in any order. It thus allows Simulink to ignore non direct-feed through blocks during the sorting process.

The result of applying these rules is an update list in which non direct-feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct-feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output. However, an algebraic loop can represent a set of simultaneous algebraic equations (hence the name) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step.

Accordingly, Simulink assumes that loops involving direct-feed through blocks do, in fact, represent a solvable set of algebraic equations and attempts to solve them each time the block is updated during a simulation.

4.11 DETERMINING BLOCK UPDATE ORDER:

During a simulation, Simulink updates the states and outputs of a model's blocks once per time step. The order in which the blocks are updated is therefore critical to the validity of the results. In particular, if a block's outputs are a function of its inputs at the current time step, the block must be updated after the blocks that drive its inputs. Otherwise, the block's outputs will be invalid. The order in which blocks are stored in a model file is not necessarily the order in which they need to be updated during a simulation. Consequently, Simulink sorts the blocks into the correct order during the model initialization phase.

In order to create a valid update ordering, Simulink categorizes blocks according to the relationship of outputs to inputs. Blocks whose current outputs depend on their current inputs are called direct feed through blocks. All other blocks are called non direct-feed through blocks. Examples of direct-feed through blocks include the Gain, Product, and Sum blocks. Examples of non direct-feed through blocks include the Integrator block (its output is a function purely of its state), the Constant block (it does not have an input), and the Memory block (its output is dependent on its input in the previous time step). Simulink allows you to assign update priorities to blocks. Simulink updates higher priority blocks before lower priority blocks. Simulink honors the priorities only if they are consistent with its block sorting rules.

CHAPTER 5

SIMULATION RESULTS

Using the MATLAB/Simulink software, several simulations are implemented to evaluate the proposed model and the results obtained are as shown. The Simulation circuit with PV UPQC is implemented and the simulation results are then compared with the circuit model without UPQC.

The below Fig. 5.1, shows the circuit model without UPQC. The circuit is simulated and the output voltage, output current waveforms and the THD of the system are observed.

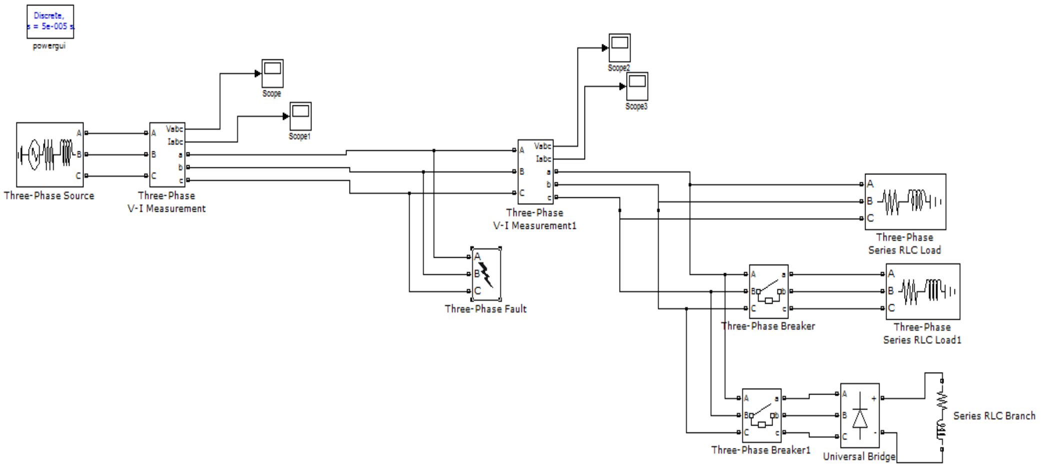

Fig. 5.1 Proposed circuit without UPQC

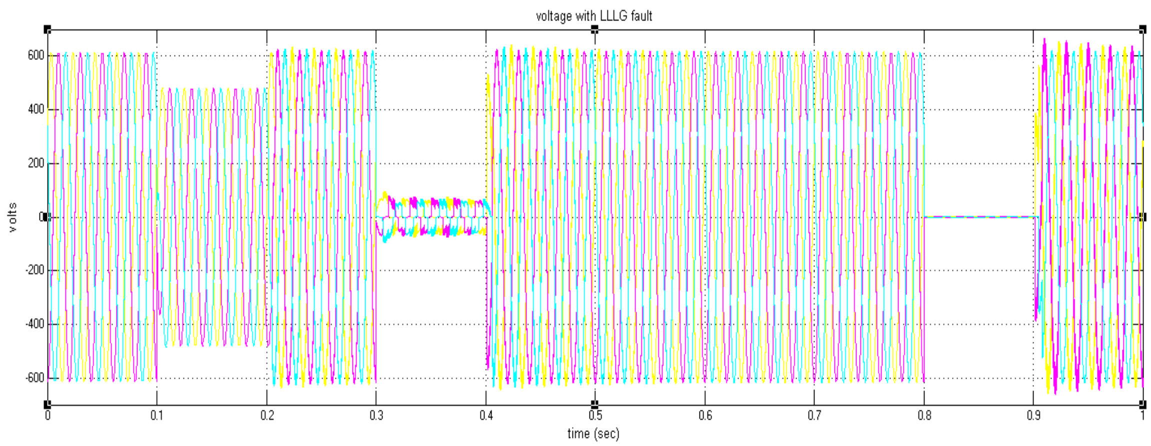

Fig. 5.2 Output voltage without UPQC

Fig. 5.2 shows the output voltage waveform without UPQC.The system without UPQC experiences a voltage disturbance when a LLLG fault occurred this effects the system power quality.

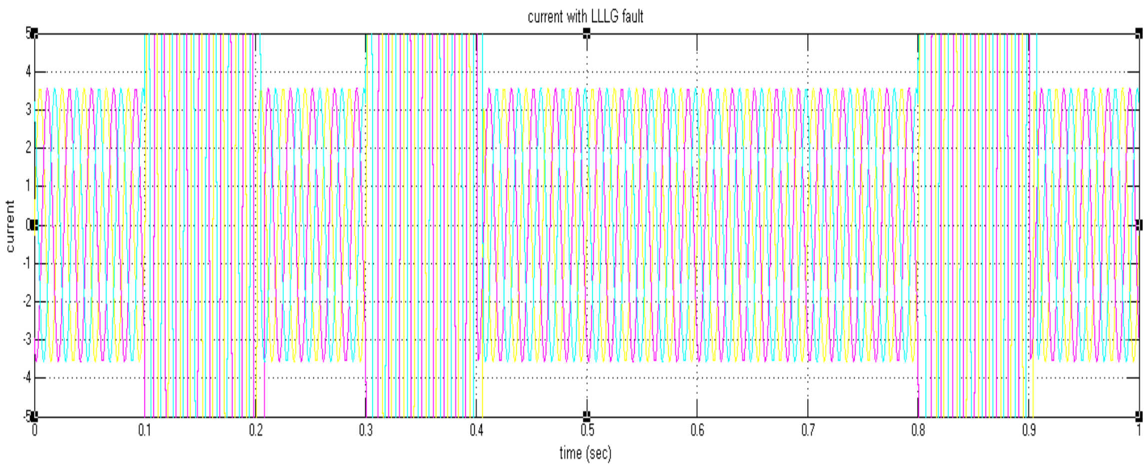

Fig. 5.3 Output current waveform

As shown in Fig. 5.3, A high current is observed under LLLG fault condition to the circuit with PI controller. This increases the system loses and effects the quality of power supply.

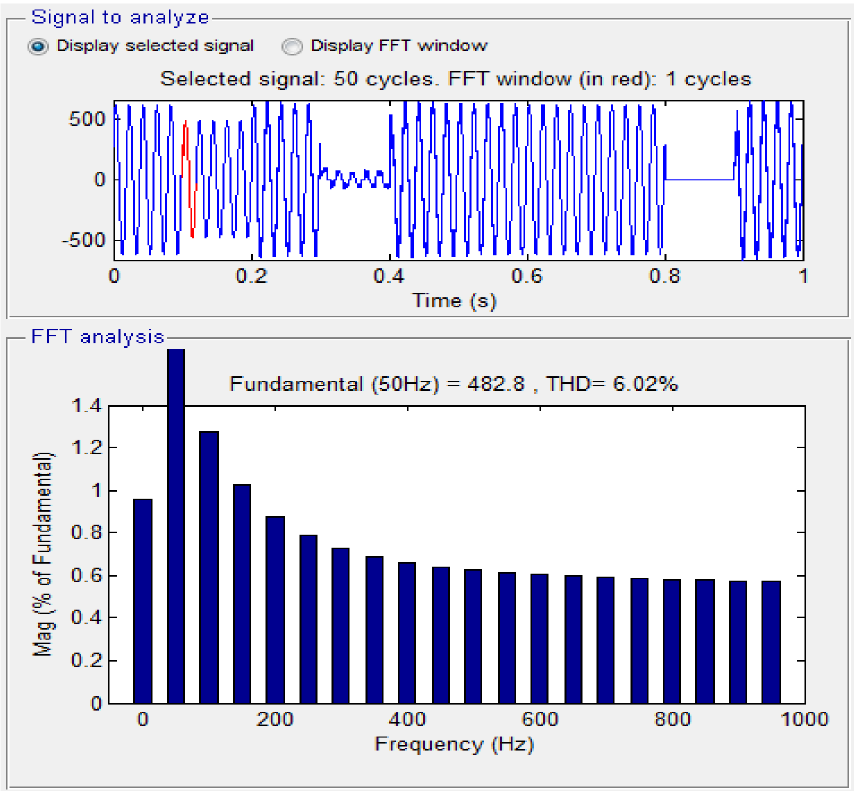

Fig. 5.4 THD with PI controller

The above graph clearly describes the THD of the system with PI controller. It is observed a total harmonic distortion of 6.02%.

The below Fig. 5.5 shows the simulation circuit with PV UPQC. The circuit is simulated and the results obtained are observed and the performance of PV UPQC is evaluated.

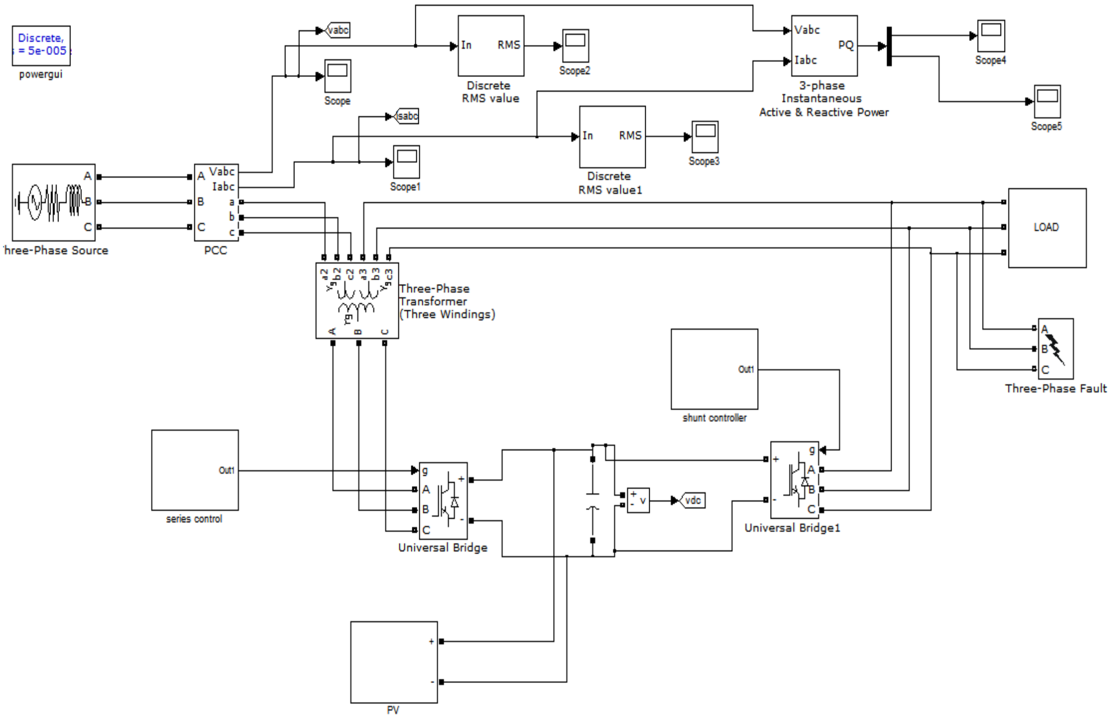

Fig. 5.5 Simulation circuit with PV UPQC

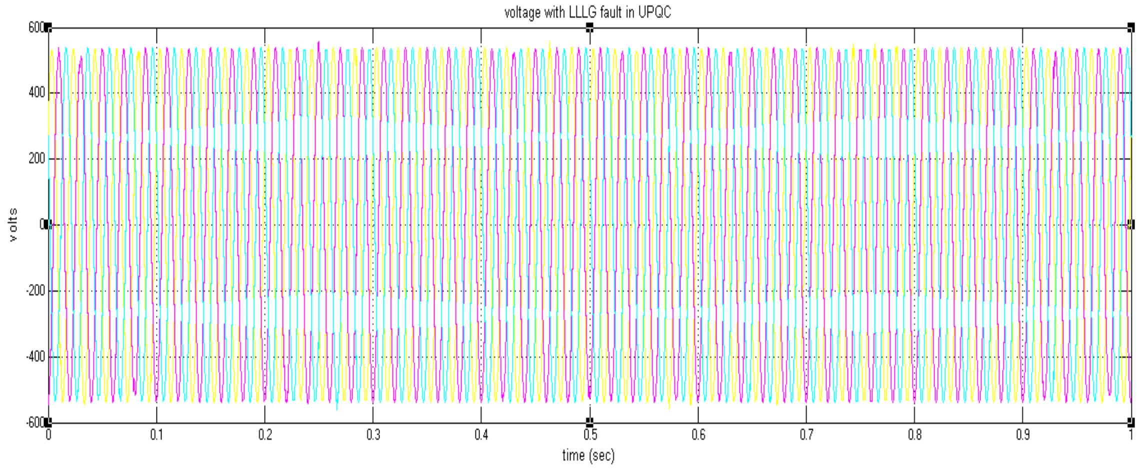

Fig. 5.6 Output voltage waveform

As shown in Fig. 5.6, the system with UPQC has generated a stabilized output voltage waveform without any distortions maintained during the LLLG fault condition.

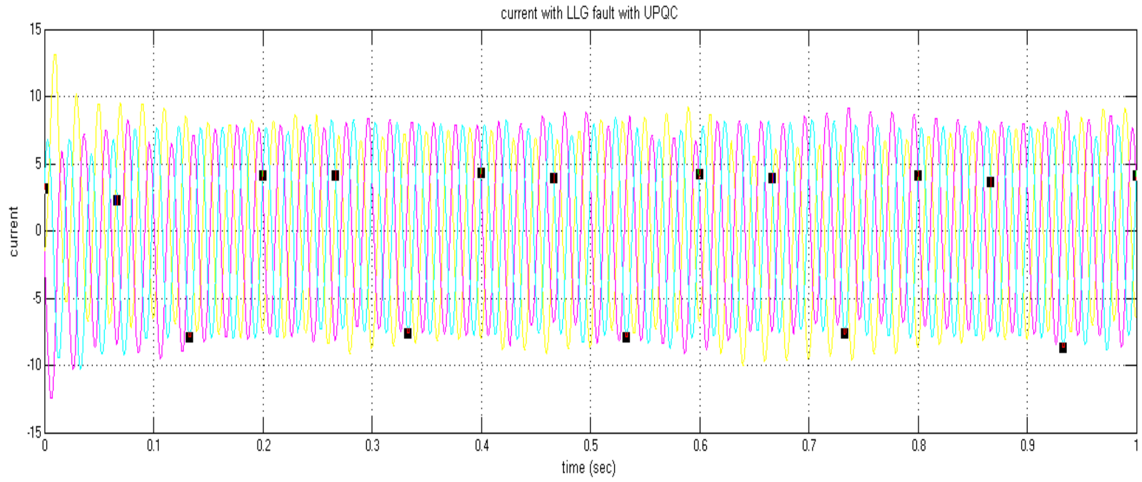

Fig. 5.7 Output current waveform

As shown in Fig. 5.7, the current waveform still have some distortions under LLLG fault condition with UPQC Controller. This effects the system parameters.

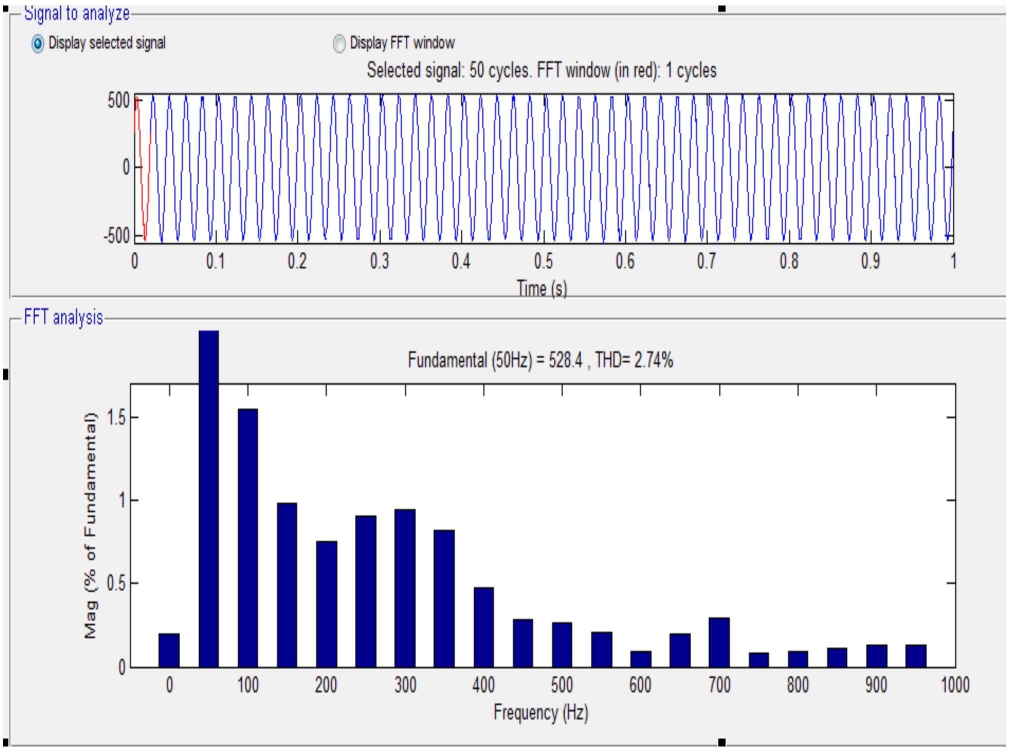

Fig. 5.8 THD with UPQC

The above figure shows that, the THD of the system with UPQC controller has reduced the THD of 6.02% to 2.74%. this clearly shows that UPQC has achieved high efficiency when compared to the PI controller.

CHAPTER 6
CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION:

A noticeable trend in distribution systems is the emergence of distributed harmonic producing loads. These loads typically have comparable sizes and are distributed all over an electric network. There is a need to develop new techniques to assess harmonic distortions for systems with distributred harmonic sources. The objective of the project is to minimize the power quality problems with the implementation of power quality enhancement device pv UPQC. This device has the capacity to improve the power quality at the point of installation. Without pv UPQC the system voltage and currents are unbalanced undar fault condition with THD of 6.02%. When we applied pv UPQC with PI controller the output voltage is balanced and still some distortions observed in current waveforms under fault conditions the THD is reduced to 2.74%. By using the proposed Hybrid controller with pv UPQC the system output voltage and currents are balanced without any distortion and the THD is reduced finally to 0.08%. Hence the analysis proves that the proposed Hybrid controller with UPQC achieved better results when compared to the existing models.

6.2 ADVANTAGES:

- UPQC can compensate voltage related power quality issues such as voltage harmonics, voltage swag/swell, voltage flicker etc.
- UPQC can also compensate current related issues like reactive power compensation, power factor correction, current harmonics and load unbalance compensation.
- There is significant increase in interest for using UPQC in distribution generation associated with smart grids because of availability of high frequency switching devices and fast computing devices at lower cost.

6.3 APPLICATIONS:

- It can be used for mitigation of voltage sag, swell and voltage dip.
- It is useful for balancing power factor, voltage and current harmonic mitigation.
- Source current THD and load voltage THD can be improved.
- The performance of UPQC has been found satisfactory during transient condition.

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APPENDIX

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

(a) Development Environment

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

(b) The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

(e) The MATLAB Application Program Interface (API)

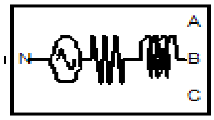
This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

(f) MATLAB Documentation

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

The various MATLAB tools used are:

(1) Three phase source block

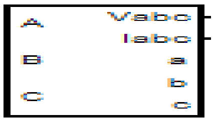


Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

(2) VI measurement block

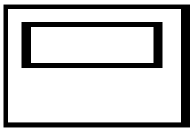
The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents.



Three Phase V-I Measurement

(3) Scope

Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes. The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation.



Scope

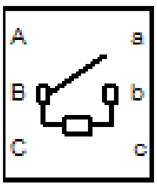
(4) Three-Phase Series RLC Load

The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

Three-Phase Series RLC Load

(5) Three-Phase Breaker block

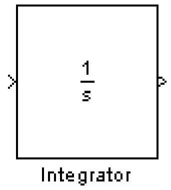
The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.



Three-Phase Breaker Block

(6) Integrator

Library: Continuous



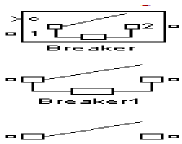
Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

(7) Breaker

Implement circuit breaker opening at current zero crossing.

Library: Elements



Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it).

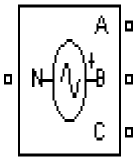
When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

(8) Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources



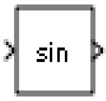
Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

(9) Trigonometric Function

Specified trigonometric function on input

Library: Math Operations



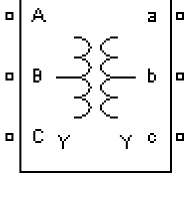
Trigonometric Function

Purpose: The Trigonometric Function block performs common trigonometric functions.

(**10) Three-Phase Transformer (Two Windings)**

Implement three-phase transformer with configurable winding connections

Library: **Elements**



Three Phase Transformer

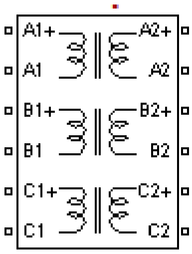
Purpose:

The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

(11) Three-Phase Transformer 12 Terminals

Implement three single-phase, two-winding transformers where all terminals are accessible

Library*:* Elements



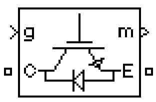
Two winding Transformer

Purpose: The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

(12) IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: **Power Electronics**



IGBT

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

A

PROJECT REPORT

on

Vehicle-To-Grid Technology in a Micro-grid Using DC Fast Charging Architecture

Submitted by

1) Ms. H.Priyanka (18K85A0210)

2) Mr. K.Yoghessh (16K81A0219)

3) Mr. Ravi Chandra (16K81A0228)

4) Mr. S.Hari Charan Reddy (17K81A0245)

In partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

V.Bharath Kumar, M.Tech,(PhD)

Assistant Professor

DEPARTMENT OF ELECTRICAL AND ELCTRONICS ENGINEERING

ST.MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled "**Vehicle-To-Grid Technology in a Micro-grid Using DC Fast Charging Architecture"**, is being submitted by **1.Ms. H.Priyanka (18K85A0210), 2.Mr. K.Yoghessh (16K81A0219), 3.Mr. Ravi Chandra (16K81A0228) 4.Mr. S.Hari Charan Reddy (17K81A0245)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN ELETRICAL AND ELECTRONICS ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

V.BharathKumar
Department of EEE

Head of the Department
Dr.N. Ramchandra
Department of EEE

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of Electrical And Electronics Engineering', session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled Vehicle-To-Grid Technology in a Micro-grid Using DC Fast Charging Architecture is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

1) Ms. H.Priyanka	(18K85A0210)
2) Mr. K.Yoghessh	(16K81A0219)
3) Mr. Ravi Chandra	(16K81A0228)
4) Mr. S.Hari Charan Reddy	(17K81A0245)

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1. Ms. H.Priyanka (18K85A0210)
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INDEX

ABSTRACT

Electric Vehicle (EV) batteries can be utilized as potential energy storage devices in micro-grids. They can help in micro-grid energy management by storing energy when there is surplus (Grid-To-Vehicle, G2V) and supplying energy back to the grid (Vehicle-To-Grid, V2G) when there is demand for it. Proper infrastructure and control systems have to be developed in order to realize this concept. Architecture for implementing a V2G-G2V system in a micro-grid using level-3 fast charging of EVs is presented in this paper. A micro-grid test system is modeled which has a dc fast charging station for interfacing the EVs. Simulation studies are carried out to demonstrate V2G-G2V power transfer. Test results show active power regulation in the micro-grid by EV batteries through G2V-V2G modes of operation. The charging station design ensures minimal harmonic distortion of grid injected current and the controller gives good dynamic performance in terms of dc bus voltage stability.

LIST OF FIGURES

LIST OF OUTPUT SCREENS

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION:

Energy storage systems are important components of a micro-grid as they enable the integration of intermittent renewable energy sources. Electric vehicle (EV) batteries can be utilized as effective storage devices in micro-grids when they are plugged-in for charging. Most personal transportation vehicles sit parked for about 22 hours each day, during which time they represent an idle asset. EVs could potentially help in micro-grid energy management by storing energy when there is surplus (Grid-To-Vehicle, G2V) and feeding this energy back to the grid when there is demand for it (Vehicle-To-Grid). V2G applied to the general power grid faces some challenges such as; it is complicated to control, needs large amount of EVs and is hard to realize in short term [1]. In this scenario, it is easy to implement V2G system in a micro-grid. The Society of Automotive Engineers defines three levels of charging for EVs. Level 1 charging uses a plug to connect to the vehicle's on-board charger and a standard household (120 V) outlet.

This is the slowest form of charging and works for those who travel less than 60 kilometers a day and have all night to charge. Level 2 charging uses a dedicated Electric Vehicle Supply Equipment (EVSE) at home or at a public station to provide power at 220 V or 240 V and up to 30 A. The level 3 charging is also referred to as dc fast charging. DC fast charging stations provide charging power up to 90 kW at 200/450 V, reducing the charging time to 20-30 mins. DC fast charging is preferred for implementing a V2G architecture in micro-grid due to the quick power transfer that is required when EVs are utilized for energy storage. Also the dc bus can be used for integrating renewable generation sources into the system. In majority of the previous studies, V2G concept has been applied in the general power grid for services like peak shaving, valley filling, regulation and spinning reserves.

The V2G development in a micro-grid facility to support power generation from intermittent renewable sources of energy is still at its infancy. Also, level 1 and level 2 ac charging is utilized for V2G technology in most of the works reported. These ac charging systems are limited by the power rating of the on-board charger. An additional issue is that the distribution grid has not been designed for bi-directional energy flow. In this scenario, there is a research need for developing technically viable charging station architectures to facilitate V2G technology in micro-grids. This work proposes a dc quick charging station infrastructure with V2G capability in a micro-grid facility. The dc bus used to interface EVs is also used for integrating a solar photo-voltaic (PV) array into the micro-grid. The proposed architecture allows high power bi-directional charging for EVs through off-board chargers. Effectiveness of the proposed model is evaluated based on MATLAB/Simulink simulations for both V2G and G2V modes of operation.

1.2 DC FAST CHARGING STATION CONFIGURATION FOR V2G:

The configuration for dc fast charging station to implement V2G-G2V infrastructure in a micro-grid. EV batteries are connected to the dc bus through off-board chargers. A grid connected inverter connects the dc bus to the utility grid through an LCL filter and a step-up transformer. The important components of the charging station are described below. For dc fast charging, the chargers are located off-board and are enclosed in an EVSE. A bidirectional dc-dc converter forms the basic building block of an off-board charger with V2G capability. It forms the interface between EV battery system and the dc distribution grid. The converter configuration is shown in Fig. 2. It consists of two IGBT/MOSFET switches that are always operated by complimentary control signals. Buck mode of operation (charging mode): When the upper switch is operating, the converter acts as a buck converter stepping down the input voltage to battery charging voltage. During the on state, current flows through the switch and inductor to the battery. This is the charging operation, where the power flow is from the grid to vehicle (G2V). When the switch is off, the current takes its return path through the inductor and diode of lower switch and completes the circuit. If is the duty ratio of the upper switch, the battery voltage is given by:

$$V_{batt} = V_{dc} * D$$

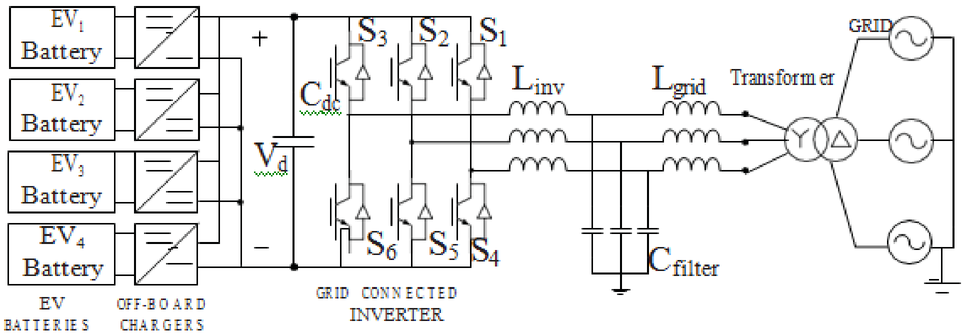

Fig.1.0. ev charging station for fast dc charging

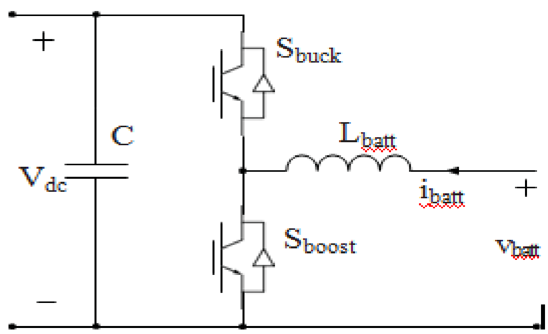

Fig.1.1..battery charger configuration

1.2.1 Boost mode of operation (discharging mode):

When the lower switch is operating, the converter acts as a boost converter stepping up the battery voltage to the dc bus voltage. When the switch is in on state, current continues to flow through the inductor and completes its circuit through the anti-parallel diode of the upper switch, and the capacitor. The net power flow in this case is from the vehicle to the grid (V2G) and the battery operates in the discharge mode. If the capacitor is large enough to provide a constant dc voltage, the output voltage during boost mode of operation is given by Where D is the duty cycle of the lower switch.

$$V_{dc} = \frac{V_{batt}}{1 - D'}$$

CHAPTER 2

BATTERY STORAGE SYSTEM

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode.[2] The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to include devices composed of a single cell.

Primary (“single-use” or "disposable") batteries are used once and discarded, as the electrode materials are irreversibly changed during discharge; a common example is the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and mobile phones.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smartphones, to large lead acid batteries or lithium-ion batteries in vehicles, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centers.

Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. In automobiles, this is somewhat offset by the higher efficiency of electric motors in converting chemical energy to mechanical work, compared to combustion engines.

The usage of "battery" to describe a group of electrical devices dates to Benjamin Franklin, who in 1748 described multiple Leyden jars by analogy to a battery of cannon (Benjamin Franklin borrowed the term "battery" from the military, which refers to weapons functioning together).

Italian physicist Alessandro Volta built and described the first electrochemical battery, the voltaic pile, in 1800.This was a stack of copper and zinc plates, separated by brine-soaked paper disks, that could produce a steady current for a considerable length of time. Volta did not understand that the voltage was due to chemical reactions. He thought that his cells were an inexhaustible source of energy, and that the associated corrosion effects at the electrodes were a mere nuisance, rather than an unavoidable consequence of their operation, as Michael Faraday showed in 1834.

Although early batteries were of great value for experimental purposes, in practice their voltages fluctuated and they could not provide a large current for a sustained period. The Daniell cell, invented in 1836 by British chemist John Frederic Daniell, was the first practical source of electricity, becoming an industry standard and seeing widespread adoption as a power source for electrical telegraph networks. It consisted of a copper pot filled with a copper sulfate solution, in which was immersed an unglazed earthenware container filled with sulfuric acid and a zinc electrode. These wet cells used liquid electrolytes, which were prone to leakage and spillage if not handled correctly. Many used glass jars to hold their components, which made them fragile and potentially dangerous. These characteristics made wet cells unsuitable for portable appliances. Near the end of the nineteenth century, the invention of dry cell batteries, which replaced the liquid electrolyte with a paste, made portable electrical devices practical.

Batteries convert chemical energy directly to electrical energy. In many cases, the electrical energy released is the difference in the cohesive[13] or bond energies of the metals, oxides, or molecules undergoing the electrochemical reaction.[3] For instance, energy can be stored in Zn or Li, which are high-energy metals because they are not stabilized by d-electron bonding, unlike transition metals. Batteries are designed such that the energetically favorable redox reaction can occur only if electrons move through the external part of the circuit.

A battery consists of some number of voltaic cells. Each cell consists of two half-cells connected in series by a conductive electrolyte containing metal cations. One half-cell includes electrolyte and the negative electrode, the electrode to which anions (negatively charged ions) migrate; the other half-cell includes electrolyte and the positive electrode, to which cations (positively charged ions) migrate. Cations are reduced (electrons are added) at the cathode, while metal atoms are oxidized (electrons are removed) at the anode.[14] Some cells use different electrolytes for each half-cell; then a separator is used to prevent mixing of the electrolytes while allowing ions to flow between half-cells to complete the electrical circuit.

Each half-cell has an electromotive force (emf, measured in volts) relative to a standard. The net emf of the cell is the difference between the emfs of its half-cells.[15] Thus, if the electrodes have emfs and then the net emf is; in other words, the net emf is the difference between the reduction potentials of the half-reactions.

The electrical driving force or across the terminals of a cell is known as the terminal voltage (difference) and is measured in volts. The terminal voltage of a cell that is neither charging nor discharging is called the open-circuit voltage and equals the emf of the cell. Because of internal resistance, the terminal voltage of a cell that is discharging is smaller in magnitude than the open-circuit voltage and the terminal voltage of a cell that is charging exceeds the open-circuit voltage. An ideal cell has negligible internal resistance, so it would maintain a constant terminal voltage of until exhausted, then dropping to zero. If such a cell maintained 1.5 volts and produce a charge of one coulomb then on complete discharge it would have performed 1.5 joules of work.[In actual cells, the internal resistance increases under discharge and the open-circuit voltage also decreases under discharge. If the voltage and resistance are plotted against time, the resulting graphs typically are a curve; the shape of the curve varies according to the chemistry and internal arrangement employed.

The voltage developed across a cell's terminals depends on the energy release of the chemical reactions of its electrodes and electrolyte. Alkaline and zinc–carbon cells have different chemistries, but approximately the same emf of 1.5 volts; likewise NiCd and NiMH cells have different chemistries, but approximately the same emf of 1.2 volts. The high electrochemical potential changes in the reactions of lithium compounds give lithium cells emfs of 3 volts or more.

2.1 BATTERIES ARE CLASSIFIED INTO PRIMARY AND SECONDARY FORMS:

Primary batteries are designed to be used until exhausted of energy then discarded. Their chemical reactions are generally not reversible, so they cannot be recharged. When the supply of reactants in the battery is exhausted, the battery stops producing current and is useless.[22]

Secondary batteries can be recharged; that is, they can have their chemical reactions reversed by applying electric current to the cell. This regenerates the original chemical reactants, so they can be used, recharged, and used again multiple times.

Some types of primary batteries used, for example, for telegraph circuits, were restored to operation by replacing the electrodes. Secondary batteries are not indefinitely rechargeable due to dissipation of the active materials, loss of electrolyte and internal corrosion.

2.1.2 Main article Primary cell :

Primary batteries, or primary cells, can produce current immediately on assembly. These are most commonly used in portable devices that have low current drain, are used only intermittently, or are used well away from an alternative power source, such as in alarm and communication circuits where other electric power is only intermittently available. Disposable primary cells cannot be reliably recharged, since the chemical reactions are not easily reversible and active materials may not return to their original forms. Battery manufacturers recommend against attempting to recharge primary cells.[25] In general, these have higher energy densities than rechargeable batteries,[26] but disposable batteries do not fare well under high-drain applications with loads under 75 ohms (75 Ω). Common types of disposable batteries include zinc–carbon batteries and alkaline batteries.

2.1.3 Main article Rechargeable battery :

Secondary batteries, also known as secondary cells, or rechargeable batteries, must be charged before first use; they are usually assembled with active materials in the discharged state. Rechargeable batteries are (re)charged by applying electric current, which reverses the chemical reactions that occur during discharge/use. Devices to supply the appropriate current are called chargers.

The oldest form of rechargeable battery is the lead–acid battery, which are widely used in automotive and boating applications. This technology contains liquid electrolyte in an unsealed container, requiring that the battery be kept upright and the area be well ventilated to ensure safe dispersal of the hydrogen gas it produces during overcharging. The lead–acid battery is relatively heavy for the amount of electrical energy it can supply. Its low manufacturing cost and its high surge current levels make it common where its capacity (over approximately 10 Ah) is more important than weight and handling issues. A common application is the modern car battery, which can, in general, deliver a peak current of 450 amperes.

The sealed valve regulated lead–acid battery (VRLA battery) is popular in the automotive industry as a replacement for the lead–acid wet cell. The VRLA battery uses an immobilized sulfuric acid electrolyte, reducing the chance of leakage and extending shelf life.[27] VRLA batteries immobilize the electrolyte. The two types are : Gel batteries (or "gel cell") use a semi-solid electrolyte.

2.2 ABSORBED GLASS MAT (AGM) BATTERIES ABSORB THE ELECTROLYTE IN A SPECIAL FIBERGLASS MATTING:

Other portable rechargeable batteries include several sealed "dry cell" types, that are useful in applications such as mobile phones and laptop computers. Cells of this type (in order of increasing power density and cost) include nickel–cadmium (NiCd), nickel–zinc (NiZn), nickel metal hydride (NiMH), and lithium-ion (Li-ion) cells. Li-ion has by far the highest share of the dry cell rechargeable market. NiMH has replaced NiCd in most applications due to its higher capacity, but NiCd remains in use in power tools, two-way radios, and medical equipment.

In the 2000s, developments include batteries with embedded electronics such as USBCELL, which allows charging an AA battery through a USB connector, nanoball batteries that allow for a discharge rate about 100x greater than current batteries, and smart battery packs with state-of-charge monitors and battery protection circuits that prevent damage on over-discharge. Low self-discharge (LSD) allows secondary cells to be charged prior to shipping.

2.2.1 Cell types :

Many types of electrochemical cells have been produced, with varying chemical processes and designs, including galvanic cells, electrolytic cells, fuel cells, flow cells and voltaic piles.[29]

2.2.2 Wet cell :

A wet cell battery has a liquid electrolyte. Other names are flooded cell, since the liquid covers all internal parts, or vented cell, since gases produced during operation can escape to the air. Wet cells were a precursor to dry cells and are commonly used as a learning tool for electrochemistry. They can be built with common laboratory supplies, such as beakers, for demonstrations of how electrochemical cells work. A particular type of wet cell known as a concentration cell is important in understanding corrosion. Wet cells may be primary cells (non-rechargeable) or secondary cells (rechargeable). Originally, all practical primary batteries such as the Daniell cell were built as open-top glass jar wet cells. Other primary wet cells are the Leclanche cell, Grove cell, Bunsen cell, Chromic acid cell, Clark cell, and Weston cell. The Leclanche cell chemistry was adapted to the first dry cells. Wet cells are still used in automobile batteries and in industry for standby power for switchgear, telecommunication or large uninterruptible power supplies, but in many places batteries with gel cells have been used instead. These applications commonly use lead–acid or nickel–cadmium cells.

A dry cell uses a paste electrolyte, with only enough moisture to allow current to flow. Unlike a wet cell, a dry cell can operate in any orientation without spilling, as it contains no free liquid, making it suitable for portable equipment. By comparison, the first wet cells were typically fragile glass containers with lead rods hanging from the open top and needed careful handling to avoid spillage. Lead–acid batteries did not achieve the safety and portability of the dry cell until the development of the gel battery.

A common dry cell is the zinc–carbon battery, sometimes called the dry Leclanché cell, with a nominal voltage of 1.5 volts, the same as the alkaline battery (since both use the same zinc–manganese dioxide combination). A standard dry cell comprises a zinc anode, usually in the form of a cylindrical pot, with a carbon cathode in the form of a central rod. The electrolyte is ammonium chloride in the form of a paste next to the zinc anode. The remaining space between the electrolyte and carbon cathode is taken up by a second paste consisting of ammonium chloride and manganese dioxide, the latter acting as a depolariser. In some designs, the ammonium chloride is replaced by zinc chloride.

2.3 MOLTEN SALT:

Molten salt batteries are primary or secondary batteries that use a molten salt as electrolyte. They operate at high temperatures and must be well insulated to retain heat.

2.4 RESERVE:

reserve battery can be stored unassembled (unactivated and supplying no power) for a long period (perhaps years). When the battery is needed, then it is assembled (e.g., by adding electrolyte); once assembled, the battery is charged and ready to work. For example, a battery for an electronic artillery fuze might be activated by the impact of firing a gun. The acceleration breaks a capsule of electrolyte that activates the battery and powers the fuze's circuits. Reserve batteries are usually designed for a short service life (seconds or minutes) after long storage (years). A water-activated battery for oceanographic instruments or military applications becomes activated on immersion in water.

2.5 CELL PERFORMANCE:

A battery's characteristics may vary over load cycle, over charge cycle, and over lifetime due to many factors including internal chemistry, current drain, and temperature. At low temperatures, a battery cannot deliver as much power. As such, in cold climates, some car owners install battery warmers, which are small electric heating pads that keep the car battery warm.

A battery's capacity is the amount of electric charge it can deliver at the rated voltage. The more electrode material contained in the cell the greater its capacity. A small cell has less capacity than a larger cell with the same chemistry, although they develop the same open-circuit voltage.[30] Capacity is measured in units such as amp-hour (A·h). The rated capacity of a battery is usually expressed as the product of 20 hours multiplied by the current that a new battery can consistently supply for 20 hours at 68 °F (20 °C), while remaining above a specified terminal voltage per cell. For example, a battery rated at 100 A·h can deliver 5 A over a 20-hour period at room temperature. The fraction of the stored charge that a battery can deliver depends on multiple factors, including battery chemistry, the rate at which the charge is delivered (current), the required terminal voltage, the storage period, ambient temperature and other factors.[30]

The higher the discharge rate, the lower the capacity. The relationship between current, discharge time and capacity for a lead acid battery is approximated (over a typical range of current values) by Peukert's law:

where

is the capacity when discharged at a rate of 1 amp.

is the current drawn from battery (A).

is the amount of time (in hours) that a battery can sustain.

is a constant around 1.3.

Batteries that are stored for a long period or that are discharged at a small fraction of the capacity lose capacity due to the presence of generally irreversible side reactions that consume charge carriers without producing current. This phenomenon is known as internal self-discharge. Further, when batteries are recharged, additional side reactions can occur, reducing capacity for subsequent discharges. After enough recharges, in essence all capacity is lost and the battery stops producing power.

Internal energy losses and limitations on the rate that ions pass through the electrolyte cause battery efficiency to vary. Above a minimum threshold, discharging at a low rate delivers more of the battery's capacity than at a higher rate. Installing batteries with varying A·h ratings does not affect device operation (although it may affect the operation interval) rated for a specific voltage unless load limits are exceeded. High-drain loads such as digital cameras can reduce total capacity, as happens with alkaline batteries.

For example, a battery rated at 2 A·h for a 10- or 20-hour discharge would not sustain a current of 1 A for a full two hours as its stated capacity implies.

The C-rate is a measure of the rate at which a battery is being charged or discharged. It is defined as the current through the battery divided by the theoretical current draw under which the battery would deliver its nominal rated capacity in one hour. It has the units h^{-1}.

C-rate is used as a rating on batteries to indicate the maximum current that a battery can safely deliver on a circuit. Standards for rechargeable batteries generally rate the capacity over a 4-hour, 8 hour or longer discharge time. Types intended for special purposes, such as in a computer uninterruptible power supply, may be rated by manufacturers for discharge periods much less than one hour. Because of internal resistance loss and the chemical processes inside the cells, a battery rarely delivers nameplate rated capacity in only one hour.

2.6 FAST-CHARGING, LARGE AND LIGHT BATTERIES:

As of 2017, the world's largest battery was built in South Australia by Tesla. It can store 129 MWh. A battery in Hebei Province, China which can store 36 MWh of electricity was built in 2013 at a cost of $500 million. Another large battery, composed of Ni–Cd cells, was in Fairbanks, Alaska. It covered 2,000 square metres (22,000 sq ft)—bigger than a football pitch—and weighed 1,300 tonnes. It was manufactured by ABB to provide backup power in the event of a blackout. The battery can provide 40 MW of power for up to seven minutes. Sodium–sulfur batteries have been used to store wind power. A 4.4 MWh battery system that can deliver 11 MW for 25 minutes stabilizes the output of the Auwahi wind farm in Hawaii.

2.6.1 Life time :

Battery life (and its synonym battery lifetime) has two meanings for rechargeable batteries but only one for non-chargeables. For rechargeable, it can mean either the length of time a device can run on a fully charged battery or the number of charge/discharge cycles possible before the cells fail to operate satisfactorily. For a non-rechargeable these two lives are equal since the cells last for only one cycle by definition. (The term shelf life is used to describe how long a battery will retain its performance between manufacture and use.) Available capacity of all batteries drops with decreasing temperature. In contrast to most of today's batteries, the Zamboni pile, invented in 1812, offers a very long service life without refurbishment or recharge, although it supplies current only in the nanoamp range. The Oxford Electric Bell has been ringing almost continuously since 1840 on its original pair of batteries, thought to be Zamboni piles.[citation needed]

2.6.2 Self-discharge :

Disposable batteries typically lose 8 to 20 percent of their original charge per year when stored at room temperature (20–30 °C).[40] This is known as the "self-discharge" rate, and is due to non-current-producing "side" chemical reactions that occur within the cell even when no load is applied. The rate of side reactions is reduced for batteries stored at lower temperatures, although some can be damaged by freezing.

Old rechargeable batteries self-discharge more rapidly than disposable alkaline batteries, especially nickel-based batteries; a freshly charged nickel cadmium (NiCd) battery loses 10% of its charge in the first 24 hours, and thereafter discharges at a rate of about 10% a month. However, newer low self-discharge nickel metal hydride (NiMH) batteries and modern lithium designs display a lower self-discharge rate (but still higher than for primary batteries).

2.6.3 Corrosion:

Internal parts may corrode and fail, or the active materials may be slowly converted to inactive forms.

2.6.4 Physical component changes :

The active material on the battery plates changes chemical composition on each charge and discharge cycle; active material may be lost due to physical changes of volume, further limiting the number of times the battery can be recharged. Most nickel-based batteries are partially discharged when purchased, and must be charged before first use. Newer NiMH batteries are ready to be used when purchased, and have only 15% discharge in a year.

Some deterioration occurs on each charge–discharge cycle. Degradation usually occurs because electrolyte migrates away from the electrodes or because active material detaches from the electrodes. Low-capacity NiMH batteries (1,700–2,000 mA·h) can be charged some 1,000 times, whereas high-capacity NiMH batteries (above 2,500 mA·h) last about 500 cycles. NiCd batteries tend to be rated for 1,000 cycles before their internal resistance permanently increases beyond usable values.

CHAPTER 3

PROPOSED DC TO DC CONVERTER

buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a fly back converter using a single inductor instead of a transformer. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, ranging from much larger (in absolute magnitude) than the input voltage, down to almost zero.

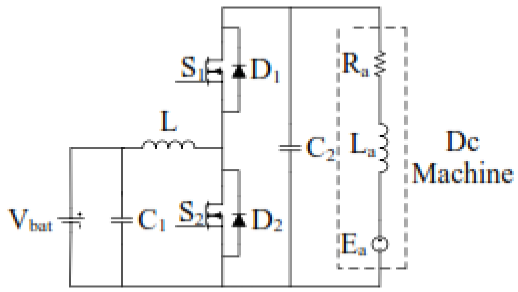

Fig.3.1.proposed converter

The output voltage is of the opposite polarity than the input. This is a switched-mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. However, this drawback is of no consequence if the power supply is isolated from the load circuit (if, for example, the supply is a battery) because the supply and diode polarity can simply be reversed. When they can be reversed, the switch can be on either the ground side or the supply side.

A buck (step-down) converter combined with a boost (step-up) converter

The output voltage is typically of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor mode and the boost inductor mode, using switches instead of diodes, sometimes called a "four-switch buck-boostconverter", it may use multiple inductors but only topologies.

3.1 INTRODUCTION TO BUCK BOOST CONVERTERS :

A Buck converter is a switch mode DC to DC converter in which the output voltage can be transformed to a level less than or greater than the input voltage. The magnitude of output voltage depends on the duty cycle of the switch.It is also called as step up/step down converter. The name step up/step down converter comes from the fact that analogous to step up/step down transformer the input voltage can be stepped up/down to a level greater than/less than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

$$\text{Input power } (P_{in}) = \text{output power } (P_{out})$$

In step up mode $V_{in} < V_{out}$ in a Buck Boost converter, it follows then that the output current will be less than the input current. Therefore for a Buck Boost converter in step up mode

$$V_{in} < V_{out} \text{ and } I_{in} > I_{out}$$

In step down mode $V_{in} > V_{out}$ in a Buck Boost converter, it follows then that the output current will be greater than the input current. Therefore for a Buck Boost converter in step down mode

$$V_{in} > V_{out} \text{ and } I_{in} < I_{out}$$

Principle of operation of Buck converter

The main working principle of Buck Boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is ON the inductor stores energy from the input in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures that in steady state a constant output voltage $V_o(t) = V_o$(constant) exists across load terminal.

3.2 BUCK BOOST CAN BE OPERATED INTO TWO MODES:

a) Continuous conduction mode in which the current through inductor never goes to zero i.e. inductor partially discharges before the start of the switching cycle.

b) Discontinuous conduction mode in which the current through inductor goes to zero i.e. inductor is completely discharged at the end of switching cycle.

3.2.1 Circuit analysis of Buck converter :

Assume in the entire analysis that the current swing (maximum to minimum value) through inductor and voltage swing through capacitor is very less so that they vary in a linear fashion. This is to ease the analysis and the results we will get through this analysis are quite accurate compared to real values.

Continuous conduction mode

case-1: When switch S is ON

When switch in ON for a time t_{on}, the diode will be open circuited since it does not allow currents in reverse direction from input to output. Hence the Buck Boost converter can be redrawn as follows

During this state the inductor charges and the inductor current increases. The current through the inductor is given as

$$I_L = (1/L) * \int V * dt$$

Assume that prior to the opening of switch the inductor current is $I'_{L,\ off}$. Since the input voltage is constant

$$I_{L,on} = (1/L) * \int V_{in} * dt + I'_{L,on}$$

Assume the switch is open for ton seconds which is given by $D*T_s$ where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch on state is given as

$I_{L,\ on} = (1/L) *V_{in}*D*T_s + I'_{L,\ on}$ (equation 1)

Hence $\Delta I_{L,on} = (1/L)*V_{in}*D*T_s$.

case 2: When switch is off

When switch in OFF the diode will be forward biased as it allows current from output to input (p to n terminal) and the Buck Boost converter circuit can be redrawn as follows

The inductor now discharges through the diode and RC combination. Assume that prior to the closing of switch the inductor current is $I''_{L,\ off}$. The current through the inductor is given as

$$I'''_{L,off} = -(1/L) * \int V_{out} * dt + I''_{L,off}$$

Note the negative sign at the front end of equation signifies that the inductor is discharging. Assume the switch is open for t_{off} seconds which is given by (1-D)*T_s where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch off state is given as

$$I'''_{L,\ off} = -(1/L) *V_{out}*(1-D)*T_s + I''_{L,\ off} \text{ (equation 2)}$$

In steady state condition as the current through the inductor does not change abruptly, the current at the end of switch on state and the current at the end of switch off state should be equal. Also the currents at the start of switch off state should be equal to current at the end of switch on state. Hence

$$I'''_{L,\ off} = I_{L,\ on} \text{ also } I'_{L,\ off} = I''_{L,\ off}$$

Using the equations 1 and 2 we get

$(1/L) *V_{in}*D*T_s = (1/L) *V_{out}*(1-D)*T_s$

$V_{in}*D = V_{out}*(1-D)$

$V_{out}/V_{in} = D/(1-D)$

Since D < 1, V_{out} can be greater than or less than V_{in}.For D>0.5 the Buck boost converter acts as boost converter with $V_{out} > V_{in}$.For D<0.5 the Buck boost converter acts as buck converter with

$$V_{out} > V_{in}.$$

Assuming no losses in the circuit and applying the law of conservation of energy

$$V_{out}*I_{out} = V_{in}*I_{in}$$

This implies $I_{out}/I_{in} = (1-D)/D$, Thus $I_{out} > I_{in}$ for D<0.5 and $I_{out} < I_{in}$ for D<0.5 . As the duty cycle increases the output voltage increases and output current decreases.

Discontinuous conduction mode

As mentioned before the converter when operated in discontinuous mode the inductor drains its stored energy completely before completion of switching cycle. The current and voltage wave forms of Buck Boost converter in discontinuous mode is shown in the figure below

The inductor in discontinuous mode drains all the current which it piled up in charging interval of same switching cycle. The current through the inductor is given as

$$I_L = (1/L)\int V_L * dt$$ = (1/L)*area under the curve of voltage v/s time. Hence from the wave forms shown in the figure

$V_{out}*\delta*T_s = V_{in}*D*T_s$

$$V_{out}/V_{in} = D/\delta$$

and the ratio of output to input current from law of conservation of energy is $I_{out}/I_{in} = \delta/D$.

Applications of Buck boost converter

- It is used in the self regulating power supplies.
- It has consumer electronics.
- It is used in the Battery power systems.
- Adaptive control applications.
- Power amplifier applications.

CHAPTER 4

SIMULATION RESULTS AND ANALYSIS

4.1 INTRODUCTION:

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.

Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor. The model depicts the time-dependent mathematical relationships among the system’s inputs, states, and outputs. Then, we use Simulink to simulate the behavior of the system over a specified time span. Simulink uses information that you entered into the model to perform the simulation.

4.2 BLOCK DIAGRAM:

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block). The lines represent connections of block inputs to block outputs. Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time. A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate. A block comprises one or more of the following:

---

1) A set of inputs,
2) A set of states, and
3) A set of outputs.

A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance. Continuous Versus discrete Blocks Simulink's standard block set includes continuous blocks and discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only at integral multiples of a fixed interval called the block's sample time. Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, depending on whether they are driven by continuous or discrete blocks. A block that can be either discrete or continuous is said to have an implicit sample rate. The implicit sample time is continuous if any of the block's inputs are continuous. The implicit sample time is equal to the shortest input sample time if all the input sample times are integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times.

Simulink can optionally color code a block diagram to indicate the sample times of the blocks it contains, e.g., black (continuous), magenta (constant), yellow (hybrid), red (fastest discrete), and so on. The block contains block name, icon, and block library that contain the block, the purpose of the block

4.3 SIMULINK BLOCK LIBRARIES :

Simulink organizes its blocks into block libraries according to their behavior.

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-time components.
4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.
6) The Functions & Tables library contains blocks that describe general functions and table look-up operations.
7) The Nonlinear library contains blocks that describe nonlinear functions.
8) The Signal & Systems library contains blocks that allow multiplexing and demultiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types of subsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

4.4 SUB SYSTEMS :

Simulink allows to model a complex system as a set of interconnected subsystems each of which is represented by a block diagram. We create a subsystem using Simulink's Subsystem block and the Simulink model editor. We can embed subsystems with subsystems to any depth to create hierarchical models. We can create conditionally executed subsystems that are executed only when a transition occurs on a triggering or enabling input.

4.4.1 Solvers :

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model. The process of computing the successive states of a system from its model is known as solving the model. No single method of solving a model suffices for all systems. Accordingly, Simulink provides a set of programs, known as solvers, that each embody a particular approach to solving a model. The Simulation Parameters dialog box allows us to choose the solver most suitable for our model.

4.4.2 Fixed-Step and Variable-Step Solvers :

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size. Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly and increasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time, required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

4.5 CONTINUOUS AND DISCRETE SOLVERS:

Continuous solvers use numerical integration to compute a model's continuous states at the current time step from the states at previous time steps and the state derivatives. Continuous solvers rely on the model's blocks to compute the values of the model's discrete states at each time step. Mathematicians have developed a wide variety of numerical integration techniques for solving the ordinary differential equations (ODEs) that represent the continuous states of dynamic systems. Simulink provides an extensive set of fixed-step and variable-step continuous solvers, each implementing a specific ODE solution method. Some continuous solvers subdivide the simulation time span into major and minor steps, where a minor time step represents a subdivision of the major time step. The solver produces a result at each major time step. It use results at the minor time steps to improve the accuracy of the result at the major time step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time-step for a model and nothing else. They do not compute continuous states and they rely on the model's blocks to update the model's discrete states. We can use a continuous solver, but not a discrete solver, to solve a model that contains both continuous and discrete states. This is because a discrete solver does not handle continuous states. If you select a discrete solver for a continuous model, Simulink disregards your selection and uses a continuous solver instead when solving the model.

Simulink provides two discrete solvers, a fixed-step discrete solver and a variable-step discrete solver. The fixed-step solver by default chooses a step size and hence simulation rate fast enough to track state changes in the fastest block in our model

.

4.6 MODEL EXECUTION PHASE:

In the simulation model execution phase, Simulink successively computes the states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps. The length of time between steps is called the step size. The step size depends on the type of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states have discontinuities (Zero Crossing Detection). At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated. At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

1) Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and states to the output function as it may require these arguments to compute the block's output. Simulink updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.
2) Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's continuous states by numerically integrating the time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.

3) Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.
4) Computes the time for the next time step.

Simulink repeats steps 1 through 4 until the simulation stop time is reached.

4.6.1 Block Sorting Rules :

Simulink uses the following basic update rules to sort the blocks:

1) Each block must be updated before any of the direct-feed through blocks that it drives. This rule ensures that the inputs to direct-feed through blocks will be valid when they are updated.
2) Non direct-feed through blocks can be updated in any order as long as they are updated before any direct-feed through blocks that they drive. This rule can be met by putting all non direct-feed through blocks at the head of the update list in any order. It thus allows Simulink to ignore non direct-feed through blocks during the sorting process.

The result of applying these rules is an update list in which non direct-feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct-feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output. However, an algebraic loop can represent a set of simultaneous algebraic equations (hence the name) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step. Accordingly, Simulink assumes that loops involving direct-feed through blocks do, in fact, represent a solvable set of algebraic equations and attempts to solve them each time the block is updated during a simulation.

4.6.2 Determining Block Update Order :

During a simulation, Simulink updates the states and outputs of a model's blocks once per time step. The order in which the blocks are updated is therefore critical to the validity of the results. In particular, if a block's outputs are a function of its inputs at the current time step, the block must be updated after the blocks that drive its inputs. Otherwise, the block's outputs will be invalid. The order in which blocks are stored in a model file is not necessarily the order in which they need to be updated during a simulation. Consequently, Simulink sorts the blocks into the correct order during the model initialization phase.

In order to create a valid update ordering, Simulink categorizes blocks according to the relationship of outputs to inputs. Blocks whose current outputs depend on their current inputs are called direct feed through blocks. All other blocks are called non direct-feed through blocks. Examples of direct-feed through blocks include the Gain, Product, and Sum blocks. Examples of non direct-feed through blocks include the Integrator block (its output is a function purely of its state), the Constant block (it does not have an input), and the Memory block (its output is dependent on its input in the previous time step). Simulink allows you to assign update priorities to blocks. Simulink updates higher priority blocks before lower priority blocks. Simulink honors the priorities only if they are consistent with its block sorting rules.

Some of SIMULINK blocks, which are used in this thesis, are given below.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

(a) Development Environment

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

(b) The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

(e) The MATLAB Application Program Interface (API)

This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

(f) MATLAB Documentation

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

(1) Three phase source block

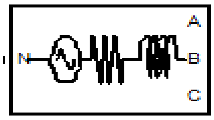

Fig.4.1.three phase source block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

(2) VI measurement block

The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents

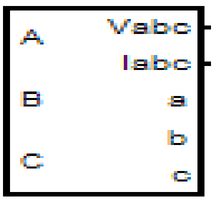

Fig.4.2.three phase v-i measurement

(3) Scope

Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port);

all axes have a common time range with independent y-axes. The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation

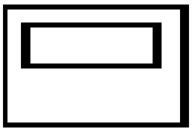

Fig.4.3..scope

(4) Three-Phase Series RLC Load

The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

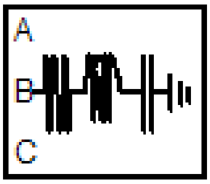

Fig.4.4.three-phase series rlc load

(5) Three-Phase Breaker block

The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.

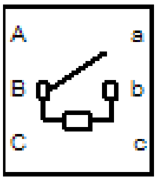

Fig.4.5.three-phase breaker block

(6) Integrator

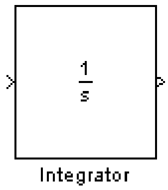

Fig.4.6. integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

(7) Breaker

Implement circuit breaker opening at current zero crossing.

Library: Elements

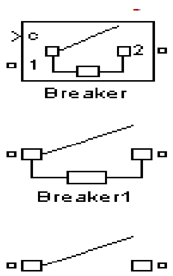

Fig.4.7.circuit breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series R_s-C snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open ci

rcuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it).

When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

(8) Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources

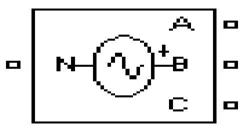

Fig.4.8.three phase voltage sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

(9) Trigonometric Function

Specified trigonometric function on input

Library: Math Operations

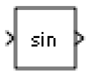

Fig.4.9.trigonometric function

Purpose: The Trigonometric Function block performs common trigonometric functions

(10) Three-Phase Transformer (Two Windings)

Implement three-phase transformer with configurable winding connections

4.6.3 Library Elements :

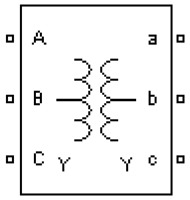

Fig.4.10.three phase transformer

Purpose:

The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

(11) Three-Phase Transformer 12 Terminals

Implement three single-phase, two-winding transformers where all terminals are accessible

Library: Elements

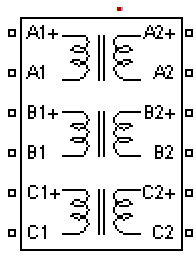

Fig.4.11.two winding transformer

Purpose: The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

(12) IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: **Power Electronics**

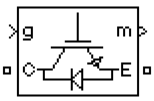

Fig.4.12.igbt

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

CHAPTER 5

PROPOSED SYSTEM SIMULATION

Thyristors can only be turned on (not off) by control action, and rely on the external AC system to effect the turn-off process, the control system only has one degree of freedom – when to turn on the thyristor. This limits the usefulness of HVDC in some circumstances because it means that the AC system to which the HVDC converter is connected must always contain synchronous machines in order to provide the commutating voltage – the HVDC converter cannot feed power into a passive system with some other types of semiconductor device such as the insulated-gate bipolar transistor (IGBT), both turn-on and turn-off can be controlled, giving a second degree of freedom. As a result, IGBTs can be used to make self-commutated converters. In such converters, the polarity of DC voltage is usually fixed and the DC voltage, being smoothed by a large capacitance, can be considered constant. For this reason, an HVDC converter using IGBTs is usually referred to as a voltage-source converter (or voltage-sourced converter). The additional controllability gives many advantages, notably the ability to switch the IGBTs on and off many times per cycle in order to improve the harmonic performance, and the fact that (being self-commutated) the converter no longer relies on synchronous machines in the AC system for its operation. A voltage-sourced converter can therefore feed power to an AC network consisting only of passive loads, something which is impossible with LCC HVDC. Voltage-source converters are also considerably more compact than line-commutated converters (mainly because much less harmonic filtering is needed) and are preferable to line-commutated converters in locations where space is at a premium, for example on offshore platforms.

In contrast to line-commutated HVDC converters, voltage-source converters maintain a constant polarity of DC voltage and power reversal is achieved instead by reversing the direction of current. This makes voltage-source converters much easier to connect into a Multi-terminal HVDC system or “DC Grid”. HVDC systems based on voltage-source converters normally use the six-pulse connection because the converter produces much less harmonic distortion than a comparable LCC and the twelve-pulse connection is unnecessary. This simplifies the construction of the converter transformer. However, there are several different configurations of voltage-source converter and research is continuing to take place into new alternatives.

5.1 TWO LEVEL CONVERTER:

From the very first VSC-HVDC scheme installed (the Hellsjön experimental link commissioned in Sweden in 1997[7]) until 2012, most of the VSC HVDC systems built were based on the two level converter. The two-level converter is the simplest type of three-phase voltage-source converter and can be thought of as a six pulse bridge in which the thyristors have been replaced by IGBTs with inverse-parallel diodes, and the DC smoothing reactors have been replaced by DC smoothing capacitors. Such converters derive their name from the fact that the voltage at the AC output of each phase is switched between two discrete voltage levels, corresponding to the electrical potentials of the positive and negative DC terminals. When the upper of the two valves in a phase is turned on, the AC output terminal is connected to the positive DC terminal, resulting in an output voltage of +½ U_d with respect to the midpoint potential of the converter. Conversely when the lower valve in a phase is turned on, the AC output terminal is connected to the negative DC terminal, resulting in an output voltage of -½ U_d. The two valves corresponding to one phase must never be turned on simultaneously, as this would result in an uncontrolled discharge of the DC capacitor, risking severe damage to the converter equipment.

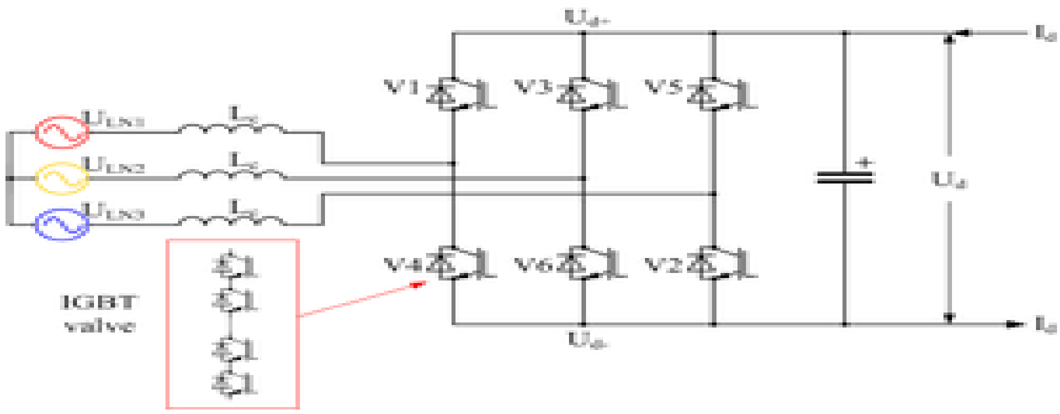

Fig .5.1. :three-phase, two-level voltage-source converter

The simplest (and also, the highest-amplitude) waveform that can be produced by a two-level converter is a square wave; however this would produce unacceptable levels of harmonic distortion, so some form of Pulse-width modulation (PWM) is always used to improve the harmonic distortion of the converter. As a result of the PWM, the IGBTs are switched on and off many times (typically 20) in each mains cycle. This results in high switching losses in the IGBTs and reduces the overall transmission efficiency.

Several different PWM strategies are possible for HVDC[31] but in all cases the efficiency of the two-level converter is significantly poorer than that of a LCC because of the higher switching losses. A typical LCC HVDC converter station has power losses of around 0.7% at full load (per end, excluding the HVDC line or cable) while with 2-level voltage-source converters the equivalent figure is 2-3% per end.

Another disadvantage of the two-level converter is that, in order to achieve the very high operating voltages required for an HVDC scheme, several hundred IGBTs have to be connected in series and switched simultaneously in each valve. This requires specialised types of IGBT with sophisticated gate drive circuits, and can lead to very high levels of electromagnetic interference. In an attempt to improve on the poor harmonic performance of the two-level converter, some HVDC systems have been built with three level converters. Three-level converters can synthesize three (instead of only two) discrete voltage levels at the AC terminal of each phase: +½ U_d, 0 and -½ U_d. A common type of three-level converter is thediode-clamped (or neutral-point-clamped) converter, where each phase contains four IGBT valves, each rated at half of the DC line to line voltage, along with two clamping diode valves.[32] The DC capacitor is split into two series-connected branches, with the clamping diode valves connected between the capacitor midpoint and the one-quarter and three-quarter points on each phase. To obtain a positive output voltage (+½ U_d) the top two IGBT valves are turned on, to obtain a negative output voltage (-½ U_d) the bottom two IGBT valves are turned on and to obtain zero output voltage the middle two IGBT valves are turned on. In this latter state, the two clamping diode valves complete the current path through the phase.

In a refinement of the diode-clamped converter, the so-called active neutral-point clamped converter, the clamping diode valves are replaced by IGBT valves, giving additional controllability. Such converters were used on the Murray link project in Australia and the Cross Sound Cable link in the United States. However, the modest improvement in harmonic performance came at a considerable price in terms of increased complexity, and the design proved to be difficult to scale up to DC voltages higher than the ±150 kV used on those two projects.

Another type of three-level converter, used in some adjustable-speed drives but never in HVDC, replaces the clamping diode valves by a separate, isolated, flying capacitor connected between the one-quarter and three-quarter points. The operating principle is similar to that of the diode-clamped converter. Both the diode-clamped and flying capacitor variants of three-level converter can be extended to higher numbers of output levels (for example, five), but the complexity of the circuit increases disproportionately and such circuits have not been considered practical for HVDC applications.

First proposed for HVDC applications in 2003 by Marquardt and first used commercially in the Trans Bay Cable project in San Francisco, the Modular Multi-Level Converter (MMC) is now becoming the most common type of voltage-source converter for HVDC.

Like the two-level converter and the six-pulse line-commutated converter, a MMC consists of six valves, each connecting one AC terminal to one DC terminal. However, where each valve of the two-level converter is effectively a high-voltage controlled switch consisting of a large number of IGBTs connected in series, each valve of a MMC is a separate controllable voltage source in its own right. Each MMC valve consists of a number of independent converter submodules, each containing its own storage capacitor. In the most common form of the circuit, the half-bridge variant, each submodule contains two IGBTs connected in series across the capacitor, with the midpoint connection and one of the two capacitor terminals brought out as external connections.[35] Depending on which of the two IGBTs in each submodule is turned on, the capacitor is either bypassed or connected into the circuit. Each submodule therefore acts as an independent two-level converter generating a voltage of either 0 or U_{sm} (where U_{sm} is the sub module capacitor voltage). With a suitable number of submodules connected in series, the valve can synthesize a stepped voltage waveform that approximates very closely to a sine-wave and contains very low levels of harmonic distortion.

The MMC differs from other types of converter in that current flows continuously in all six valves of the converter throughout the mains-frequency cycle. As a result, concepts such as “on-state” and “off-state” have no meaning in the MMC. The direct current splits equally into the three phases and the alternating current splits equally into the upper and lower valve of each phase. The current in each valve is therefore related to the direct current I_d and alternating current I_{ac} as follows:

Upper valve: $I_v = \frac{I_d}{3} + \frac{I_{ac}}{2}$

Lower valve: $I_v = \frac{I_d}{3} - \frac{I_{ac}}{2}$

A typical MMC for an HVDC application contains around 300 submodules connected in series in each valve and is therefore equivalent to a 301-level converter. Consequently, the harmonic performance is excellent and usually no filters are needed. A further advantage of the MMC is that PWM is not necessary, with the result that the power losses are much lower than those of the 2-level converter, at around 1% per end. Finally, because direct series-connection of IGBTs is not necessary, the IGBT gate drives do not need to be as sophisticated as those for a 2-level converter.

The MMC has two principal disadvantages. Firstly, the control is much more complex than that of a 2-level converter. Balancing the voltages of each of the submodule capacitors is a significant challenge and requires considerable computing power and high-speed communications between the central control unit and the valve. Secondly, the submodule capacitors themselves are large and bulky. A MMC is considerably larger than a comparable-rated 2-level converter, although this may be offset by the saving in space from not requiring filters.

As of 2012 the largest-capacity MMC HVDC system in operation is still the 400 MW Trans Bay Cable scheme but many larger schemes are under construction, including an underground cable interconnection from France to Spain consisting of two 1000 MW links in parallel at a voltage of ±320 kV.

A variant of the MMC, proposed by one manufacturer, involves connecting multiple IGBTs in series in each of the two switches that make up the submodule. This gives an output voltage waveform with fewer, larger, steps than the conventional MMC arrangement. This arrangement is referred to as the Cascaded Two Level (CTL) converter. Functionally it is exactly equivalent to the conventional half-bridge MMC in every respect except for the harmonic performance, which is slightly inferior – although still claimed to be good enough to avoid the need for filtering in most instances.

Another alternative replaces the half bridge MMC submodule described above, with a full bridge submodule containing four IGBTs in an H bridge arrangement, instead of two. The full-bridge variant of MMC allows the submodule capacitor to be inserted into the circuit in either polarity. This confers additional flexibility in controlling the converter and allows the converter to block the fault current which arises from a short-circuit between the positive and negative DC terminals (something which is impossible with any of the preceding types of VSC). Furthermore, it allows the DC voltage to be of either polarity (like a LCC HVDC scheme), giving rise to the possibility of hybrid LCC and VSC HVDC systems. However, the full-bridge arrangement requires twice as many IGBTs and has higher power losses than the equivalent half-bridge arrangement.

The result of applying these rules is an update list in which non-direct-feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct-feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output. However, an algebraic loop can represent a set of simultaneous algebraic equations (hence the name) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step. Accordingly, Simulink assumes that loops involving direct-feed through blocks do, in fact, represent a solvable set of algebraic equations and attempts to solve them each time the block is updated during a simulation.

TABLE I. CURRENT SET-POINTS TO EV BATTERIES

Time range (s)	0 to 1	1 to 4	4 to 6
Current set-point to EV_1 battery (A)	0	+80	0
Current set-point to EV_2 battery(A)	0	0	-40

Table 1: current set points of EV Batteries

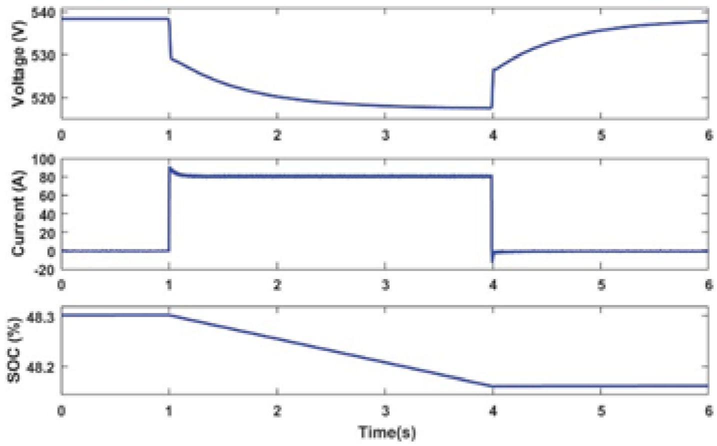

Fig.5.2.voltage, current and soc or ev1battery during v2g operation

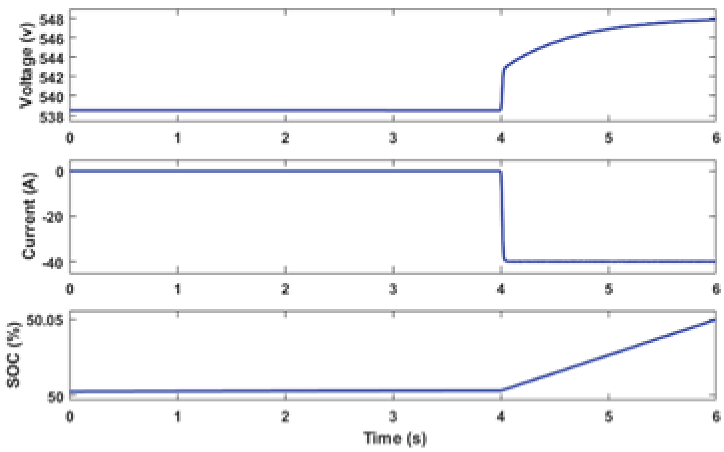

Fig.5.3.voltage,current and soc or ev2 battery during g2v operation

The active power contribution from various components of the system is shown in Fig. 8. The grid power changes to accommodate the power transferred by the EVs. The negative polarity of the grid power from 1s to 4s shows that the power is being fed to the grid from the vehicle. The change in polarity of grid power at 4s shows that the power is supplied by the grid for charging the vehicle battery. This demonstrates the V2G-G2V operation. Also, the net power at PCC is zero showing an optimal power balance in the system.

The dc bus voltage is regulated at 1500 V by the outer voltage control loop of the inverter controller and is shown in Fig. 9. This in turn is achieved by the inner current control loop tracking the changed d-axis reference current as shown in Fig. 10.

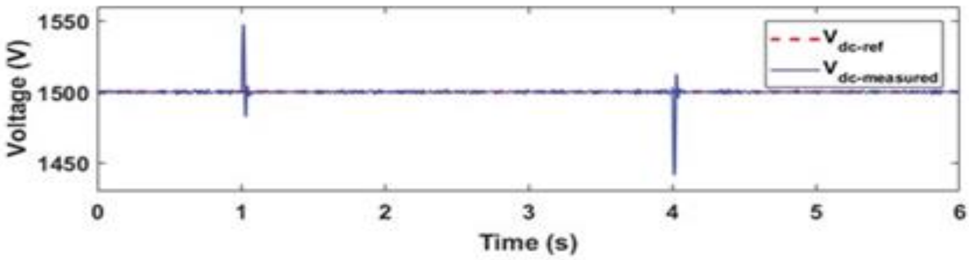

Fig.5.4.variation in dc bus voltage

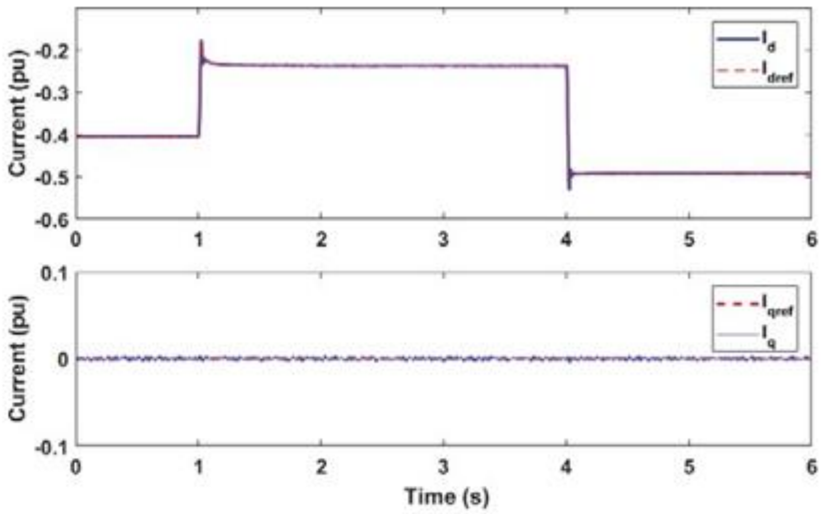

Fig.5.5.reference current tracking by inverter controller

The grid voltage and current at PCC are shown in Fig. 11. Voltage and current are in phase during G2V operation and out of phase during V2G operation showing the reverse power flow.

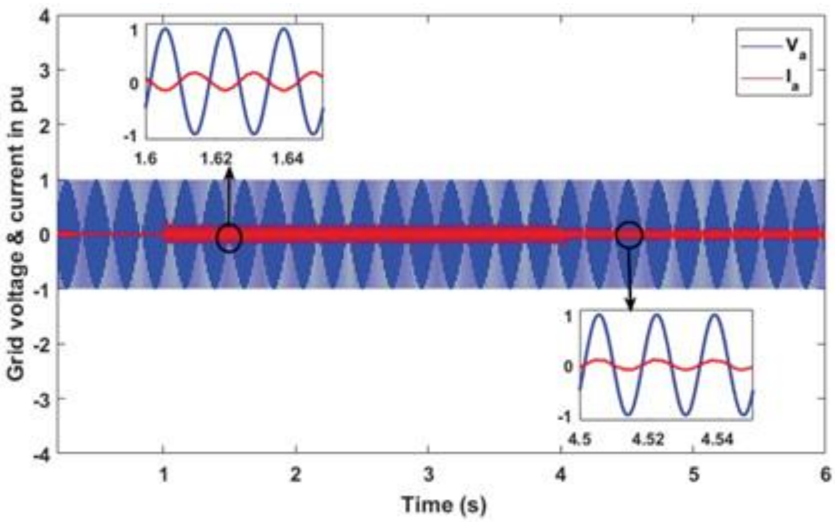

Fig.5.6.grid voltage and grid injected current during v2g-g2v operation

Total harmonic distortion (THD) analysis is done on the grid injected current and the result is shown in Fig. 12. According to IEEE Std. 1547, harmonic current distortion on power systems 69 kV and below are limited to 5% THD. The THD of grid- injected current is obtained as 2.31 % and is achieved by the judicious design of LCL filter.

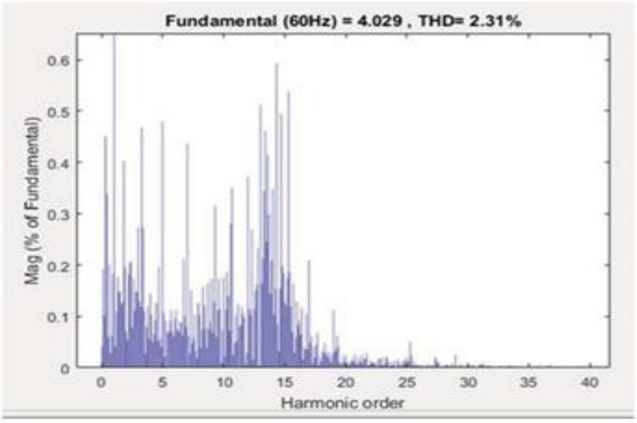

Fig.5.7.harmonic spectrum and thd of grid-injected current

5.2 SIMULATION EVALUATION :

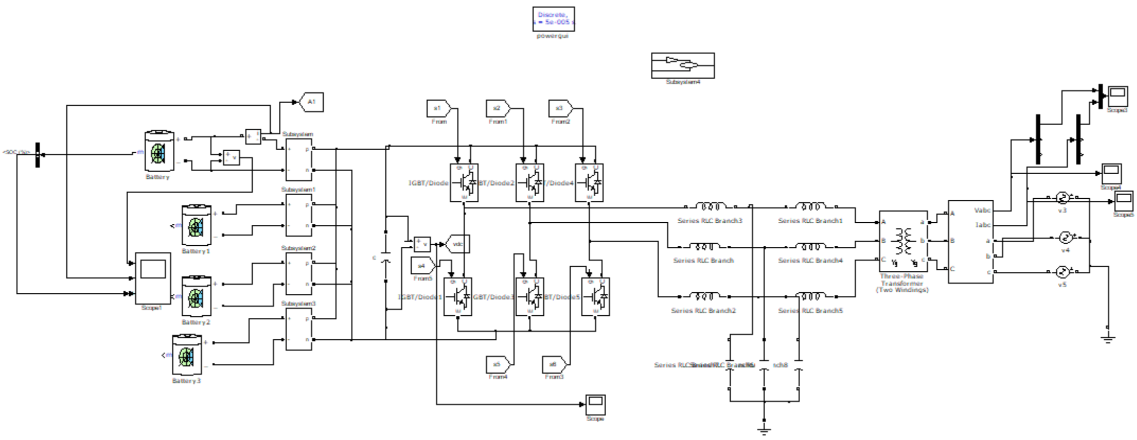

Fig.5.8. v2g technology simulation circuit

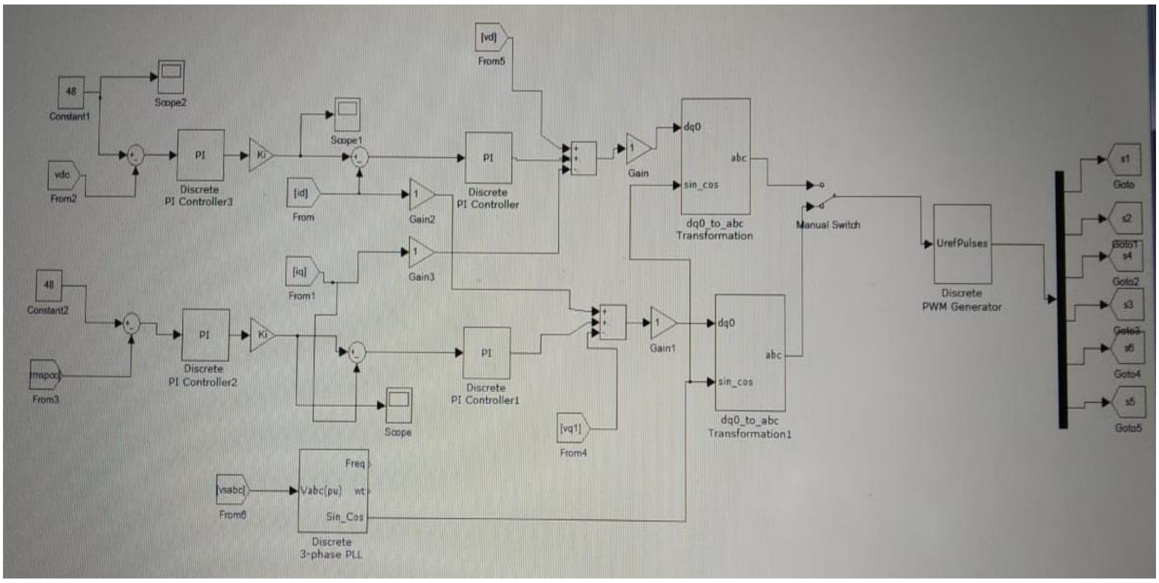

Fig.5.9. subsystem (inverter control system)

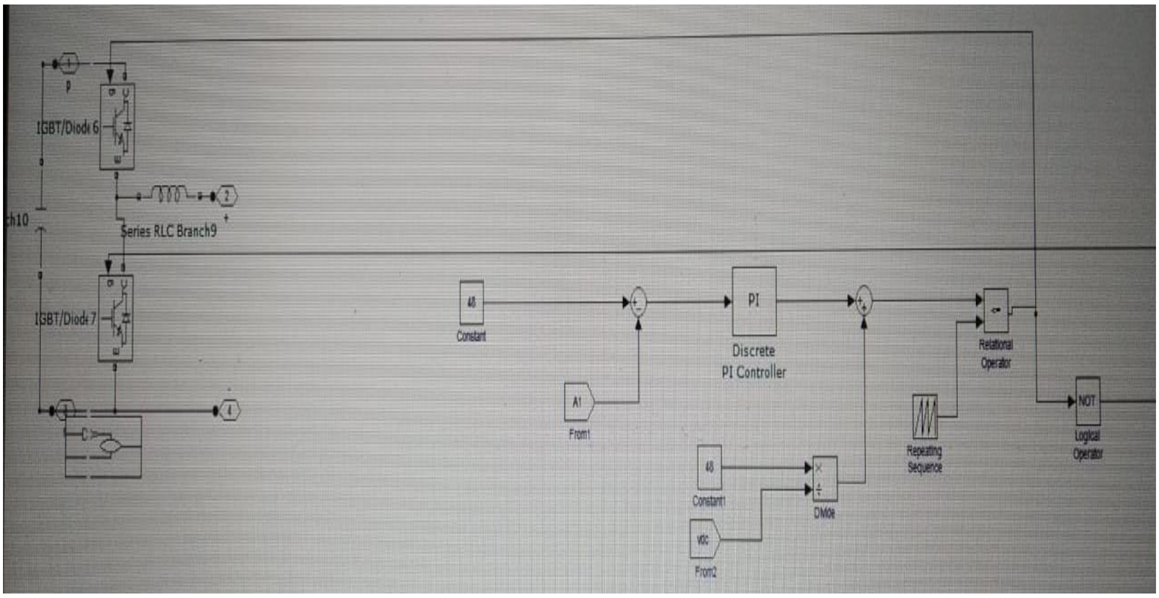

Fig.5.10. subsystem (off-board charger)

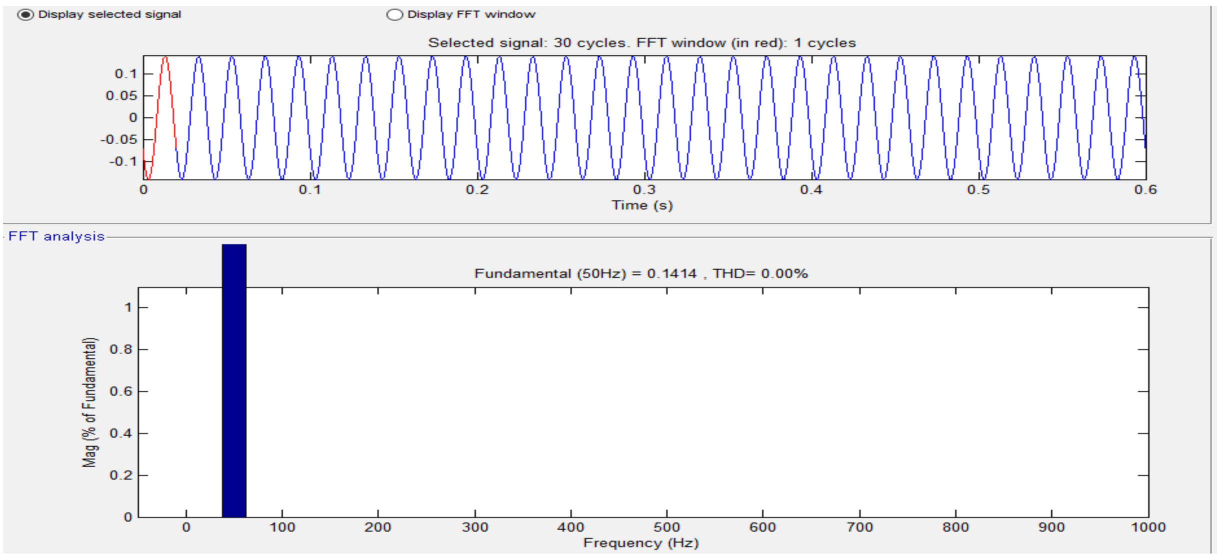

Fig.5.11. total harmonic distortion

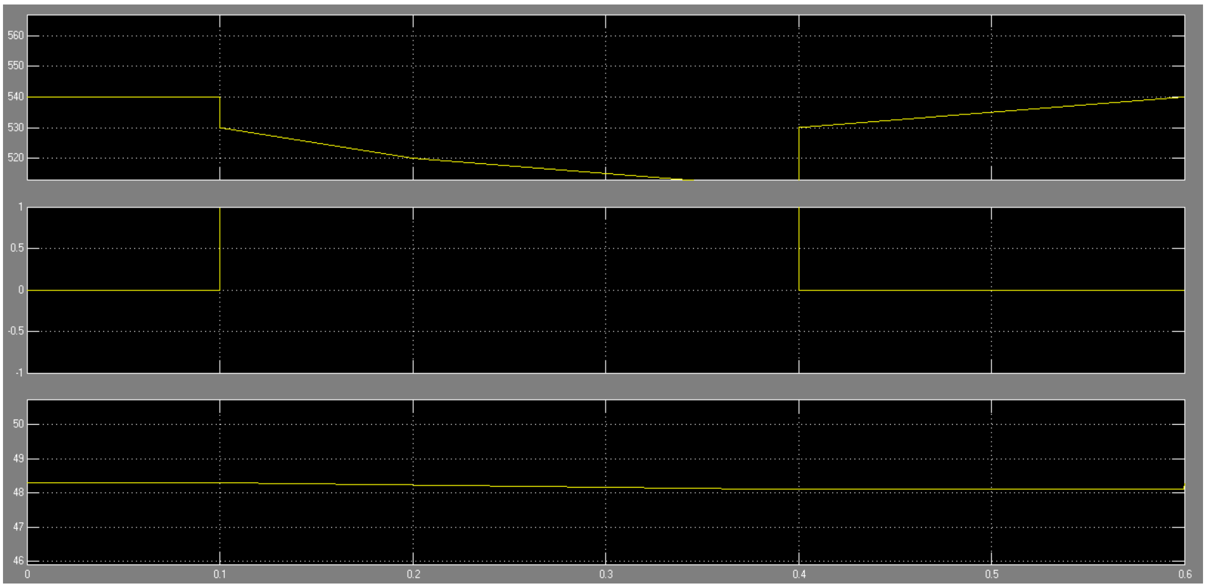

Fig.5.12. v2g voltage, current, soc

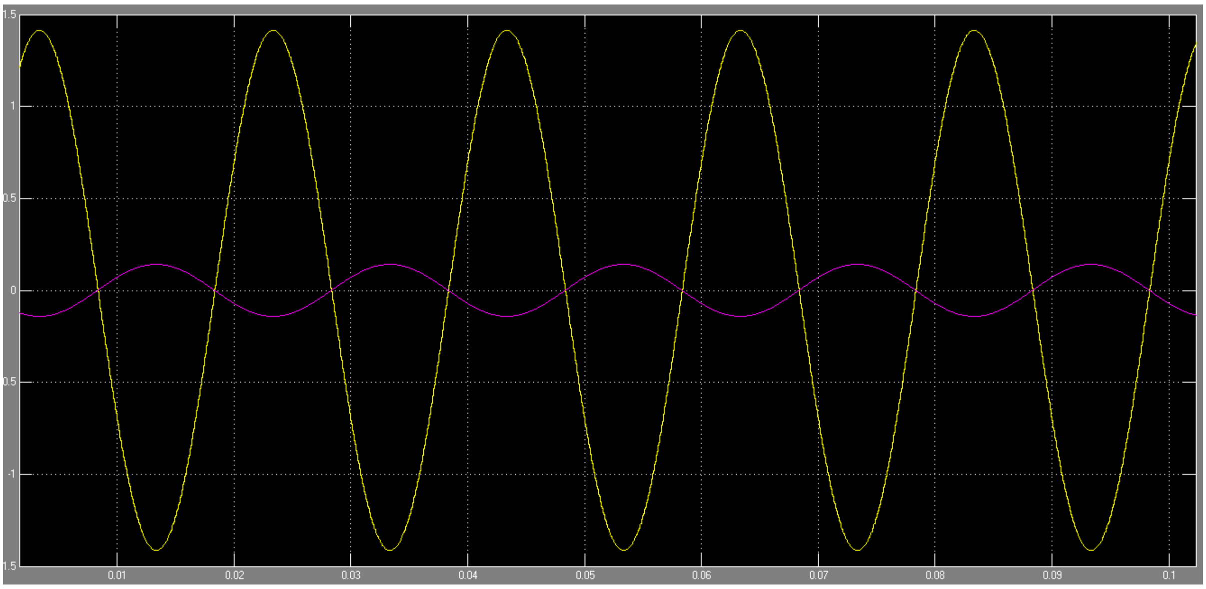

Fig.5.13. voltage and current during v2g operation

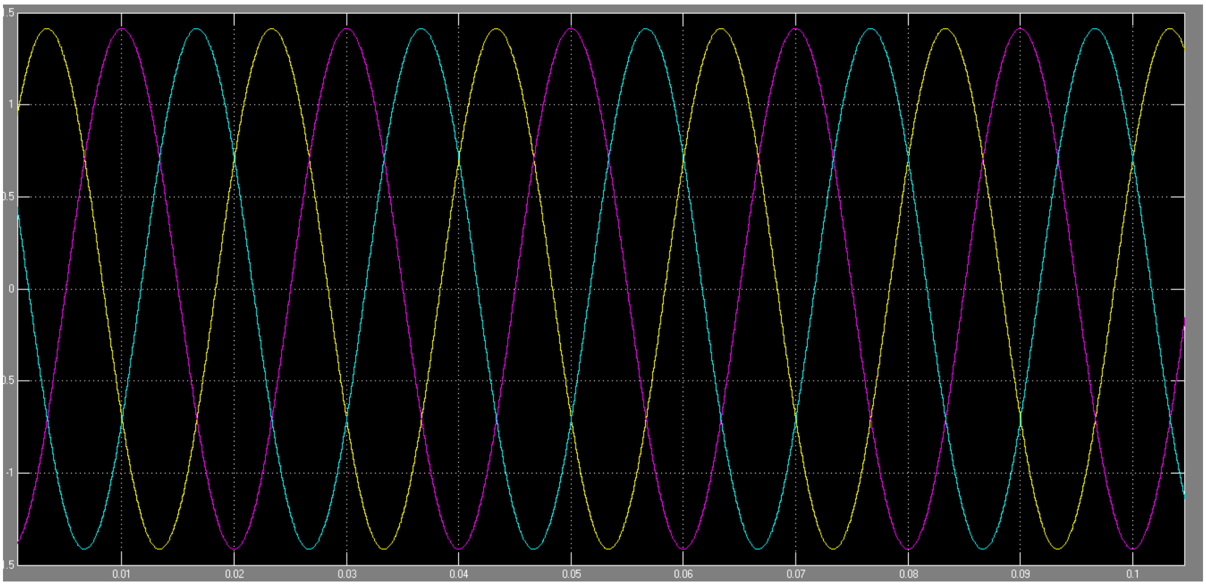

Fig.5.14. grid voltage and injected current during v2g and g2v operation

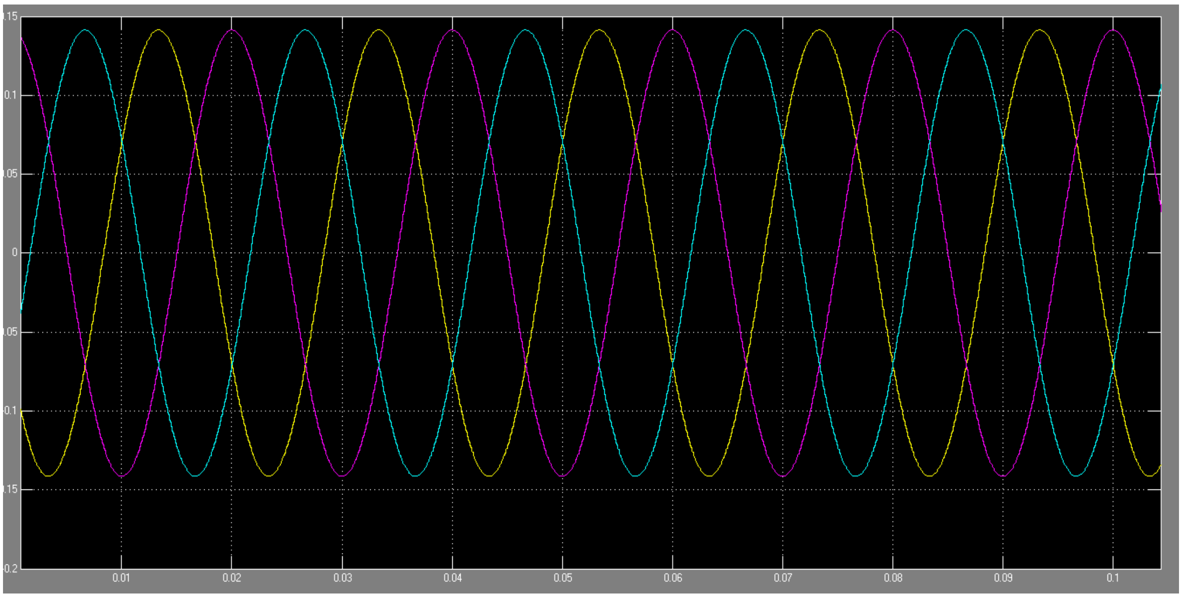

Fig.5.15. three phase power signal

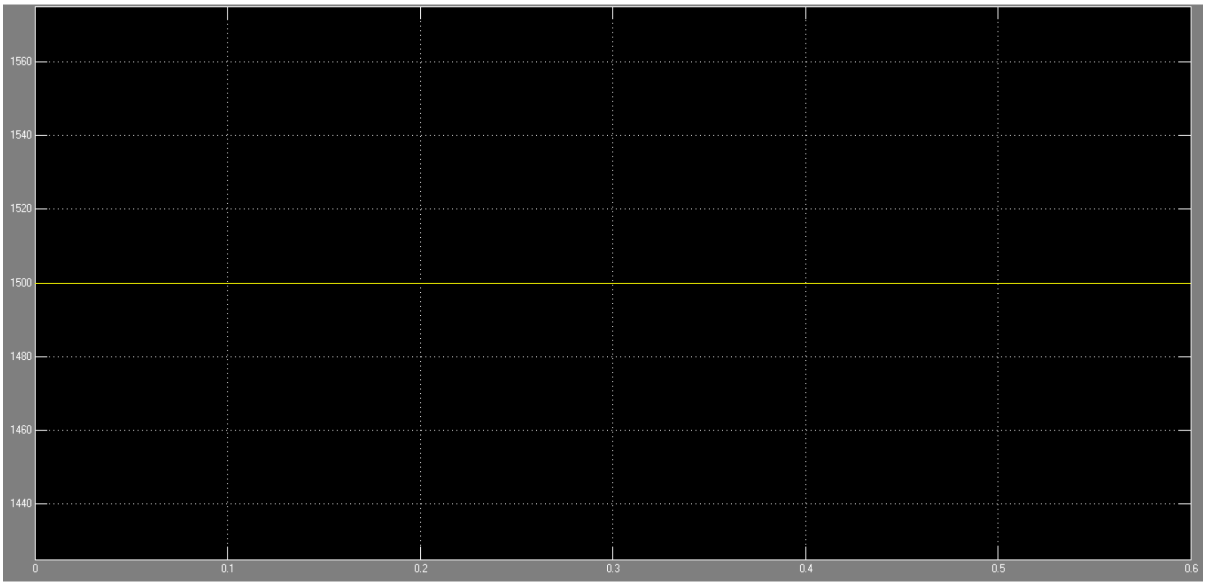

Fig.5.16. dc input voltage

CHAPTER 6

CONCLUSION

Modeling and design of a V2G system in a micro-grid using dc fast charging architecture is presented in this paper. A dc fast charging station with off-board chargers and a grid connected inverter is designed to interface EVs to the micro- grid. The control system designed for this power electronic interface allows bi-directional power transfer between EVs and the grid. The simulation results show a smooth power transfer between the EVs and the grid, and the quality of grid injected current from the EVs adheres to the relevant standards. The designed controller gives good dynamic performance in terms of dc bus voltage stability and in tracking the changed active power reference. Active power regulation aspects of the micro- grid are considered in this work, and the proposed V2G system can be utilized for several other services like reactive power control and frequency.

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A

PROJECT REPORT

On

MODELLING AND CONTROL OF BIDIRECTIONAL BUCK BOOST CONVERTER FOR ELECTRICAL VEHICLE APPLICATIONS.

Submitted by

1)Ms.K.S.Navya(17K81A0220) 2)Ms.K.Mounika (17K81A0221)

3)Mr.V.Kapil (17K81A0241) 4)Mr.A.Sriramreddy(17K81A0247)

in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

Mr C.H.Srinivas M.E.(Ph.d)

Associate Professor

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ST.MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled "**Modelling and Control of Bidirectional buck boost Converter for Electrical Vehicle Applications"**, is being submitted by **1.Ms. K.S.Navya (17K81A0220) 2.Ms K.Mounika (17K81A0221) 3.Mr. V.Kapil (17K81A0241) 4.Mr. A.Sriram reddy (17K81A0247)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN** Electrical and Electronics Engineering is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Head of the Department

Mr C.H.Srinivas
Department of EEE

Dr.N.Ramchandra
Department of EEE

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the students of **Bachelor of Technology** in Department of **Electrical and Electronics Engineering** session: **2017 – 2021**, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled " **Modelling and control of Bidirectional buck boost Converter for Electrical Vehicle Applications"** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

K. S. Navya (17K81A0220)
K. Mounika (17K81A0221)
V. Kapil (17K81A0241)
A. Sriram reddy (17K81A0247)

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1. K.S.Navya
2 K. Mounika
3. V. Kapil
4 A. Sriram reddy

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NOMENCLATURE

EV	:	Electrical Vehicle
HEVs	:	Hybrid Electrical Vehicle
ICE	:	Internal combustion engine
FLC	:	Fuzzy Logic Controller
BEVs	:	Battery Electrical Vehicles
VRLA	:	Valve regulated lead–acid battery
AGM	:	Absorbed Glass Mat
PWM	:	Pulse Width Modulation
BLDC	:	Brushless dc synchronous motor
PHEV	:	Plug in hybrid Electrical vehicle

ABSTRACT

The level of exhaust gases is rising with increasing usage of internal combustion engine vehicles. In order to reduce carbon emission, researchers and industry head up for improving electric vehicle technologies in all over the word. This paper deals with design and simulation of a bi-directional power converter of electric vehicle. The power electronics block is comprised by batteries, bi-directional dc-dc converter and BLDC machine.

The initial state of battery charge is set around 90% where the discharge current is 44.5 A during motor mode. The nominal voltage of battery stack is 350 V and maximum capacity is 100 Ah.The operating mode of power converter is determined according to the torque values of BLDC machine which is operated in motor and generator modes. The charge and discharge conditions of batteries have been controlled regarding to operating modes of dc machine. The proposed converter and controller are designed to meet charge control and motor drive requirements of an all-electric vehicle.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO THE PROJECT

Transportation sector occupies a fundamental place in the world. Fossil fuels used in conventional vehicles technology emit greenhouse gases such as carbon dioxide, carbon monoxide and methane. The excessive consumption of these gases causes air pollution, climate change and global warming. In order to reduce these effects, there is a tendency to electric vehicle (EV) technology. The EV has much lower fuel cost according to fossil fueled car since they are mainly composed of battery system, power electronic circuits and electric machine.

The battery system in an EV is the most crucial component in charge control time and determining distance . The electric machines of an EV are operated in both motor and generator modes due to regenerative breaking feature that enables electric machine to be operated in generator mode which is impossible in conventional internal combustion engine (ICE) vehicles.

Therefore, electric machine charges the battery by operating in generator mode during the regenerative braking and it ensures recharging the batteries . EV are classified into two types as hybrid EVs (HEVs) and all-electric vehicles. The HEV technology is used in conjunction conventional vehicle technology.

The main system in HEV technology includes fuel tank and ICE such as diesel or gasoline engine, and auxiliary system which is comprised by electric machine, power electronic circuits and battery. HEVs are classified as parallel and series hybrid vehicles that the parallel HEV consists ICE and electrical machine together . As the parallel electric vehicles operates at electric mode during the acceleration of electric machine, the motor operation is supplied from battery.

The designed EV motor driver is comprised by four sections such as battery, bi-directional dc-dc converter, FLC and dc machine as shown In this study, the starting voltage of battery is set to 378 V while the operating voltage of dc machine used in traction system is 500 V dc. The battery voltage is increased up to 500 V with bi-directional dc-dc converter in generator mode.

The battery is discharged when dc machine is started acceleration. The motor mode simulation with various torque values are performed to observe battery parameters such as state of charge (SoC), current, voltage and voltage of the dc machine. The voltage of the dc machine is decreased to 500 V with

bidirectional dc-dc converter which is controlled with FLC. The battery is charged during the generator mode operation of dc machine. The FLC determines duty cycle of S1 and S2 to ensure
charge and discharge of battery.

The dc machine is comprised by brushes, armature core and windings, commutator, field core and windings. Armature circuit is comprised by series structure with inductor, resistance and counter-electromotive source. Similarly, battery parameters such as SoC, current, voltage and voltage of the dc machine are observed in the generator mode simulation regarding to various torque values applied to dc machine.

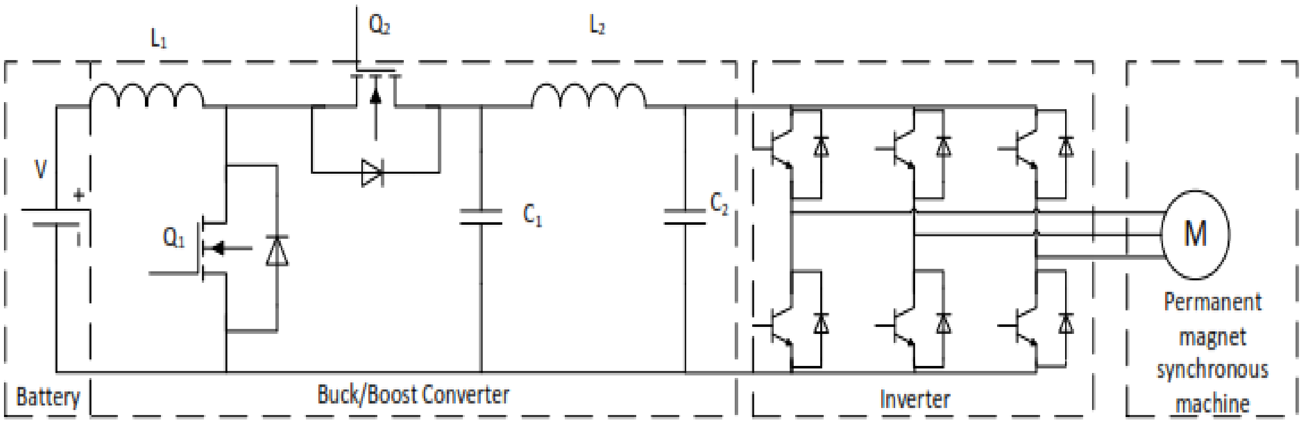


Fig: 1.1.1 Proposed circuit configuration

The electrical energy is converted to mechanical energy or vice versa by dc machine that operates regarding to electromechanical energy conversion theory . If a conductor is moved within the magnetic field, the voltage is induced on it which is known as generator operating mode.

If alternating current passes through the conductor, magnetic field is created around it which explains the motor mode operation. When the dc machine is started acceleration, the resultant positive torque is achieved. On the other hand, negative torque is generated at the dc machine when it is operated in generator mode.

FLC is comprised by fuzzification, rule base, interface mechanism, defuzzification. Fuzzification is used to convert digital signals received through the system into linguistic variable. Rule base is comprised by the conditions to set for controlling the system at desired location. Interface mechanism makes inferences according to the rules of system by establishing a relationship between inputs. Defuzzification is used to convert linguistic variable received through the system into digital signals.

The European new vehicle CO2 regulation (with a mandatory target value of 95 grams of CO2 per kilometer by 2021 for passenger cars) is currently in the process of being extended to 2025. In this context, one of the key questions is at what point a significant uptake of the electric vehicle market is to be expected. In order to help inform this debate about how electric vehicle technology could fit in a lower-carbon 2020–2030 new vehicle fleet in Europe, this paper focuses on collecting, analyzing, and aggregating the available research literature on the underlying technology costs and carbon emissions. In terms of technologies, this paper concentrates on the three electric propulsion systems: battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hydrogen fuel cell electric vehicles (HFCEVs). The collected cost data is used to estimate the technology cost for automotive lithium-ion (Li-ion) batteries and fuel cells. The cost of battery packs for BEVs declined to an estimated €250 per kWh for industry leaders in 2015.

Further cost reductions down to as low as €130–€180 per kWh are anticipated in the 2020–25 time frame. The costs of fuel cell systems are also expected to decrease considerably, but cost estimates are highly uncertain. Furthermore, the application of fuel cells and batteries in HFCEVs, BEVs, and PHEVs is approximated using a bottom-up cost approach. Overall, the different power train costs largely depend on battery and fuel cell costs. This paper concludes that the costs of all power trains will decrease significantly between 2015 and 2030 .

As shown, power trains for PHEVs will achieve about a 50% cost reduction, compared with approximate cost reductions of 60% for BEVs and 70% for HFCEVs. Costs for hydrogen and electricity chargers are estimated separately. Greenhouse gas (GHG) emissions and energy demand for electric and conventional vehicles are presented on a well-to-wheel (WTW) basis, capturing all direct and indirect emissions of fuel and electricity production and vehicle operation.

The results are based on former analyses, and are updated and refined with real-world fuel consumption levels. Real-world fuel consumption is commonly about 20%–40% higher than official typeapproval measurements. Finally, WTW estimates for electric and conventional vehicles are put in the context of the 2021 CO2 standard for European passenger vehicles.

It is found that carbon emissions of BEVs using European grid-mix electricity are about half of average European vehicle emissions, whereas HFCEVs and PHEVs have a lower emissions reduction potential. In the 2020 context, electric vehicle WTW emissions are expected to continue offering greater carbon benefits due to more efficient power trains and increasing low-carbon electric power.

A lower-carbon grid and higher power train efficiency by 2020 could cut average electric vehicle emissions by one-third again. However, the expected cost reductions and potential CO2 emission cuts will not be achieved without targeted policy intervention.

More stringent CO2 standards, and fiscal and non-fiscal incentives for electric vehicles, can help the electric vehicle market to grow and costs to fall. Also, efforts need to be combined with activities to decarbonize the grid, or emission reductions will not be as great as they could be.

Although the analysis is focused on the European context, similar dynamics with electric vehicle technology, policy, and market development are prevalent across major markets in North America and Asia.

The first EVs were introduced as early as 1838—or 52 years before internal combustion engine vehicles (ICEVs) entered the market. Despite recent growing interest, EVs have remained a relatively small market until today (IEA, 2015).

However, the global share of EVs is expected to increase significantly, driven by substantial battery technology improvements and a variety of policies that are accelerating the development of the electric vehicle market. Overall, the market has grown from just hundreds of EV sales in 2010 to more than 500,000 sales worldwide in 2015 (EV Sales, 2016).

The early development of markets for electric vehicles is seen predominantly in parts of China, Europe, and the United States, where electric vehicle support policies are helping promote the technology, while costs are still relatively high compared with conventional vehicles. The global and regional estimated stock of BEV and PHEV passenger cars as of 2015, and electric vehicle supply equipment (EVSE) as of 2014. EVSE includes semipublic or public charging points or outlets, but not private charging points. Most of the electric vehicles on the road today are registered in the United States, with about half of those in the state of California.

The United States also has the largest number of electric vehicle charging points. The Netherlands is the European country with the highest electric vehicle passenger car and charging-plug stock in terms of absolute sales. The following countries have achieved relatively high market sales shares of passenger electric vehicles, as a percentage of all 2014 passenger vehicle sales: Norway (13.7%), the Netherlands (3.9%), Sweden (1.5%) (Mock, 2015), and the United States (1.5%) (Lutsey, 2015). Most other major automobile markets have EV sales shares at or below 1%.

Pure battery electric vehicles (BEVs) are also referred to as battery-only electric vehicles (BOEVs). BEVs have no engine and are propelled by electricity that comes from one or several onboard high-energy batteries. Modern models use a regenerative braking system to save energy. Examples include the Renault Zoe and the Nissan Leaf. The Zoe has a 22 kWh Li-ion battery, and an energy consumption of 14.6 kWh per 100 km, which yields a range of about 140 km to 210 km per battery charge on the New European Driving Cycle (NEDC).

The 2015 Leaf comes with a 24 kWh battery (plus a 30 KWh option for the 2016 model), and an official consumption of 15 kWh per 100 km. 3.2. PHEVs Plug-in hybrid electric vehicles (PHEVs) allow electric driving on batteries (in charge-depleting mode), but also conventional combustionfueled driving (in charge-sustaining mode). Usually, they are equipped with an electric motor and a highenergy battery, which can be charged from the power grid. Modern PHEVs can be driven in electric mode over varying distances before the combustion engine is required. In electric-driving mode, the energy efficiency of the propulsion system is much higher, and is comparable to that of a BEV.

Available models include the Chevrolet Volt in U.S. markets (which is the Opel Ampera in EU markets), and the Toyota Prius Plug-in Hybrid. The 2015 Opel Ampera uses a 16 kWh Li-ion battery and consumes 16.9 kWh per 100 km in electric mode on the NEDC. The 2015 Chevrolet Volt has a 16.5 kWh battery, and the 2016 model has an 18.4 kWh battery

PHEVs and BEVs use similar batteries, with Li-ion being the most common chemistry. There are two primary ways to extract the lithium used in batteries: mining spodumene and petalite ore using evaporation ponds on salt lakes. The majority of lithium is obtained from brine operation (USGS, 2015). The battery system is the key technology of electric vehicles and defines their range and performance characteristics.

The battery works like a transducer by turning chemical energy into electrical energy. Li-ion is expected to be the dominant chemistry for BEVs and PHEVs for the foreseeable future, as most research is done in the field of Li-ion batteries. They provide relatively high power and energy for a given weight or size, and can significantly reduce costs compared with other battery concepts. Energy density of the battery pack is estimated to roughly double, up to about 300 Wh per kg, between 2007 and 2030 (Kromer & Heywood, 2007; Ricardo-AEA, 2015; NAS, 2013).

Also, they have a relatively long life cycle and low selfdischarging losses. One of their few drawbacks is their sensitivity to overcharging, which is why they require a battery management system. Other automotive battery concepts include nickel-metal hydride (Ni-MH), sodium-nickel chloride (Na/NiCl2), and non-electrochemical alternatives such as supercapacitors, which allow fast charging but provide low energy density.

As a result, batteries with higher energy and power densities are being developed, such as lithiumair (Li-air), lithium-metal or lithiumsulphur (Li-S), but these are far from commercialization (Cookson, 2015; Hacker, Harthan, Matthes & Zimmer, 2009). Li-air batteries may reach energy densities of up to 11,680 Wh per kg (Imanishi & Yamamoto, 2014), which approximates the energetic content of gasoline.

CHAPTER 2

LITERATURE SURVEY

2.1 Literature survey

F. Wang, Yutao Luo, H. Li and X. Xu

“Switching Characteristics Optimization of Two-Phase Interleaved Bidirectional DC/DC for Electric Vehicles”

In electric vehicles (EVs), bidirectional DC/DC (Bi-DC/DC) is installed between the battery pack and the DC bus to step up the voltage. In the process of mode switching under step signal, the Bi-DC/DC will be affected by a large current inrush which threatens the safety of the circuit. In this paper, a Bi-DC/DC mode switching method based on the optimized Bezier curve is proposed. The Boost and Buck modes can be switched based on the proposed method with fast and non-overshoot switching performance. The experimental results show that the mode switching can be finished in 4 ms without overshoot based on the optimal switching curve.

Srdjan Srdic, S.Lukic

“Electric vehicle charging infrastructure and dc microgrids”

With substantial growth in sales of electric vehicles (EVs) globally, there is a push for expansion of the recharging infrastructure to service these vehicles. Over 2 million of electric cars (battery-electric and plug-in hybrid electric), 200 million electric motorcycles and 345 thousand buses (primarily in China) were deployed worldwide by the end of 2016, and over 1.2 million of electric cars were sold globally in 2017 alone. However, the global electric car stock made only a 0.2% of the total number of passenger cars globally in 2017. Assessments of country targets, original equipment manufacturer announcements and deployment scenarios for electric cars indicate that the number of EVs will range between 9 and 20 million by 2020 and between 40 and 70 million by 2025. Furthermore, a number of countries have decided to end the sales of fossil-fuel-powered cars in the near future (Norway by 2025, India and Netherlands by 2030, Scotland by 2032, France and rest of the United Kingdom by 2040), further accelerating the shift to electric transportation. The electric vehicle supply equipment (EVSE) is closely following the EV stock growth, with 2.3 million EVSE outlets (including 110,000 publicly available fast-charging outlets) available globally in 2016, and predicted six-fold increase in the available outlets by 2025. The fastest growing EVSE market is the Chinese market, with over 88,000 publicly available fast-charging outlets in 2016.

A.G. Ter Gazarian

“Electrical vehicles as distributed energy sources and storage”

Electric motors typically have on-board efficiencies of around 80% at converting electrical energy into driving a vehicle. Electric motors do not consume energy while freewheeling or idling. Moreover, modern plug-in electric cars can recharge their on-board batteries using regenerative braking and reuse most of the energy normally lost during braking. Electric vehicle requires electricity to power its motor either directly or via a battery. Hybrid electric car generates the required energy by an on -board ICE mechanically connected to electric generator which feeds electricity to a motor and may charge an on -board battery. Plug in hybrid electric car is an example of distributed energy source with storage. So, electric vehicle might be an alternative to an ICE -driven one and it is not surprising that as of September 2018, there were over 4 million all -electric and plug-in hybrid cars in use all over the world.

A.Bindra

“Electric Vehicle Batteries Eye solid state Technology: Prototypes promise lower cost,faster charging and greater safety”

The global pressure to cut carbon dioxide emissions from automobiles is driving more and more buyers toward electric vehicles (EVs) and hybrid EVs (HEVs). As the market for EVs and HEVs slowly grows with lithium-ion (Liion) as the battery technology of choice, for reasons well known, there is another technology emerging. Researchers are developing a solid-state (SS) version of Li-ion batteries for EVs that promises to charge and discharge rapidly, offer longer lifecycles, provide a much higher energy density, cost less, and provide greater safety. Besides the performance improvement, safety is a major factor driving automakers toward SS technology. In SS batteries (SSBs), the flammable liquid electrolyte, which passes the charge that carries Li ions during charge and discharge cycles, is replaced by a solid electrolyte.

Brennan A. Borlaug, S. Salisbury, M. Gerdes

“Levelized cost of charging Electric vehicles in the United states”

The cost to charge an electric vehicle (EV) varies depending on the price of electricity at different charging sites (home, workplace, public), vehicle use, region, and time of day, and for different charging power levels and equipment and installation costs. This paper provides a detailed assessment of the current (2019) levelized cost of light-duty EV charging in the United States, considering the purchase and installation costs of charging equipment and electricity prices from real-world utility tariffs. We find national averages of \$0.15/kWh for battery EVs and \$0.14/kWh for plug-in hybrid EVs in the United States. Costs, however, vary considerably (e.g., \$0.08/kWh to \$0.27/kWh for battery EVs) for different charging behaviors and equipment costs, corresponding to a total projected fuel cost savings between \$3,000 and \$10,500 compared with gasoline vehicles (over a 15-year time horizon). Regional heterogeneities and uncertainty on lifetime vehicle use and future fuel prices produce even greater variations.

Callie W. Babbitt

" Sustainability perspectives on lithium ion batteries''

Research on novel battery materials, designs, manufacturing, and performance has expanded rapidly in the last decade, yet has only begun to comprehend the potential sustainability challenges inherent to this system. Sustainability challenges span the entire technology life cycle for energy storage systems like lithium-ion batteries (LIBs): from raw material extraction, battery manufacturing, electric vehicle use, and management of LIBs at end-oflife. Raw material impacts typically stem from the resources that provide LIBs with their necessary electrochemical functionality, including the typically graphitic anode and the cathode, which is usually comprised of lithium, cobalt, nickel, and manganese in varied concentrations. While early attention was focused on lithium availability, recent research has demonstrated that cobalt may actually present the greatest concerns with respect to sustainability and long-term availability. Cobalt is primarily sourced in the Democratic Republic of the Congo, a region historically characterized by political instability, social impacts in the mining sector, and lack of supply chain transparency. The global reliance on such a concentrated supply chain introduces risks of resource shortages or price spikes due to disruptions, which may translate to downstream impacts on battery and even vehicle price competitiveness (Leader et al. 2019). Ensuring a long-term, stable supply of cobalt will require expanding the geographic diversity of the supply chain while at the same time developing secondary sources to be obtained through increased recycling (Fu et al. 2020).

D.Xu, Q.Liu W.Yang

"Adaptive terminal sliding mode control for hybrid energy storage systems of fuel cell,battery and supercapacitor"

In this paper, a terminal sliding mode control strategy with projection operator adaptive law is proposed in a hybrid energy storage system (HESS). The objective of the proposed control strategy is to provide power for load in time, get good tracking performance of the current of the fuel cell, battery, and supercapacitor, and obtain a stable voltage of the dc bus. At first, the topological structure of the system is proposed, and the mathematical models are derived.

Then, on the basis of the working characteristics of the energy storage unit, the load power is reasonably and effectively distributed to increase the service life of HESS and improve energy efficiency. Meanwhile, according to the tracking errors of reference and actual values, the terminal sliding surfaces can be set out. The controller can be designed by the constraint condition, combining the projection operator adaptive law. In addition, the HESS with the proposed control is proved to be asymptotically stable by using the Lyapunov method. Finally, the simulation results show that the proposed control strategy can make the whole system stable, and the control objective can also be better realized

CHAPTER 3

BATTERY STORAGE SYSTEM

3.1 INTRODUCTION TO BATTERY:

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal.

When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to include devices composed of a single cell.

Primary (single-use or "disposable") batteries are used once and discarded, as the electrode materials are irreversibly changed during discharge; a common example is the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and mobile phones.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smartphones, to large lead acid batteries or lithium-ion batteries in vehicles, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centers.

Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. In automobiles, this is somewhat offset by the higher efficiency of electric motors in converting chemical energy to mechanical work, compared to combustion engines.

The usage of "battery" to describe a group of electrical devices dates to Benjamin Franklin, who in 1748 described multiple Leyden jars by analogy to a battery of cannon (Benjamin Franklin borrowed the term "battery" from the military, which refers to weapons functioning together).

Italian physicist Alessandro Volta built and described the first electrochemical battery, the voltaic pile, in 1800.This was a stack of copper and zinc plates, separated by brine-soaked paper disks, that could produce a steady current for a considerable length of time.

Volta did not understand that the voltage was due to chemical reactions. He thought that his cells were an inexhaustible source of energy, and that the associated corrosion effects at the electrodes were a mere nuisance, rather than an unavoidable consequence of their operation, as Michael Faraday showed in 1834.

Although early batteries were of great value for experimental purposes, in practice their voltages fluctuated and they could not provide a large current for a sustained period. The Daniell cell, invented in 1836 by British chemist John Frederic Daniell, was the first practical source of electricity, becoming an industry standard and seeing widespread adoption as a power source for electrical telegraph networks.

It consisted of a copper pot filled with a copper sulfate solution, in which was immersed an unglazed earthenware container filled with sulfuric acid and a zinc electrode.

These wet cells used liquid electrolytes, which were prone to leakage and spillage if not handled correctly. Many used glass jars to hold their components, which made them fragile and potentially dangerous. These characteristics made wet cells unsuitable for portable appliances.

Near the end of the nineteenth century, the invention of dry cell batteries, which replaced the liquid electrolyte with a paste, made portable electrical devices practical

Batteries convert chemical energy directly to electrical energy. In many cases, the electrical energy released is the difference in the cohesive or bond energies of the metals, oxides, or molecules undergoing the electrochemical reaction. For instance, energy can be stored in Zn or Li, which are high-energy metals because they are not stabilized by d-electron bonding, unlike transition metals. Batteries are designed such that the energetically favorable redox reaction can occur only if electrons move through the external part of the circuit.

A battery consists of some number of voltaic cells. Each cell consists of two half-cells connected in series by a conductive electrolyte containing metal cations. One half-cell includes electrolyte and the negative electrode, the electrode to which anions (negatively charged ions) migrate; the other half-cell includes electrolyte and the positive electrode, to which cations (positively charged ions) migrate.

Cations are reduced (electrons are added) at the cathode, while metal atoms are oxidized (electrons are removed) at the anode. Some cells use different electrolytes for each half-cell; then a separator is used to prevent mixing of the electrolytes while allowing ions to flow between half-cells to complete the electrical circuit.

Each half-cell has an electromotive force (emf, measured in volts) relative to a standard. The net emf of the cell is the difference between the emfs of its half-cells. Thus, if the electrodes have emfs and ,then the net emf is; in other words, the net emf is the difference between the reduction potentials of the half-reactions.

The electrical driving force or across the terminals of a cell is known as the terminal voltage (difference) and is measured in volts. The terminal voltage of a cell that is neither charging nor discharging is called the open-circuit voltage and equals the emf of the cell. Because of internal resistance, the terminal voltage of a cell that is discharging is smaller in magnitude than the open-circuit voltage and the terminal voltage of a cell that is charging exceeds the open-circuit voltage.

An ideal cell has negligible internal resistance, so it would maintain a constant terminal voltage of until exhausted, then dropping to zero. If such a cell maintained 1.5 volts and produce a charge of one coulomb then on complete discharge it would have performed 1.5 joules of work. In actual cells, the internal resistance increases under discharge and the open-circuit voltage also decreases under discharge. If the voltage and resistance are plotted against time, the resulting graphs typically are a curve; the shape of the curve varies according to the chemistry and internal arrangement employed.

The voltage developed across a cell's terminals depends on the energy release of the chemical reactions of its electrodes and electrolyte. Alkaline and zinc–carbon cells have different chemistries, but approximately the same emf of 1.5 volts; likewise NiCd and NiMH cells have different chemistries, but approximately the same emf of 1.2 volts. The high electrochemical potential changes in the reactions of lithium compounds give lithium cells emfs of 3 volts or more.

3.2 CLASSIFICATION OF BATTERIES:

Primary batteries are designed to be used until exhausted of energy then discarded. Their chemical reactions are generally not reversible, so they cannot be recharged. When the supply of reactants in the battery is exhausted, the battery stops producing current and is useless.

Secondary batteries can be recharged; that is, they can have their chemical reactions reversed by applying electric current to the cell. This regenerates the original chemical reactants, so they can be used, recharged, and used again multiple times.

Some types of primary batteries used, for example, for telegraph circuits, were restored to operation by replacing the electrodes. Secondary batteries are not indefinitely rechargeable due to dissipation of the active materials, loss of electrolyte and internal corrosion.

3.2.1 PRIMARY

Main article: Primary cell

Primary batteries, or primary cells, can produce current immediately on assembly. These are most commonly used in portable devices that have low current drain, are used only intermittently, or are used well away from an alternative power source, such as in alarm and communication circuits where other electric power is only intermittently available. Disposable primary cells cannot be reliably recharged, since the chemical reactions are not easily reversible and active materials may not return to their original forms. Battery manufacturers recommend against attempting to recharge primary cells. In general, these have higher energy densities than rechargeable batteries, but disposable batteries do not fare well under high-drain applications with loads under 75 ohms (75 Ω). Common types of disposable batteries include zinc–carbon batteries and alkaline batteries.

3.2.2 SECONDARY:

Main article: Rechargeable battery

Secondary batteries, also known as secondary cells, or rechargeable batteries, must be charged before first use; they are usually assembled with active materials in the discharged state. Rechargeable batteries are (re)charged by applying electric current, which reverses the chemical reactions that occur during discharge/use. Devices to supply the appropriate current are called chargers.

The oldest form of rechargeable battery is the lead–acid battery, which are widely used in automotive and boating applications. This technology contains liquid electrolyte in an unsealed container, requiring that the battery be kept upright and the area be well ventilated to ensure safe dispersal of the hydrogen gas it produces during overcharging. The lead–acid battery is relatively heavy for the amount of electrical energy it can supply.

Its low manufacturing cost and its high surge current levels make it common where its capacity (over approximately 10 Ah) is more important than weight and handling issues. A common application is the modern car battery, which can, in general, deliver a peak current of 450 amperes.

The sealed valve regulated lead–acid battery (VRLA battery) is popular in the automotive industry as a replacement for the lead–acid wet cell. The VRLA battery uses an immobilized sulfuric acid electrolyte, reducing the chance of leakage and extending shelf life. VRLA batteries immobilize the electrolyte. The two types are:

Gel batteries (or "gel cell") use a semi-solid electrolyte.

Absorbed Glass Mat (AGM) batteries absorb the electrolyte in a special fiberglass matting.

Other portable rechargeable batteries include several sealed "dry cell" types, that are useful in applications such as mobile phones and laptop computers. Cells of this type (in order of increasing power density and cost) include nickel–cadmium (NiCd), nickel–zinc (NiZn), nickel metal hydride (NiMH), and lithium-ion (Li-ion) cells. Li-ion has by far the highest share of the dry cell rechargeable market. NiMH has replaced NiCd in most applications due to its higher capacity, but NiCd remains in use in power tools, two-way radios, and medical equipment.

In the 2000s, developments include batteries with embedded electronics such as USBCELL, which allows charging an AA battery through a USB connector, nanoball batteries that allow for a discharge rate about 100x greater than current batteries, and smart battery packs with state-of-charge monitors and battery protection circuits that prevent damage on over-discharge. Low self-discharge (LSD) allows secondary cells to be charged prior to shipping.

3.3 CELL TYPES:

Many types of electrochemical cells have been produced, with varying chemical processes and designs, including galvanic cells, electrolytic cells, fuel cells, flow cells and voltaic piles.

WET CELL

A wet cell battery has a liquid electrolyte. Other names are flooded cell, since the liquid covers all internal parts, or vented cell, since gases produced during operation can escape to the air. Wet cells were a precursor to dry cells and are commonly used as a learning tool for electrochemistry. They can be built with common laboratory supplies, such as beakers, for demonstrations of how electrochemical cells work. A particular type of wet cell known as a concentration cell is important in understanding corrosion. Wet cells may be primary cells (non-rechargeable) or secondary cells (rechargeable).

Originally, all practical primary batteries such as the Daniell cell were built as open-top glass jar wet cells. Other primary wet cells are the Leclanche cell, Grove cell, Bunsen cell, Chromic acid cell, Clark cell, and Weston cell. The Leclanche cell chemistry was adapted to the first dry cells. Wet cells are still used in automobile batteries and in industry for standby power for switchgear, telecommunication or large uninterruptible power supplies, but in many places batteries with gel cells have been used instead. These applications commonly use lead–acid or nickel–cadmium cells.

Dry cell

A dry cell uses a paste electrolyte, with only enough moisture to allow current to flow. Unlike a wet cell, a dry cell can operate in any orientation without spilling, as it contains no free liquid, making it suitable for portable equipment. By comparison, the first wet cells were typically fragile glass containers with lead rods hanging from the open top and needed careful handling to avoid spillage. Lead–acid batteries did not achieve the safety and portability of the dry cell until the development of the gel battery.

A common dry cell is the zinc–carbon battery, sometimes called the dry Leclanché cell, with a nominal voltage of 1.5 volts, the same as the alkaline battery (since both use the same zinc–manganese dioxide combination). A standard dry cell comprises a zinc anode, usually in the form of a cylindrical pot, with a carbon cathode in the form of a central rod.

The electrolyte is ammonium chloride in the form of a paste next to the zinc anode. The remaining space between the electrolyte and carbon cathode is taken up by a second paste consisting of ammonium chloride and manganese dioxide, the latter acting as a depolariser. In some designs, the ammonium chloride is replaced by zinc chloride.

MOLTEN SALT

Molten salt batteries are primary or secondary batteries that use a molten salt as electrolyte. They operate at high temperatures and must be well insulated to retain heat.

RESERVE

A reserve battery can be stored unassembled (unactivated and supplying no power) for a long period (perhaps years). When the battery is needed, then it is assembled (e.g., by adding electrolyte); once assembled, the battery is charged and ready to work. For example, a battery for an electronic artillery fuze might be activated by the impact of firing a gun.

The acceleration breaks a capsule of electrolyte that activates the battery and powers the fuze's circuits. Reserve batteries are usually designed for a short service life (seconds or minutes) after long storage (years). A water-activated battery for oceanographic instruments or military applications becomes activated on immersion in water.

3.3.1 CELL PERFORMANCE:

A battery's characteristics may vary over load cycle, over charge cycle, and over lifetime due to many factors including internal chemistry, current drain, and temperature. At low temperatures, a battery cannot deliver as much power. As such, in cold climates, some car owners install battery warmers, which are small electric heating pads that keep the car battery warm.

A battery's capacity is the amount of electric charge it can deliver at the rated voltage. The more electrode material contained in the cell the greater its capacity. A small cell has less capacity than a larger cell with the same chemistry, although they develop the same open-circuit voltage. Capacity is measured in units such as amp-hour (A·h). The rated capacity of a battery is usually expressed as the product of 20 hours multiplied by the current that a new battery can consistently supply for 20 hours at 68 °F (20 °C), while remaining above a specified terminal voltage per cell. For example, a battery rated at 100 A·h can deliver 5 A over a 20-hour period at room temperature.

The fraction of the stored charge that a battery can deliver depends on multiple factors, including battery chemistry, the rate at which the charge is delivered (current), the required terminal voltage, the storage period, ambient temperature and other factors.

The higher the discharge rate, the lower the capacity. The relationship between current, discharge time and capacity for a lead acid battery is approximated (over a typical range of current values) by Peukert's law:
where
is the capacity when discharged at a rate of 1 amp.
is the current drawn from battery (A).
is the amount of time (in hours) that a battery can sustain.
is a constant around 1.3.

Batteries that are stored for a long period or that are discharged at a small fraction of the capacity lose capacity due to the presence of generally irreversible side reactions that consume charge carriers without producing current.

This phenomenon is known as internal self-discharge. Further, when batteries are recharged, additional side reactions can occur, reducing capacity for subsequent discharges. After enough recharges, in essence all capacity is lost and the battery stops producing power.

Internal energy losses and limitations on the rate that ions pass through the electrolyte cause battery efficiency to vary. Above a minimum threshold, discharging at a low rate delivers more of the battery's capacity than at a higher rate. Installing batteries with varying A·h ratings does not affect device operation (although it may affect the operation interval) rated for a specific voltage unless load limits are exceeded. High-drain loads such as digital cameras can reduce total capacity, as happens with alkaline batteries. For example, a battery rated at 2 A·h for a 10- or 20-hour discharge would not sustain a current of 1 A for a full two hours as its stated capacity implies.

The C-rate is a measure of the rate at which a battery is being charged or discharged. It is defined as the current through the battery divided by the theoretical current draw under which the battery would deliver its nominal rated capacity in one hour. It has the units h^{-1}.

C-rate is used as a rating on batteries to indicate the maximum current that a battery can safely deliver on a circuit. Standards for rechargeable batteries generally rate the capacity over a 4-hour, 8 hour or longer discharge time. Types intended for special purposes, such as in a computer uninterruptible power supply, may be rated by manufacturers for discharge periods much less than one hour. Because of internal resistance loss and the chemical processes inside the cells, a battery rarely delivers nameplate rated capacity in only one hour.

Fast-charging, large and light batteries

As of 2017, the world's largest battery was built in South Australia by Tesla. It can store 129 MWh. A battery in Hebei Province, China which can store 36 MWh of electricity was built in 2013 at a cost of $500 million. Another large battery, composed of Ni–Cd cells, was in Fairbanks, Alaska. It covered 2,000 square metres (22,000 sq ft)—bigger than a football pitch—and weighed 1,300 tonnes.

It was manufactured by ABB to provide backup power in the event of a blackout. The battery can provide 40 MW of power for up to seven minutes. Sodium–sulfur batteries have been used to store wind power. A 4.4 MWh battery system that can deliver 11 MW for 25 minutes stabilizes the output of the Auwahi wind farm in Hawaii.
Lithium–sulfur batteries were used on the longest and highest solar-powered flight.

Lifetime

Battery life (and its synonym battery lifetime) has two meanings for rechargeable batteries but only one for non-chargeables. For rechargeables, it can mean either the length of time a device can run on a fully charged battery or the number of charge/discharge cycles possible before the cells fail to operate satisfactorily. For a non-rechargeable these two lives are equal since the cells last for only one cycle by definition. (The term shelf life is used to describe how long a battery will retain its performance between manufacture and use.)

Available capacity of all batteries drops with decreasing temperature. In contrast to most of today's batteries, the Zamboni pile, invented in 1812, offers a very long service life without refurbishment or recharge, although it supplies current only in the nanoamp range. The Oxford Electric Bell has been ringing almost continuously since 1840 on its original pair of batteries, thought to be Zamboni piles

Self-discharge

Disposable batteries typically lose 8 to 20 percent of their original charge per year when stored at room temperature (20–30 °C) . This is known as the "self-discharge" rate, and is due to non-current-producing "side" chemical reactions that occur within the cell even when no load is applied. The rate of side reactions is reduced for batteries stored at lower temperatures, although some can be damaged by freezing.

Old rechargeable batteries self-discharge more rapidly than disposable alkaline batteries, especially nickel-based batteries; a freshly charged nickel cadmium (NiCd) battery loses 10% of its charge in the first 24 hours, and thereafter discharges at a rate of about 10% a month. However, newer low self-discharge nickel metal hydride (NiMH) batteries and modern lithium designs display a lower self-discharge rate (but still higher than for primary batteries).

Corrosion

Internal parts may corrode and fail, or the active materials may be slowly converted to inactive forms.

Physical component changes

The active material on the battery plates changes chemical composition on each charge and discharge cycle; active material may be lost due to physical changes of volume, further limiting the number of times the battery can be recharged. Most nickel-based batteries are partially discharged when purchased, and must be charged before first use. Newer NiMH batteries are ready to be used when purchased, and have only 15% discharge in a year.

Some deterioration occurs on each charge–discharge cycle. Degradation usually occurs because electrolyte migrates away from the electrodes or because active material detaches from the electrodes. Low-capacity NiMH batteries (1,700–2,000 mA·h) can be charged some 1,000 times, whereas high-capacity NiMH batteries (above 2,500 mA·h) last about 500 cycles. NiCd batteries tend to be rated for 1,000 cycles before their internal resistance permanently increases beyond usable values

3.4 LITHIUM ION BATTERY:

A lithium-ion battery or Li-ion battery is a type of rechargeable battery. Lithium-ion batteries are commonly used for portable electronics and electric vehicles and are growing in popularity for military and aerospace applications.

A prototype Li-ion battery was developed by Akira Yoshino in 1985, based on earlier research by John Goodenough, M. Stanley Whittingham, Rachid Yazami and Koichi Mizushima during the 1970s–1980s, and then a commercial Li-ion battery was developed by a Sony and Asahi Kasei team led by Yoshio Nishi in 1991.

In the batteries, lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. Li-ion batteries use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode.

The batteries have a high energy density, no memory effect (other than LFP cells) and low self-discharge. They can however be a safety hazard since they contain flammable electrolytes, and if damaged or incorrectly charged can lead to explosions and fires. Samsung was forced to recall Galaxy Note 7 handsets following lithium-ion fires, and there have been several incidents involving batteries on Boeing 787s.

Chemistry, performance, cost and safety characteristics vary across types of lithium-ion batteries. Handheld electronics mostly use lithium polymer batteries (with a polymer gel as electrolyte), a lithium cobalt oxide ($LiCoO_2$) cathode material, and a graphite anode, which together offer a high energy density.

Lithium iron phosphate ($LiFePO_4$), lithium manganese oxide ($LiMn_2O_4$ spinel, or Li_2MnO_3-based lithium rich layered materials (LMR-NMC)), and lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$ or NMC) may offer longer lives and may have better rate capability. Such batteries are widely used for electric tools, medical equipment, and other roles. NMC and its derivatives are widely used in electric vehicles.

Research areas for lithium-ion batteries include extending lifetime, increasing energy density, improving safety, reducing cost, and increasing charging speed, among others. Research has been under way in the area of non-flammable electrolytes as a pathway to increased safety based on the flammability and volatility of the organic solvents used in the typical electrolyte. Strategies include aqueous lithium-ion batteries, ceramic solid electrolytes, polymer electrolytes, ionic liquids, and heavily fluorinated systems.

3.4.1 Lithium ion battery advantages

There are many advantages to using a li-ion cell of battery. As a result the technology is being used increasingly for a huge number of widely varying applications. Everything from small electronic devices, through smartphones and laptops to vehicles and many other applications.

The advantages of Li-ion technology mean that these batteries are finding an increasing number of applications, and as a result a huge amount of development is being invested into them.

The li-ion battery advantages include:

- **High energy density:** The high energy density is one of the chief advantages of lithium ion battery technology. With electronic equipment such as mobile phones needing to operate longer between charges while still consuming more power, there is always a need to batteries with a much higher energy density.

  In addition to this, there are many power applications from power tools to electric vehicles. The much higher power density offered by lithium ion batteries is a distinct advantage. Electric vehicles also need a battery technology that has a high energy density.

- **Self-discharge:** One issue with many rechargeable batteries is the self discharge rate. Lithium ion cells is that their rate of self-discharge is much lower than that of other rechargeable cells such as Ni-Cad and NiMH forms. It is typically around 5% in the first 4 hours after being charged but then falls to a figure of around 1 or 2% per month.

- **Low maintenance:** One major lithium ion battery advantage is that they do not require and maintenance to ensure their performance.Ni-Cad cells required a periodic discharge to ensure that they did not exhibit the memory effect.

  As this does not affect lithium ion cells, this process or other similar maintenance procedures are not required. Likewise lead acid cells require maintenance, some needing the battery acid to be topped up periodically.Fortunately one of the advantages of lithium ion batteries is that there is no active maintenance required.

- **Cell voltage:** The voltage produced by each lithium ion cell is about 3.6 volts. This has many advantages. Being higher than that of the standard nickel cadmium, nickel metal hydride and even standard alkaline cells at around 1.5 volts and lead acid at around 2 volts per cell, the voltage of each lithium ion cell is higher, requiring less cells in many battery applications. For smartphones a single cell is all that is needed and this simplifies the power management.

- **Load characteristics:** The load characteristics of a lithium ion cell or battery are reasonably good. They provide a reasonably constant 3.6 volts per cell before falling off as the last charge is used.

- **No requirement for priming:** Some rechargeable cells need to be primed when they receive their first charge. One advantage of lithium ion batteries is that there is no requirement for this they are supplied operational and ready to go.

- **Variety of types available:** There are several types of lithium ion cell available. This advantage of lithium ion batteries can mean that the right technology can be used for the particular application needed. Some forms of lithium ion battery provide a high current density and are ideal for consumer mobile electronic equipment. Others are able to provide much higher current levels and are ideal for power tools and electric vehicles

- **Options:** One of the biggest advantages of lithium ion batteries is the fact that they come in all shapes and sizes- presenting users with a large number of options to choose from according to their needs.

It must, however, be noted that it is not all hunky dory in the land of lithium. A Lithium Ion Battery comes with its own flaws too.

3.4.2 Lithium ion battery disadvantages

Like the use of any technology, there are some disadvantages that need to be balanced against the benefits.

Although Lithium ion battery technology does have its disadvantages, this does not mean these cannot be overcome or at least mitigated and excellent performance obtained.

Knowing the disadvantages means that work arounds can often be included int he design to reduce the effects of the shortcomings.

The li-ion battery disadvantages include:

- **Protection required***:* Lithium ion cells and batteries are not as robust as some other rechargeable technologies. They require protection from being over charged and discharged too far. In addition to this, they need to have the current maintained within safe limits. Accordingly one lithium ion battery disadvantage is that they require protection circuitry incorporated to ensure they are kept within their safe operating limits.

  Fortunately with modern integrated circuit technology, this can be relatively easily incorporated into the battery, or within the equipment if the battery is not interchangeable. Incorporation of the battery management circuitry enables li-ion batteries to be used without any special knowledge. They can be left on charge and after the battery is fully charged the charger will cut the supply to it.

The protection circuitry built into lithium ion batteries monitors a number of aspects of their operation. The protection circuit limits the peak voltage of each cell during charge as excessive voltage can damage the cells.

They are typically charged in series as there is normally only one connection for a battery and therefore as different cells may require different levels of charge there is a possibility of one cell experiencing a higher than required voltage.Also the protection circuitry prevents the cell voltage from dropping too low on discharge. Again this can happen if one cell can store less charge than others on the battery and its charge becomes exhausted before the others.

A further aspect of the protection circuitry is that the cell temperature is monitored to prevent temperature extremes.

The maximum charge and discharge current on most packs is limited to between 1°C and 2°C. That said, some do become a little warm on occasions when fast charging.

- **Ageing:** One of the major lithium ion battery disadvantages for consumer electronics is that lithium ion batteries suffer from ageing. Not only is this time or calendar dependent, but it is also dependent upon the number of charge discharge cycles that the battery has undergone.

  Often batteries will only be able to withstand 500 - 1000 charge discharge cycles before their capacity falls. With the development of li-ion technology, this figure is increasing, but after a while batteries may need replacing and this can be an issue if they are embedded in the equipment.

  Lithium ion batteries also age whether they are in use or not. Despite the usage there is also a time related element to the reduction in capacity.

When a typical consumer lithium cobalt oxide, LCO battery or cell needs to be stored it should be partially charged - around 40% to 50% and kept in a cool storage area. Storage under these conditions will help increase the life.

3.4.3 Applications of Lithium-Ion Batteries

As established above, Li-ion batteries are available in all shapes and sizes. And that renders them to be the perfect option for power needs irrespective of the size of the system. Along with that, lithium-ion batteries offer power solutions across the spectrum- from energy storage solutions to portable energy solutions. Some of the most common applications of lithium-ion batteries are:

- Power backups/UPS

- Mobile, Laptops, and other commonly used consumer electronic goods
- Electric mobility
- Energy Storage Systems

As there are varied uses of a Lithium Ion Battery, it comes in different types of packaging. However, there are some general advantages of using a Li-ion battery over other traditional batteries

Future of Lithium-Ion batteries

When Tesla launched their Model S, it was then that Lithium-ion batteries became a household name. It was then that the world stopped and took notice of a battery could virtually power a car for more than 300 miles. As the market for electric automotive increases and as they become more and more accessible to the common man, the costs surrounding the lithium ion battery technology will also come down. Apart from that, with the world pushing for maximum portability of most gadgets, there is a huge market for the lithium-ion technology.

CHAPTER 4

PROPOSED DC DC CONVERTER

4.1 DC-DC CONVERTER:

Buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, ranging from much larger (in absolute magnitude) than the input voltage, down to almost zero.

The output voltage is of the opposite polarity than the input. This is a switched-mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry.

However, this drawback is of no consequence if the power supply is isolated from the load circuit (if, for example, the supply is a battery) because the supply and diode polarity can simply be reversed. When they can be reversed, the switch can be on either the ground side or the supply side.

A buck (step-down) converter combined with a boost (step-up) converter .The output voltage is typically of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor mode and the boost inductor mode, using switches instead of diodes,[2][3] sometimes called a "four-switch buck-boost converter",[4] it may use multiple inductors but only a single switch as in the SEPIC and Ćuk topologies.

4.1.1 Introduction to Buck Boost converter

A Buck converter is a switch mode DC to DC converter in which the output voltage can be transformed to a level less than or greater than the input voltage. The magnitude of output voltage depends on the duty cycle of the switch.It is also called as step up/step down converter.

The name step up/step down converter comes from the fact that analogous to step up/step down transformer the input voltage can be stepped up/down to a level greater than/less than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

$$\text{Input power } (P_{in}) = \text{output power } (P_{out})$$

In step up mode $V_{in} < V_{out}$ in a Buck Boost converter, it follows then that the output current will be less than the input current. Therefore for a Buck Boost converter in step up mode

$$V_{in} < V_{out} \text{ and } I_{in} > I_{out}$$

In step down mode $V_{in} > V_{out}$ in a Buck Boost converter, it follows then that the output current will be greater than the input current. Therefore for a Buck Boost converter in step down mode

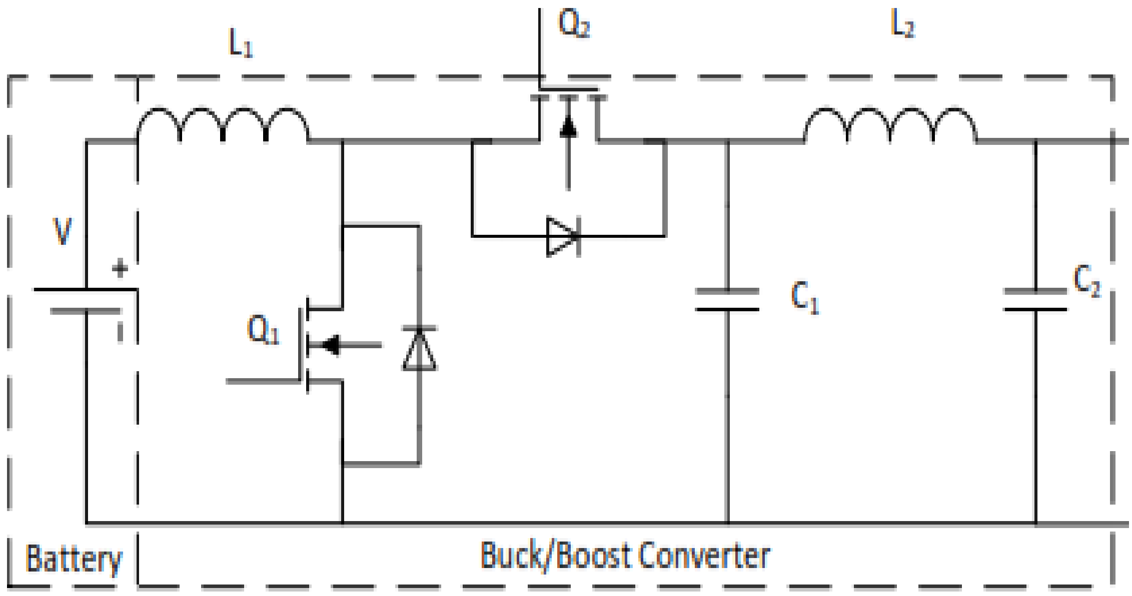
$$V_{in} > V_{out} \text{ and } I_{in} < I_{out}$$

4.2 Principle of operation of Buck Boost converter

The main working principle of Buck Boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is ON the inductor stores energy from the input in the form of magnetic energy and discharges it when switch is closed.

The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures that in steady state a constant output voltage $V_o(t) = V_o$(constant) exists .

4.2.1 Circuit diagram of Buck Boost converter



4.2.1 Proposed converter

4.3 Modes of operation of Buck Boost converter

The Buck Boost converter can be operated in two modes

a) Continuous conduction mode in which the current through inductor never goes to zero i.e. inductor partially discharges before the start of the switching cycle.

b) Discontinuous conduction mode in which the current through inductor goes to zero i.e. inductor is completely discharged at the end of switching cycle.

Circuit analysis of Buck converter

Assume in the entire analysis that the current swing (maximum to minimum value) through inductor and voltage swing through capacitor is very less so that they vary in a linear fashion. This is to ease the analysis and the results we will get through this analysis are quite accurate compared to real values.

Continuous conduction mode

case-1: When switch S is ON

When switch in ON for a time t_{on}, the diode will be open circuited since it does not allow currents in reverse direction from input to output. Hence the Buck Boost converter can be redrawn as follows

During this state the inductor charges and the inductor current increases. The current through the inductor is given as

$$I_L = (1/L) * \int V * dt$$

Assume that prior to the opening of switch the inductor current is $I'_{L,\ off}$. Since the input voltage is constant

$$I_{L,on} = (1/L) * \int V_{in} * dt + I'_{L,on}$$

Assume the switch is open for ton seconds which is given by $D*T_s$ where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch on state is given as

$I_{L,\ on} = (1/L) *V_{in}*D*T_s + I'_{L,\ on}$ (equation 1)

Hence $\Delta I_{L,on} = (1/L)*V_{in}*D*T_s$.

case 2: When switch is off

When switch in OFF the diode will be forward biased as it allows current from output to input (p to n terminal) and the Buck Boost converter circuit can be redrawn as follows

The inductor now discharges through the diode and RC combination. Assume that prior to the closing of switch the inductor current is $I''_{L,\ off}$. The current through the inductor is given as

$$I'''_{L,off} = -(1/L) * \int V_{out} * dt + I''_{L,off}$$

Note the negative sign at the front end of equation signifies that the inductor is discharging. Assume the switch is open for t_{off} seconds which is given by $(1-D)*T_s$ where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch off state is given as

$$I'''_{L, off} = -(1/L) * V_{out} * (1-D) * T_s + I''_{L, off} \text{ (equation 2)}$$

In steady state condition as the current through the inductor does not change abruptly, the current at the end of switch on state and the current at the end of switch off state should be equal. Also the currents at the start of switch off state should be equal to current at the end of switch on state. Hence

$$I'''_{L, off} = I_{L, on} \text{ also } I'_{L, off} = I''_{L, off}$$

Using the equations 1 and 2 we get

$$(1/L) * V_{in} * D * T_s = (1/L) * V_{out} * (1-D) * T_s$$

$$V_{in} * D = V_{out} * (1-D)$$

$$V_{out}/V_{in} = D/(1-D)$$

Since D < 1, V_{out} can be greater than or less than V_{in}.For D>0.5 the Buck boost converter acts as boost converter with $V_{out} > V_{in}$.For D<0.5 the Buck boost converter acts as buck converter with $V_{out} > V_{in}$.

Assuming no losses in the circuit and applying the law of conservation of energy

$$V_{out} * I_{out} = V_{in} * I_{in}$$

This implies $I_{out}/I_{in} = (1-D)/D$, Thus $I_{out} > I_{in}$ for D<0.5 and $I_{out} < I_{in}$ for D<0.5 . As the duty cycle increases the output voltage increases and output current decreases.

Discontinuous conduction mode

As mentioned before the converter when operated in discontinuous mode the inductor drains its stored energy completely before completion of switching cycle. The current and voltage wave forms of Buck Boost converter in discontinuous mode is shown in the figure below

The inductor in discontinuous mode drains all the current which it piled up in charging interval of same switching cycle. The current through the inductor is given as

$$I_L = (1/L) \int V_L * dt$$ = (1/L)* area under the curve of voltage v/s time. Hence from the wave forms shown in the figure

$$V_{out}*\delta*T_s = V_{in}*D*T_s$$

$$V_{out}/V_{in} = D/\delta$$

and the ratio of output to input current from law of conservation of energy is $I_{out}/I_{in} = \delta/D$.

Benefits or advantages of Buck Boost Converters

Following are the benefits or advantages of Buck Boost Converters:

➡Buck converter offers most efficient solution with smallest external components.

➡It performs step-up or step-down of voltage using minimum components.

➡It offers lower operating duty cycle.

➡It offers high efficiency across wide input and output voltage ranges.

➡It is less expensive compare to most of the converters.

Drawbacks or disadvantages of Buck Boost Converters

Following are the drawbacks or disadvantages of Buck Boost Converters:

➡Input current and charging current of output capacitor is discontinuous as it results in large filter size and more EMI issues.

➡Output is inverted which results in complex sensing and feedback circuit. As sensed voltage is negative, inverting op-amp is needed for feedback and closed loop control.

➡High gain can not be achieved with this converter type as efficiency is poor for high gain (i.e. very small duty cycle or large duty cycle).

➡There is no isolation from input side to output side which is very critical for many applications.

➡Transfer function of the converter contains right half plane as zero which introduces control complexity. Hence it is very difficult to control such converter type.

4.3.1 Applications of Buck boost converter

- It is used in the self regulating power supplies.
- It has consumer electronics.
- It is used in the Battery power systems.
- Adaptive control applications.
- Power amplifier applications.

4.4 PULSE WIDTH MODULATION:

A modulation technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photovoltaic solar battery chargers, the other being MPPT.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. Typically switching has to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

An example of PWM in an idealized inductor driven by a voltage source: the voltage source (blue) is modulated as a series of pulses that results in a sine-like current/flux (red) in the inductor. The blue rectangular pulses nonetheless result in a smoother and smoother red sine wave as the switching frequency increases. Note that the red waveform is the (definite) integral of the blue waveform.

Principle

Pulse-width modulation uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform. If we consider a pulse waveform $f(t)$, with period T, low value y_{min}, a high value y_{max} and a duty cycle D (see figure 1), the average value of the waveform is given by:

$$\bar{y} = \frac{1}{T}\int_0^T f(t)\,dt.$$

As $f(t)$ is a pulse wave, its value is y_{max} for $0 < t < D \cdot T$ and y_{min} for $D \cdot T < t < T$. The above expression then becomes:

$$\begin{aligned}\bar{y} &= \frac{1}{T}\left(\int_0^{DT} y_{max}\,dt + \int_{DT}^{T} y_{min}\,dt\right)\\ &= \frac{D \cdot T \cdot y_{max} + T\,(1-D)\,y_{min}}{T}\\ &= D \cdot y_{max} + (1-D)\,y_{min}.\end{aligned}$$

This latter expression can be fairly simplified in many cases where $y_{min} = 0$ as $\bar{y} = D \cdot y_{max}$. From this, it is obvious that the average value of the signal ($\bar{y}$) is directly dependent on the duty cycle D.

The simplest way to generate a PWM signal is the intersective method, which requires only a sawtooth or a triangle waveform (easily generated using a simple oscillator) and a comparator. When the value of the reference signal (the red sine wave in figure 2) is more than the modulation waveform (blue), the PWM signal (magenta) is in the high state, otherwise it is in the low state.

The **PWM** is a technique which is used to drive the inertial loads since a very long time.The simple example of an inertial load is a motor. Apply the power to a motor for a very short period of time and then turn off the power: it can be observed that the motor is still running even after the power has been cut off from it.

This is due to the inertia of the motor and the significance of this factor is that the continuous power is not required for that kind of devices to operate. A burst power can save the total power supplied to the load while achieving the same performance from the device as it runs on continuous power.

The **PWM technique** is use in devices like DC motors, Loudspeakers, Class -D Amplifiers, SMPS etc. They are also used in communication field as-well.

The modulation techniques like AM, FM are widely used RF communication whereas the PWM is modulation technique is mostly used in Optical Fiber Communication (OFC).

As in the case of the inertial loads mentioned previously, the PWM in a communication link greatly saves the transmitter power.

The immunity of the PWM transmission against the inter-symbol interference is another advantage. This article discusses the technique of generating a PWM wave corresponding to a modulating sine wave.

4.4.1 DESCRIPTION:

The **Pulse Width Modulation** is a technique in which the ON time or OFF time of a pulse is varied according to the amplitude of the modulating signal, keeping t the (ON time + OFF time) time of the pulse as constant. The (ON time + OFF time) of a pulse is called ‘Period’ of the pulse, and the ratio of the ON time or OFF time with the Period is called the ‘Duty Cycle’.

Hence the PWM is a kind of modulation which keeps the Period of pulses constant but varying their duty cycle according to the amplitude of the modulating signal.

The conventional method of generating a PWM modulated wave is to compare the message signal with a ramp waveform using a comparator. The block diagram required for the generation of a simple PWM is shown

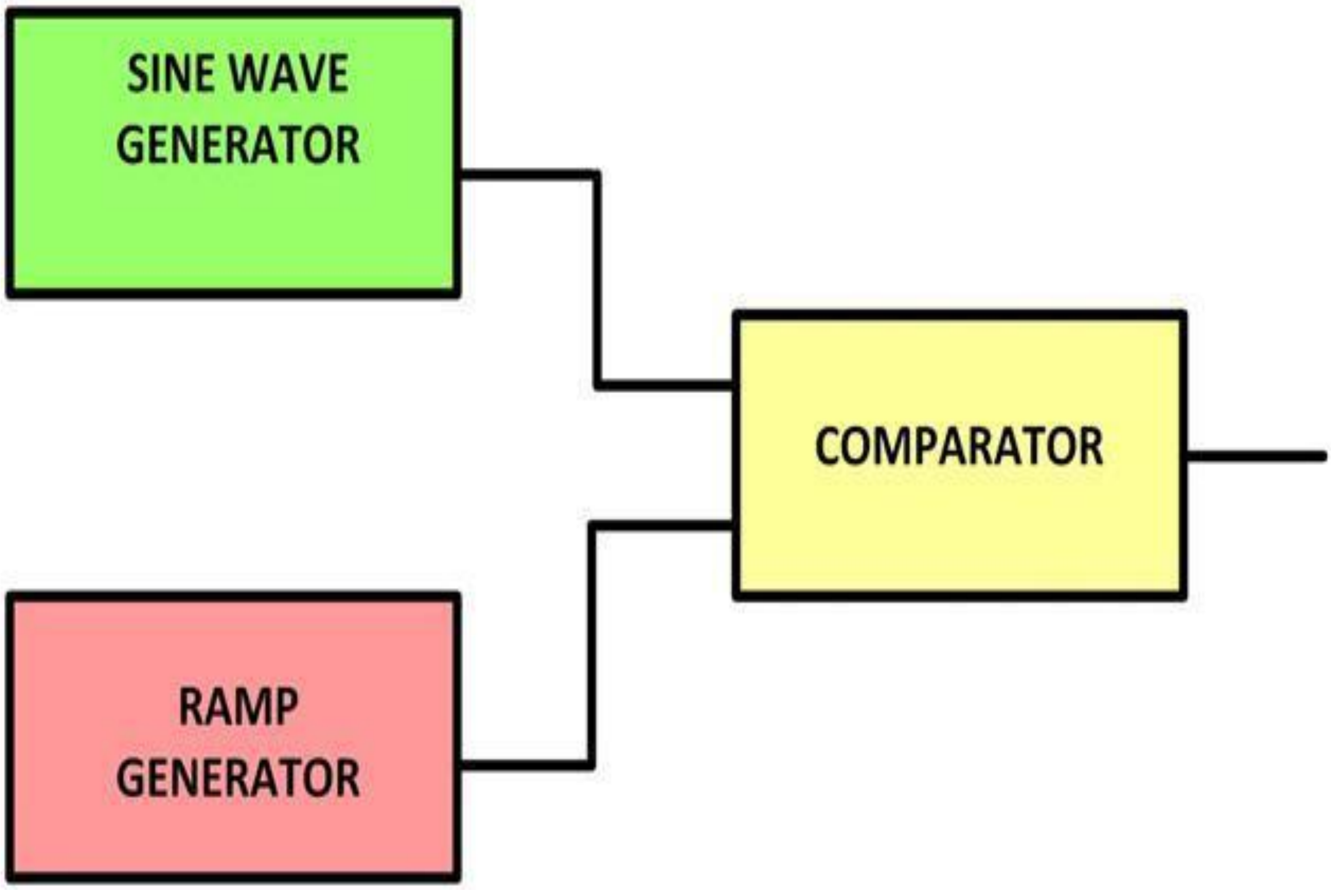


Fig: 4.4.2 SPWM block diagram

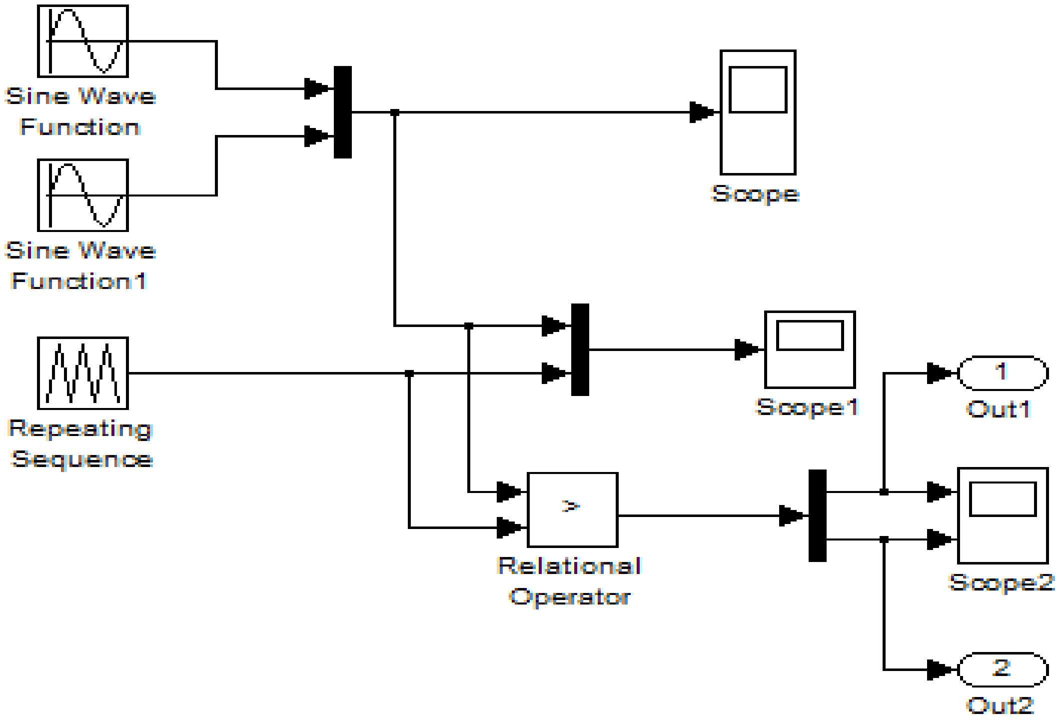


Fig: 4.4.3 SPWM SIMULATION DIAGRAM

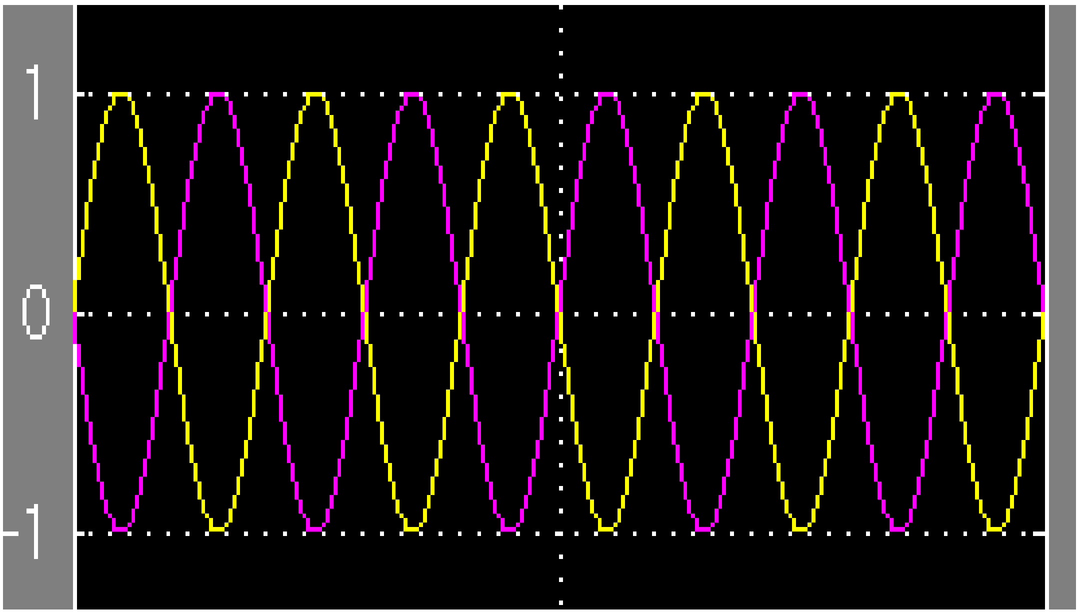


Fig: 4.4.4 SCOPE view

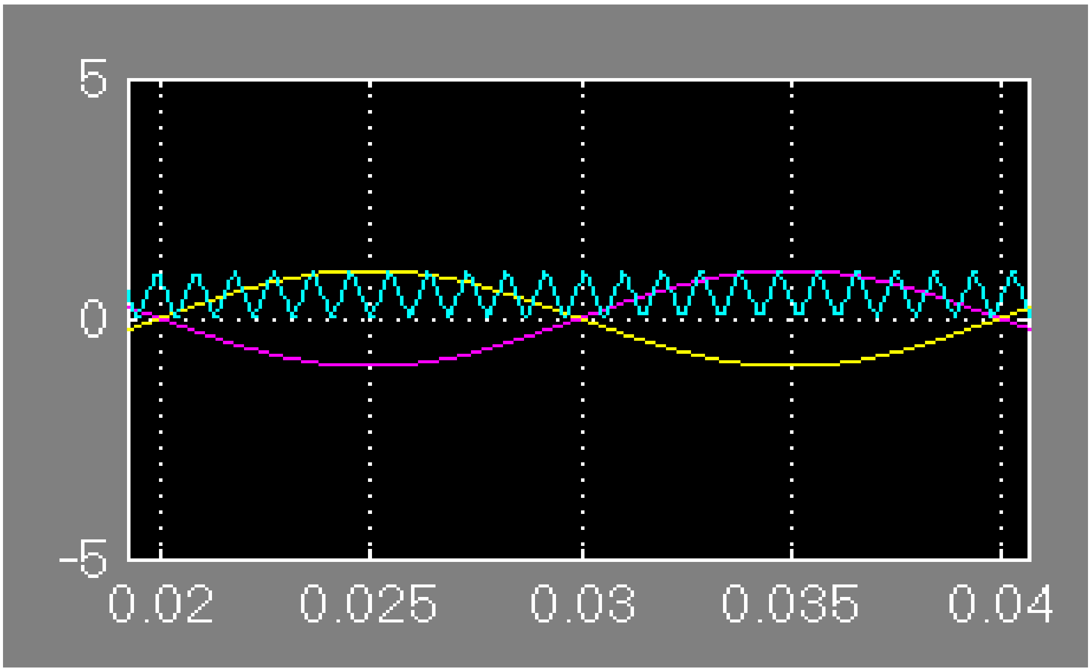


Fig: 4.4.5 SCOPE 1 view

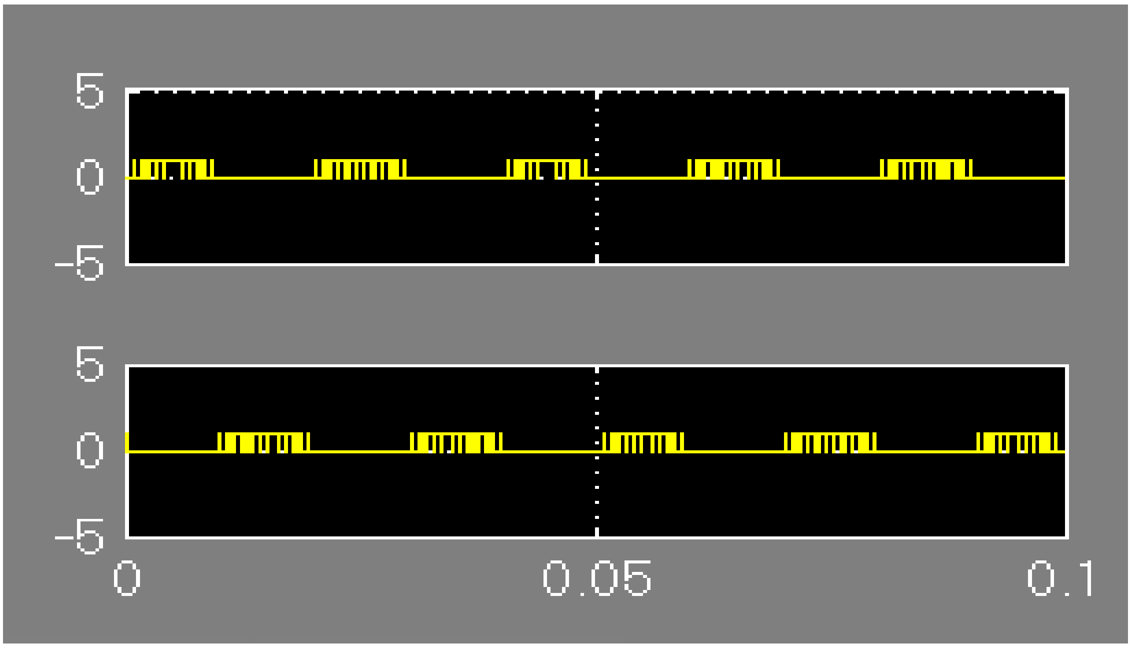


Fig: 4.4.6 SCOPE 2 view

CHAPTER 5

PROPOSED BRUSHLESS DC MOTORS

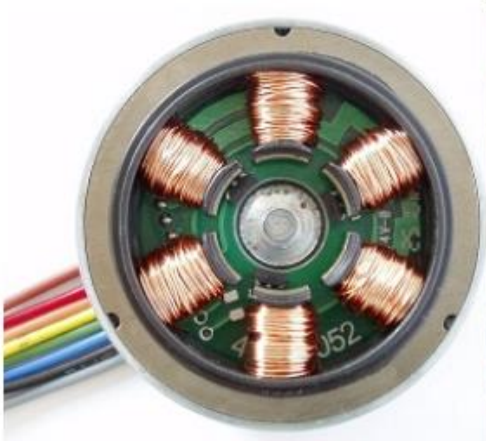
5.1 BRUSHLESS DC MOTOR:

Brushless DC motors (BLDC) have been a much focused area for numerous motor manufacturers as these motors are increasingly the preferred choice in many applications, especially in the field of motor control technology. BLDC motors are superior to brushed DC motors in many ways, such as ability to operate at high speeds, high efficiency, and better heat dissipation.

They are an indispensable part of modern drive technology, most commonly employed for actuating drives, machine tools, electric propulsion, robotics, computer peripherals and also for electrical power generation. With the development of sensorless technology besides digital control, these motors become so effective in terms of total system cost, size and reliability.

A brushless DC motor (known as BLDC) is a permanent magnet synchronous electric motor which is driven by direct current (DC) electricity and it accomplishes electronically controlled commutation system (commutation is the process of producing rotational torque in the motor by changing phase currents through it at appropriate times) instead of a mechanically commutation system. BLDC motors are also referred as trapezoidal permanent magnet motors.

Unlike conventional brushed type DC motor, wherein the brushes make the mechanical contact with commutator on the rotor so as to form an electric path between a DC electric source and rotor armature windings, BLDC motor employs electrical commutation with permanent magnet rotor and a stator with a sequence of coils. In this motor, permanent magnet (or field poles) rotates and current carrying conductors are fixed.



The armature coils are switched electronically by transistors or silicon controlled rectifiers at the correct rotor position in such a way that armature field is in space quadrature with the rotor field poles. Hence the force acting on the rotor causes it to rotate.

Hall sensors or rotary encoders are most commonly used to sense the position of the rotor and are positioned around the stator. The rotor position feedback from the sensor helps to determine when to switch the armature current.

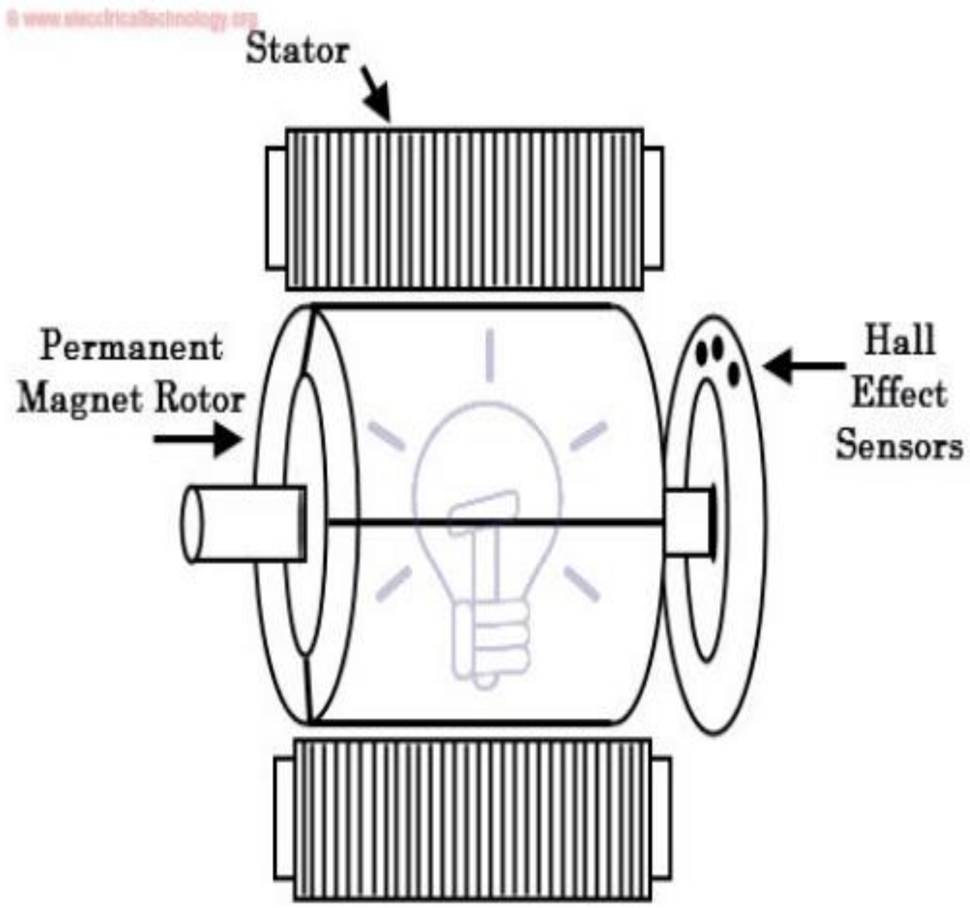
This electronic commutation arrangement eliminates the commutator arrangement and brushes in a DC motor and hence more reliable and less noisy operation is achieved. Due to the absence of brushes BLDC motors are capable to run at high speeds.

The efficiency of BLDC motors is typically 85 to 90 percent, whereas as brushed type DC motors are 75 to 80 percent efficient. There are wide varieties of BLDC motors available ranging from small power range to fractional horsepower, integral horsepower and large power ranges.

Construction of BLDC Motor

BLDC motors can be constructed in different physical configurations. Depending on the stator windings, these can be configured as single-phase, two-phase, or three-phase motors. However, three-phase BLDC motors with permanent magnet rotor are most commonly used.

The construction of this motor has many similarities of three phase induction motor as well as conventional DC motor. This motor has stator and rotor parts as like all other motors.



Stator of a BLDC motor made up of stacked steel laminations to carry the windings. These windings are placed in slots which are axially cut along the inner periphery of the stator. These windings can be arranged in either star or delta.

However, most BLDC motors have three phase star connected stator. Each winding is constructed with numerous interconnected coils, where one or more coils are placed in each slot. In order to form an even number of poles, each of these windings is distributed over the stator periphery.

The stator must be chosen with the correct rating of the voltage depending on the power supply capability. For robotics, automotive and small actuating applications, 48 V or less voltage BLDC motors are preferred. For industrial applications and automation systems, 100 V or higher rating motors are used.

ROTOR

BLDC motor incorporates a permanent magnet in the rotor. The number of poles in the rotor can vary from 2 to 8 pole pairs with alternate south and north poles depending on the application requirement. In order to achieve maximum torque in the motor, the flux density of the material should be high. A proper magnetic material for the rotor is needed to produce required magnetic field density

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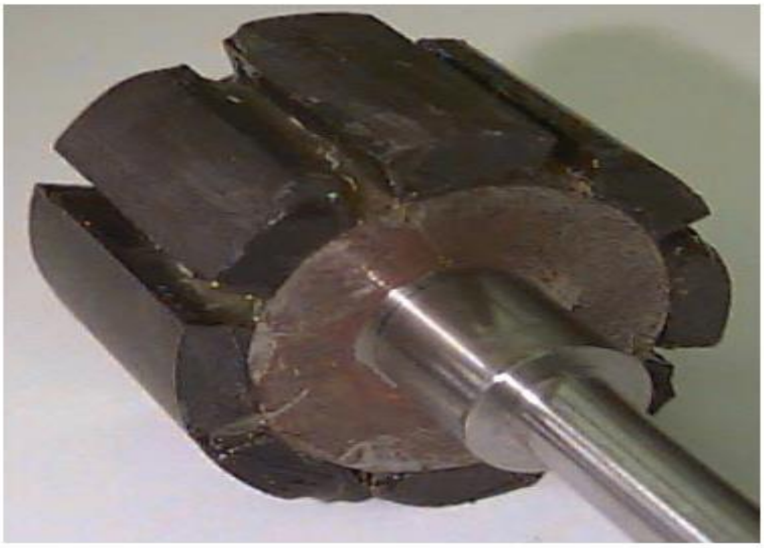


Ferrite magnets are inexpensive, however they have a low flux density for a given volume. Rare earth alloy magnets are commonly used for new designs. Some of these alloys are Samarium Cobalt (SmCo), Neodymium (Nd), and Ferrite and Boron (NdFeB).

The rotor can be constructed with different core configurations such as the circular core with permanent magnet on the periphery, circular core with rectangular magnets, etc.

Hall Sensors

Hall sensor provides the information to synchronize stator armature excitation with rotor position. Since the commutation of BLDC motor is controlled electronically, the stator windings should be energized in sequence in order to rotate the motor. Before energizing a particular stator winding, acknowledgment of rotor position is necessary.

So the Hall Effect sensor embedded in stator senses the rotor position. Most BLDC motors incorporate three Hall sensors which are embedded into the stator. Each sensor generates Low and High signals whenever the rotor poles pass near to it. The exact commutation sequence to the stator winding can be determined based on the combination of these three sensor’s response.

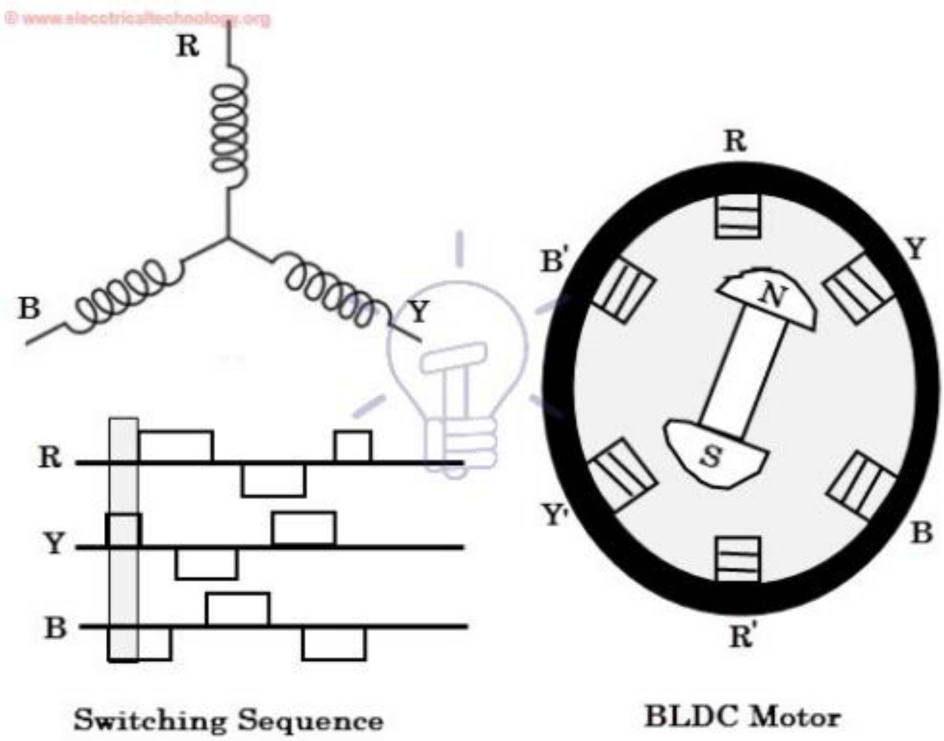
5.2 Working Principle and Operation of BLDC Motor

BLDC motor works on the principle similar to that of a conventional DC motor, i.e., the Lorentz force law which states that whenever a current carrying conductor placed in a magnetic field it experiences a force. As a consequence of reaction force, the magnet will experience an equal and opposite force. In case BLDC motor, the current carrying conductor is stationary while the permanent magnet moves.

When the stator coils are electrically switched by a supply source, it becomes electromagnet and starts producing the uniform field in the air gap. Though the source of supply is DC, switching makes to generate an AC voltage waveform with trapezoidal shape. Due to the force of interaction between electromagnet stator and permanent magnet rotor, the rotor continues to rotate. Consider the figure below in which motor stator is excited based on different switching states.

With the switching of windings as High and Low signals, corresponding winding energized as North and South poles. The permanent magnet rotor with North and South poles align with stator poles causing motor to rotate. Observe that motor produces torque because of the development of attraction forces (when North-South or South-North alignment) and repulsion forces (when North-North or South-South alignment). By this way motor moves in a clockwise direction.

Here, one might get a question that how we know which stator coil should be energized and when to do. This is because; the motor continuous rotation depends on the switching sequence around the coils. As discussed above that Hall sensors give shaft position feedback to the electronic controller unit. Based on this signal from sensor, the controller decides particular coils to energize. Hall-effect sensors generate Low and High level signals whenever rotor poles pass near to it. These signals determine the position of the shaft.



5.3 Brushless DC Motor Drive

As described above that the electronic controller circuit energizes appropriate motor winding by turning transistor or other solid state switches to rotate the motor continuously.

The figure below shows the **s**imple BLDC motor drive circuit which consists of MOSFET bridge (also called as inverter bridge), electronic controller, hall effect sensor and BLDC motor.

Here, Hall-effect sensors are used for position and speed feedback. The electronic controller can be a microcontroller unit or microprocessor or DSP processor or FPGA unit or any other controller.

This controller receives these signals, processes them and sends the control signals to the MOSFET driver circuit.

5.3.1 MOSFET BRIDGE:

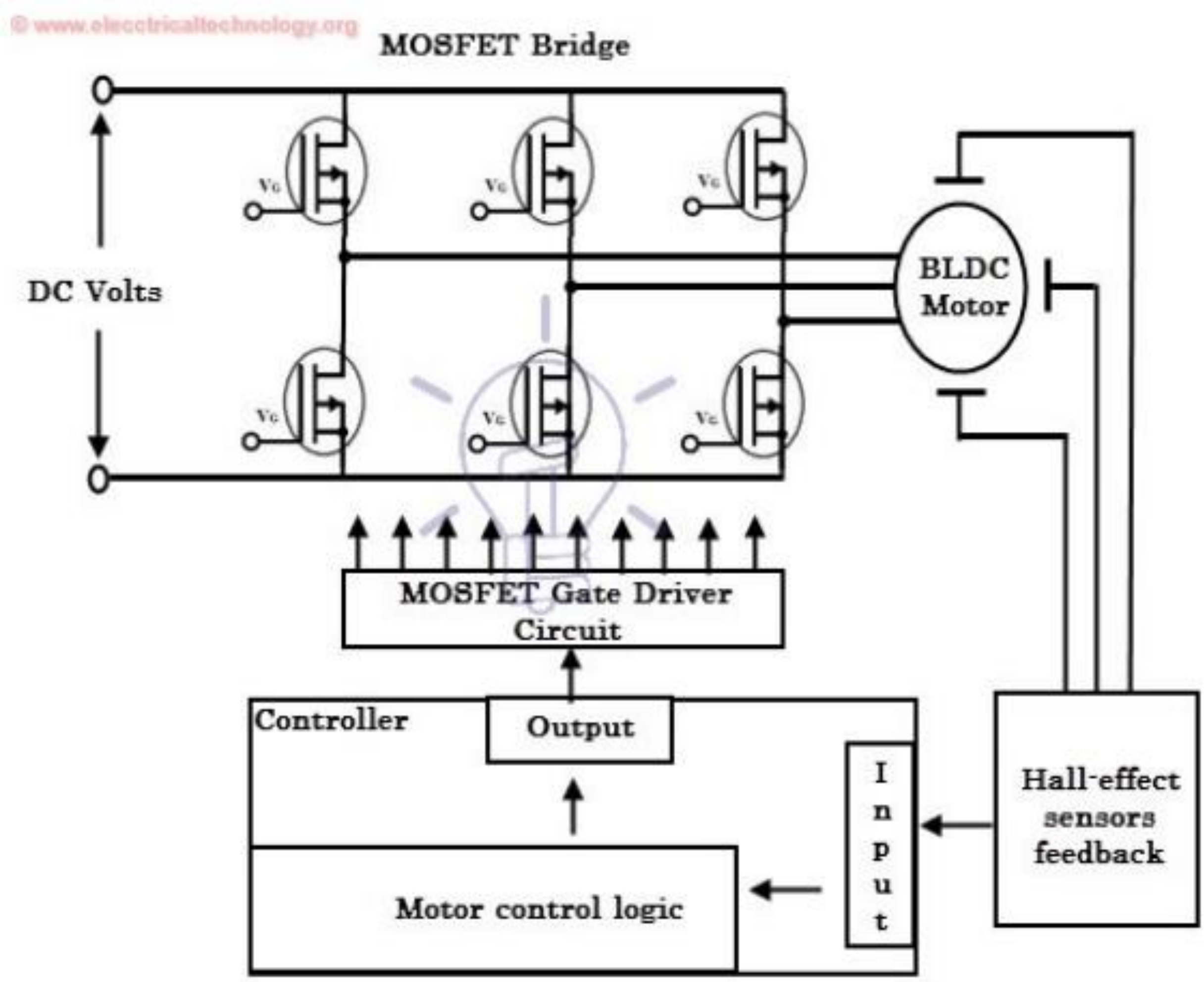


Fig: 5.3.1 Mosfet bridge

In addition to the switching for a rated speed of the motor, additional electronic circuitry changes the motor speed based on required application. These speed control units are generally implemented with PID controllers to have precise control. It is also possible to produce four-quadrant operation from the motor whilst maintaining good efficiency throughout the speed variations using modern drives.

5.3.2 Advantages of BLDC Motor

BLDC motor has several advantages over conventional DC motors and some of these are

- It has no mechanical commutator and associated problems
- High efficiency due to the use of permanent magnet rotor.
- High speed of operation even in loaded and unloaded conditions due to the absence of brushes that limits the speed
- Smaller motor geometry and lighter in weight than both brushed type DC and induction AC motors

- Long life as no inspection and maintenance is required for commutator system
- Higher dynamic response due to low inertia and carrying windings in the stator
- Less electromagnetic interference
- Quite operation (or low noise) due to absence of brushes

5.3.3 Disadvantages of Brushless Motor

- These motors are costly
- Electronic controller required control this motor is expensive
- Not much availability of many integrated electronic control solutions, especially for tiny BLDC motors
- Requires complex drive circuitry
- Need of additional sensors

5.3.4 Applications of Brushless DC Motors (BLDC)

Brushless DC Motors (BLDC) are used for a wide variety of application requirements such as varying loads, constant loads and positioning applications in the fields of industrial control, automotive, aviation, automation systems, health care equipments, etc. Some specific applications of BLDC motors are

- Computer hard drives and DVD/CD players
- Electric vehicles, hybrid vehicles, and electric bicycles
- Industrial robots, CNC machine tools, and simple belt driven systems
- Washing machines, compressors and dryers
- Fans, pumps and blowers

CHAPTER 6

PROPOSED CONTROLLER

6.1 Introduction about Fuzzy Logic Technique

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection.

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalve logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with un-sharp boundaries in which membership is a matter of degree.

In this perspective, fuzzy logic in its narrow sense is a branch of fl. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalve logical systems.

The basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if-then rule or, simply, fuzzy rule. Although rule-based systems have a long history of use in Artificial Intelligence (AI), what is missing in such systems is a mechanism for dealing with fuzzy consequents and fuzzy antecedents. In fuzzy logic, this mechanism is provided by the calculus of fuzzy rules.

The calculus of fuzzy rules serves as a basis for what might be called the Fuzzy Dependency and Command Language (FDCL). Although FDCL is not used explicitly in the toolbox, it is effectively one of its principal constituents. In most of the applications of fuzzy logic, a fuzzy logic solution is, in reality, a translation of a human solution into FDCL.

A trend that is growing in visibility relates to the use of fuzzy logic in combination with neuro computing and genetic algorithms. More generally, fuzzy logic, neuro-computing, and genetic algorithms may be viewed as the principal constituents of what might be called soft computing. Unlike the traditional, hard computing, soft computing accommodates the imprecision of the real world.

The guiding principle of soft computing is: Exploit the tolerance for imprecision, uncertainty, and partial truth to achieve tractability, robustness, and low solution cost. In the future, soft computing could play an increasingly important role in the conception and design of systems who's MIQ (Machine IQ) is much higher than that of systems designed by conventional methods.

Among various combinations of methodologies in soft computing, the one that has highest visibility at this juncture is that of fuzzy logic and neuro computing, leading to neuro-fuzzy systems. Within fuzzy logic, such systems play a particularly important role in the induction of rules from observations.

Fuzzy logic is a fascinating area of research because it does a good job of trading off between significance and precision. something that humans have been managing for a very long time. In this sense, fuzzy logic is both old and new because, although the modern and methodical science of fuzzy logic is still young, the concept of fuzzy logic relies on age-old skills of human reasoning.

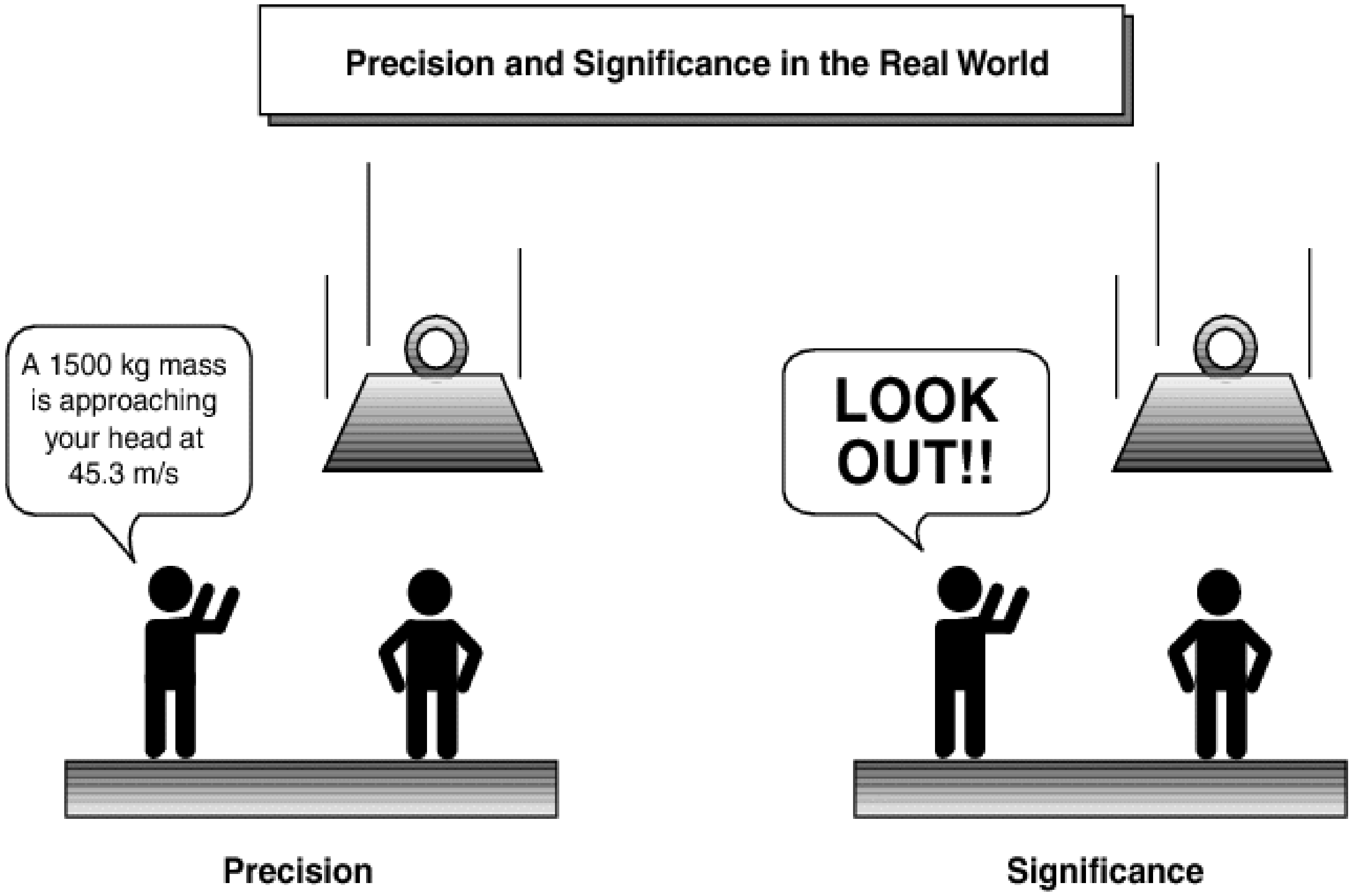


Fig. 6.1.1 Fuzzy Description

6.2. Uses of fuzzy logic

Fuzzy logic is a convenient way to map an input space to an output space. Mapping input to output is the starting point for everything. Consider the following examples:

- With information about how good your service was at a restaurant, a fuzzy logic system can tell you what the tip should be.
- With your specification of how hot you want the water, a fuzzy logic system can adjust the faucet valve to the right setting.
- With information about how far away the subject of your photograph is, a fuzzy logic system can focus the lens for you.
- With information about how fast the car is going and how hard the motor is working, a fuzzy logic system can shift gears for you.

To determine the appropriate amount of tip requires mapping inputs to the appropriate outputs. Between the input and the output, the preceding figure shows a black box that can contain any number of things: fuzzy systems, linear systems, expert systems, neural networks, differential equations, interpolated multidimensional lookup tables, or even a spiritual advisor, just to name a few of the possible options. Clearly the list could go on and on. Fuzzy is faster and cheaper.

6.3. Fuzzy Logic Controller

6.3.1. Simple Fuzzy Logic Controllers

First-generation simple fuzzy logic controllers can generally be depicted by a block diagram.
The knowledge-base module contains knowledge about all the input and output fuzzy partitions.

It will include the term set and the corresponding membership functions defining the input variables to the fuzzy rule-base system and the output variables, or control actions, to the plant under control.

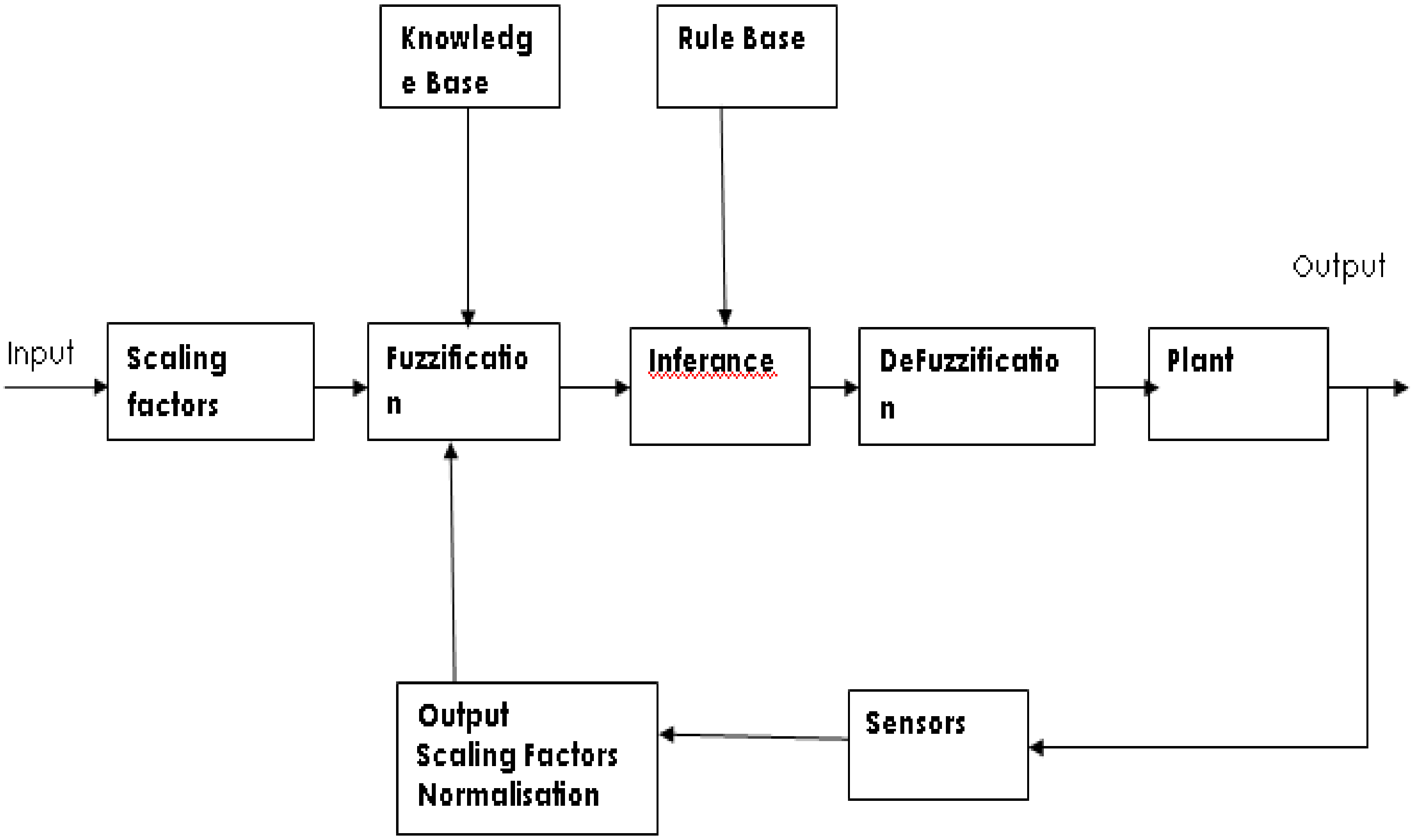


Fig. 6.3.2 A Simple Fuzzy Logic Control System

- The steps in designing a simple fuzzy logic control system are as follows:
- Identify the variables (inputs, states and outputs) of the plant. Partition the universe of discourse or the interval spanned by each variable into a number of fuzzy subsets, assigning each a linguistic label (subsets include all the elements in the universe).
- Assign or determine a membership function for each fuzzy subset.
- Assign the fuzzy relationships between the inputs or states fuzzy subsets on the one hand and the outputs fuzzy subsets on the other hand, thus forming the rule-base.
- Choose appropriate scaling factors for the input and output variables in order to normalize the variables to the [0, 1] or the [-1, 1] interval.
- Fuzzily the inputs to the controller.
- Use fuzzy approximate reasoning to infer the output contributed from each rule.
- Aggregate the fuzzy outputs recommended by each rule.

- ❖ Apply defuzzification to form a crisp output.

In a nonadaptive simple fuzzy logic controller, the methodology used and the results of the nine steps mentioned above are fixed, whereas in an adaptive fuzzy logic controller, they are adaptively modified based on some adaptation law in order to optimize the control.

A simple fuzzy logic control system has the following features:

- ❖ Fixed and uniform input- and output- scaling factors.
- ❖ Flat, single-partition rule-base with fixed and noninetractive rules. All the rules have the same degree of certainty and confidence, equal to unity.
- ❖ Fixed membership functions.
- ❖ Limited number of rules, which increase exponentially with the number of input variables.
- ❖ Fixed metaknowledge including the methodology for approximate reasoning, rules-aggregation, and output defuzzification.
- ❖ Low-level control and no hierarchical rule structure.

6.3.3. General Fuzzy Logic Controllers

The principal design elements in a general fuzzy logic control system are as follows:

1. Fuzzification strategies and the interpretation of a fuzzification operator, or fuzzifier.

2. **Knowledge base:**

a. Discrimination/normalization of the universe of discourse.

b. Fuzzy partitions of the input and output spaces.

c. Completeness of the partitions.

d. Choice of the membership functions of a primary fuzzy set.

3. **Rule-base:**

a. Choice of process state (input) variables and control (output) variables.

b. Source of derivation of fuzzy control rules.

c. Types of fuzzy control rules.

d. Consistency, interactivity, and completeness of fuzzy control rules.

4. **Decision-making logic:**

a. Definition of a fuzzy implication.

b. Interpretation of sentence connective and

c. Interpretation of sentence connective or.

d. Inference mechanism.

5. **Defuzzification** strategies and the interpretation of a defuzzification operator (defuzzifier).

Adaptation or change in any of the five design parameters above creates an adaptive fuzzy logic control system. If all are fixed, the fuzzy logic control system is simple and nonadaptive.

6.4. Membership Functions

Definition: A graph that defines how each point in the input space is mapped to membership value between 0 and 1. Input space is often referred as the universe of discourse or universal set (u), which contain all the possible elements of concern in each particular application.

6.4.1. Types of membership functions

Before we start defining different types of membership functions, let us consider a Fuzzy IF-THEN rule for a car:

IF the speed of a car is high, THEN apply less force to the accelerator

IF the speed is low, THEN apply more force to the accelerator

Straight line: The simplest membership function is formed by straight line. We consider the speed of car in Fig. 5.3 and plot the membership function for high. Where the horizontal represent the speed of the car and vertical axis represent the membership value for high.

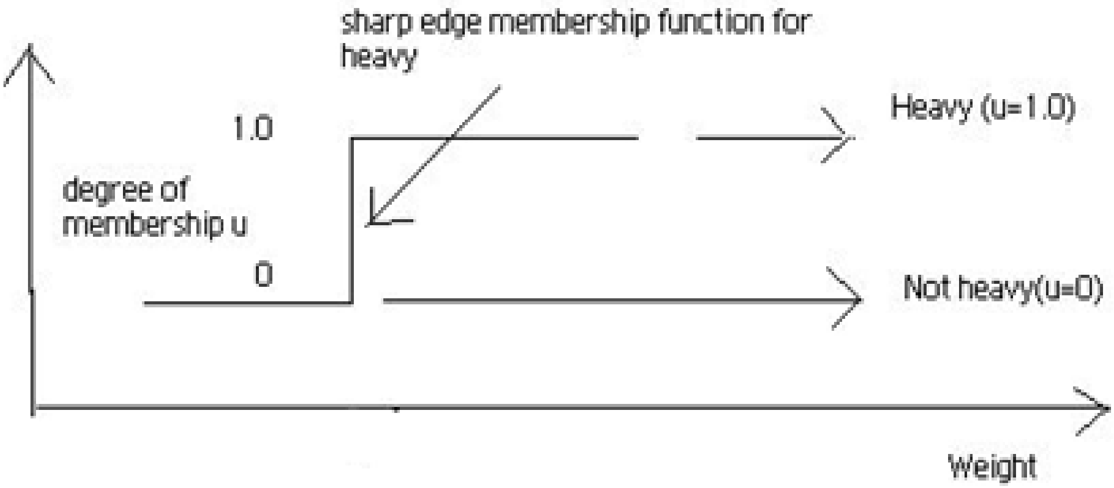


Fig. 6.4.2 Straight Line Membership Function

Trapezoidal: If we consider the case 5.3 and plot the membership function for "less", we get a trapezoidal membership function. Fig. 5.3 shows a graphical representation, where the horizontal axis represent the force applied to the accelerator and the vertical shows membership value for "less". The function is often represented by "trapmf".

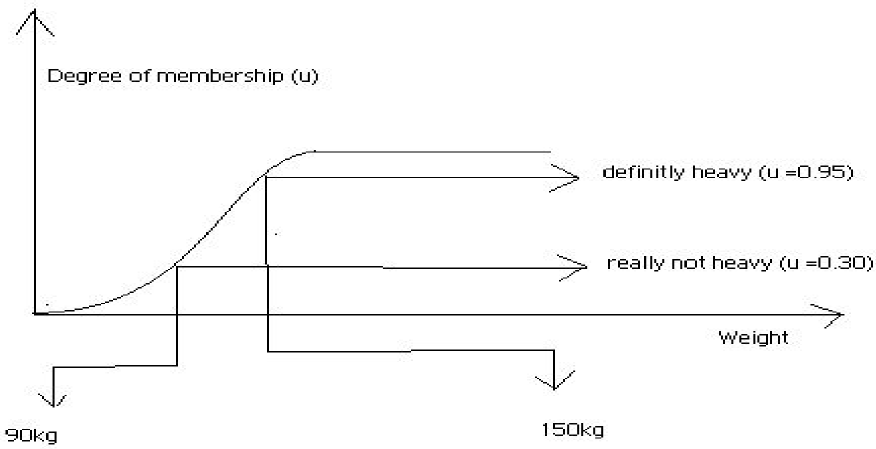


Fig. 6.4.3 Trapezoidal Membership Function

Gaussian: Let say a fuzzy set Z which represent "number close to zero". The possible membership function for Z is

If we plot this function we get a graph shown in Fig 5.5 and are refer as Gaussian membership function.

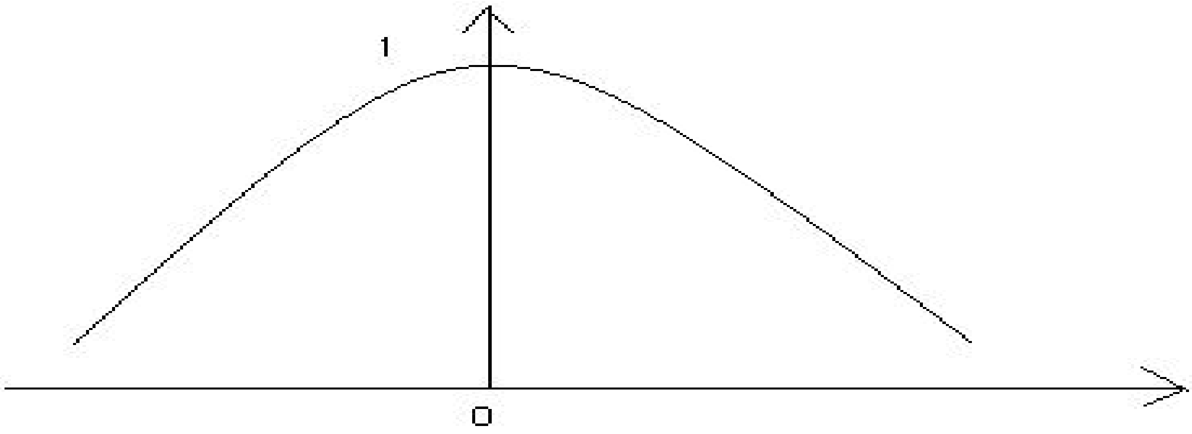


Fig. 6.4.4 Gaussian Membership Function

Triangular: This is formed by the combination of straight lines. The function is name as "trimf" .We considers the above case i.e. fuzzy set Z to represent the "number close to zero". So mathematically we can also represent it as

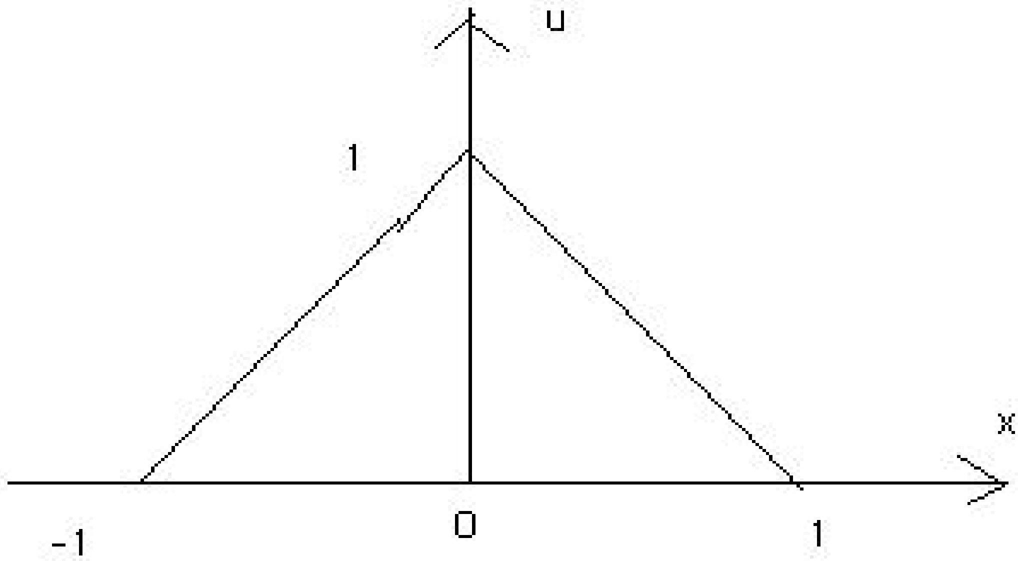


Fig. 6.5.5 Traingular Membership Function

6.5 Fuzzy Logic Tool Box:

In fuzzy Logic Toolbox software, fuzzy logic should be interpreted as FL, that is, fuzzy logic in its wide sense. The basic ideas underlying FL are explained very clearly and insightfully in Foundations of Fuzzy Logic

. What might be added is that the basic concept underlying FL is that of a linguistic variable, that is, a variable whose values are words rather than numbers.

In effect, much of FL may be viewed as a methodology for computing with words rather than numbers. Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution

The fuzzy logic toolbox is highly impressive in all respects. It makes fuzzy logic an effective tool for the conception and design of intelligent systems.

The fuzzy logic toolbox is easy to master and convenient to use. And last, but not least important, it provides a reader friendly and up-to-date introduction to methodology of fuzzy logic and its wide ranging applications.

You can create and edit fuzzy inference systems with Fuzzy Logic Toolbox software. You can create these systems using graphical tools or command-line functions, or you can generate them automatically using either clustering or adaptive neuro-fuzzy techniques.

If you have access to SIMULINK software, you can easily test your fuzzy system in a block diagram simulation environment.

The toolbox also lets you run your own stand-alone C programs directly. This is made possible by a stand-alone Fuzzy Inference Engine that reads the fuzzy systems saved from a MATLAB session. You can customize the stand-alone engine to build fuzzy inference into your own code. All provided code is ansi compliant.

Because of the integrated nature of the MATLAB environment, you can create your own tools to customize the toolbox or harness it with another toolbox, such as the Control System Toolbox, Neural Network Toolbox, or

Optimization Toolbox software.

The Fuzzy Logic Toolbox extends the MATLAB technical computing environment with tools for designing systems based on fuzzy logic.

Graphical user interfaces (GUIs) guide you through the steps of fuzzy inference system design. Functions are provided for many common fuzzy logic methods, including fuzzy clustering and adaptive neuro fuzzy learning.

The toolbox lets you model complex system behaviors using simple logic rules and then implements these rules in a fuzzy inference system.

You can use the toolbox as a standalone fuzzy inference engine. Alternatively, you can use fuzzy inference blocks in SIMULINK and simulate the fuzzy systems within a comprehensive model of the entire dynamic system.

CHAPTER 7

SIMULATION RESULTS

7.1 RESULT OF THE PROJECT:

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

(a) Development Environment

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces.
It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

(b) The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features.

It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics.

It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

(e) The MATLAB Application Program Interface (API)

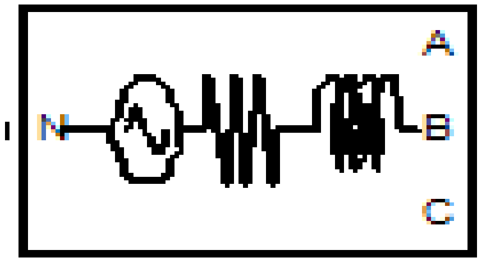
This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

(f) MATLAB Documentation

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples.

The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

(1) Three phase source block

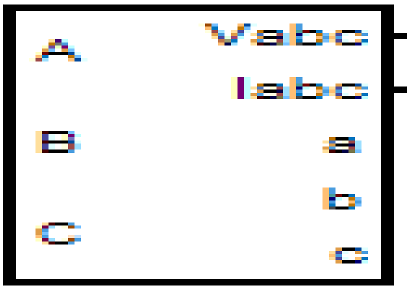


Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

(2) VI measurement block

The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents

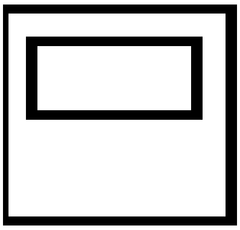


Three Phase V-I Measurement

(3) Scope

Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes.

The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation



Scope

(4) Three-Phase Series RLC Load

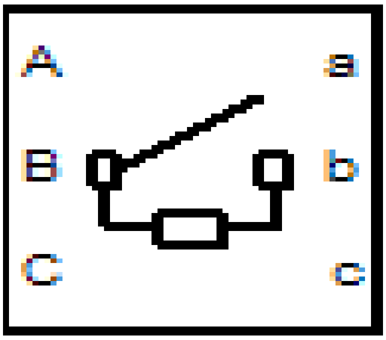
The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements.

At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

Three-Phase Series RLC Load

(5) Three-Phase Breaker block

The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.

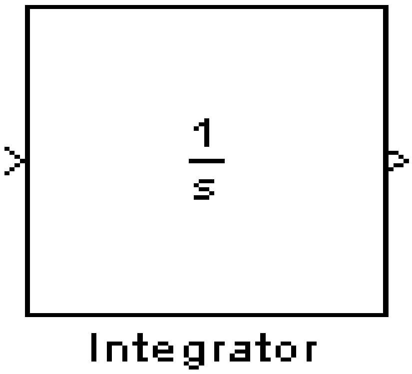


Three-Phase Breaker Block

(6) Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

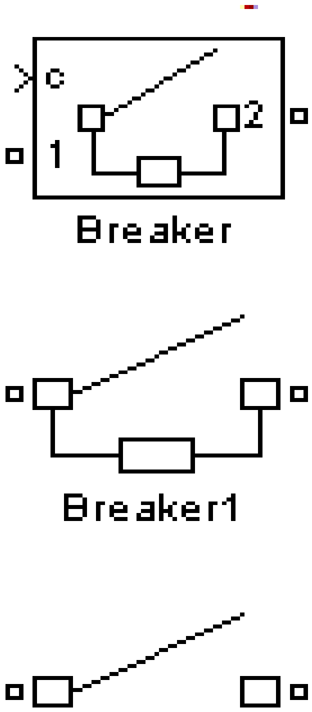
Library: Continuous



(7) Breaker

Implement circuit breaker opening at current zero crossing.

Library: Elements



Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it).

When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

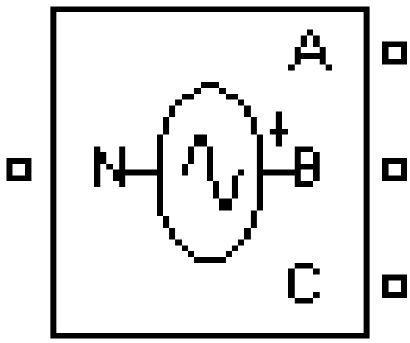
When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms).

When the breaker is open, it has an infinite resistance.

(8) Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources



Three Phase Voltage Sources

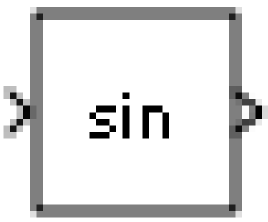
Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source.

In addition, two harmonics can be programmed and superimposed on the fundamental signal.

(9) Trigonometric Function

Specified trigonometric function on input

Library: Math Operations



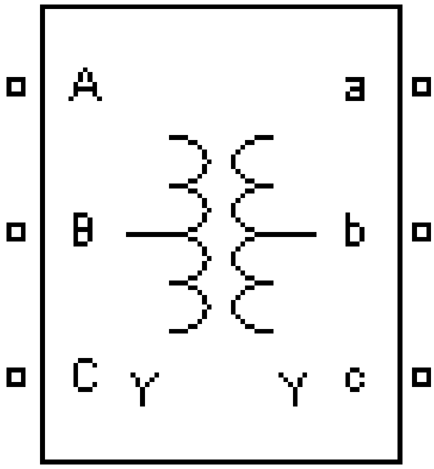
Trigonometric Function

Purpose: The Trigonometric Function block performs common trigonometric functions

(10) Three-Phase Transformer (Two Windings)

Implement three-phase transformer with configurable winding connections

Library: **Elements**



Three Phase Transformer

Purpose:

The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers.

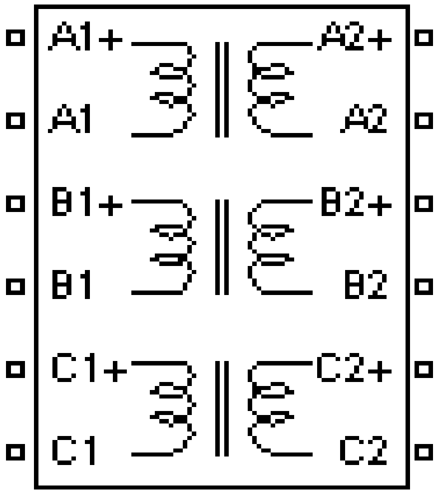
The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated.

If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

(11) Three-Phase Transformer 12 Terminals

Implement three single-phase, two-winding transformers where all terminals are accessible

Library: Elements



Two winding Transformer

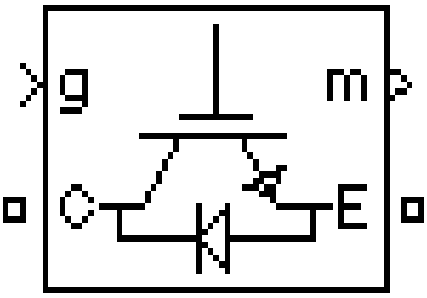
Purpose: The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible.

The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

(12) IGBT/Diode

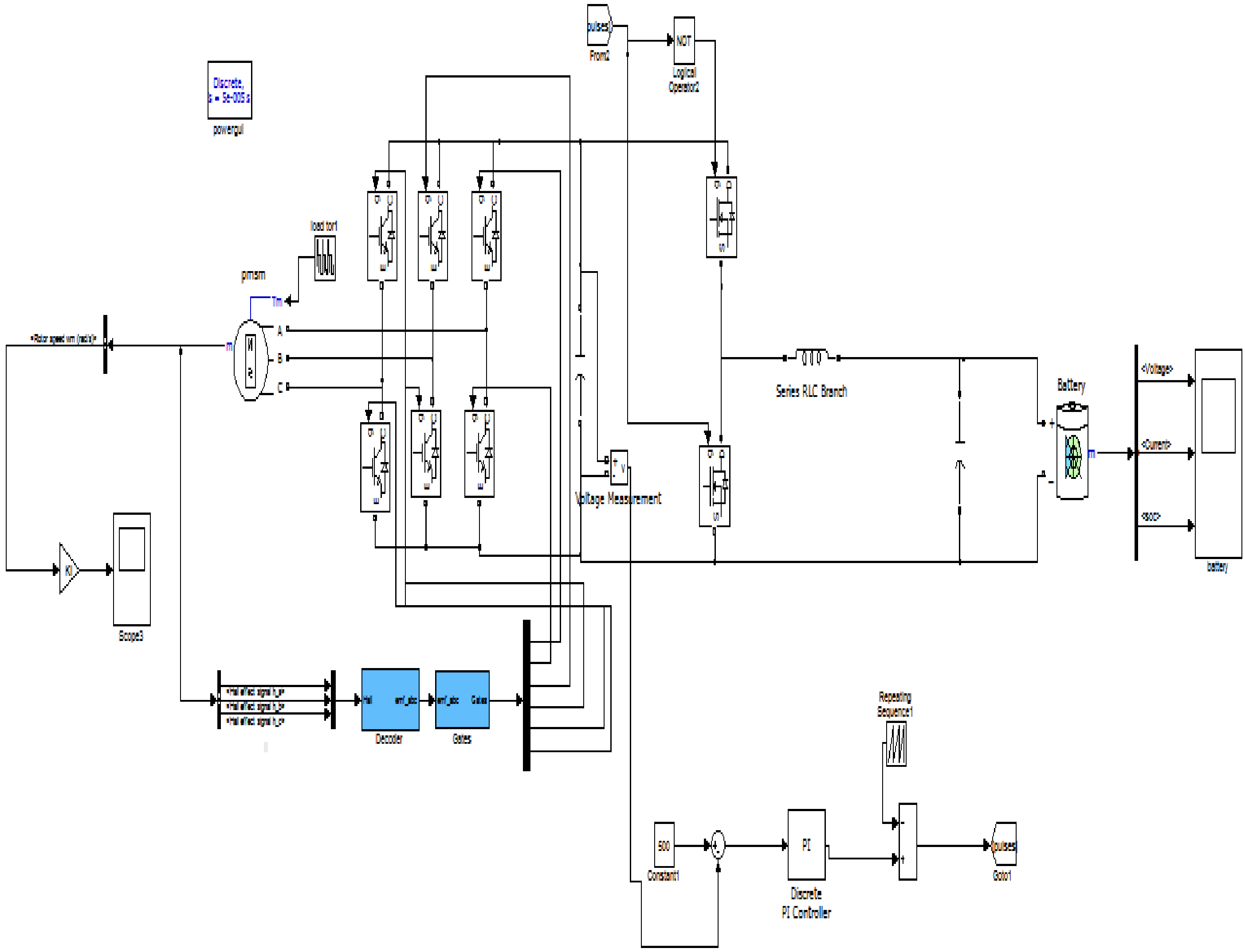
Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: **Power Electronics**

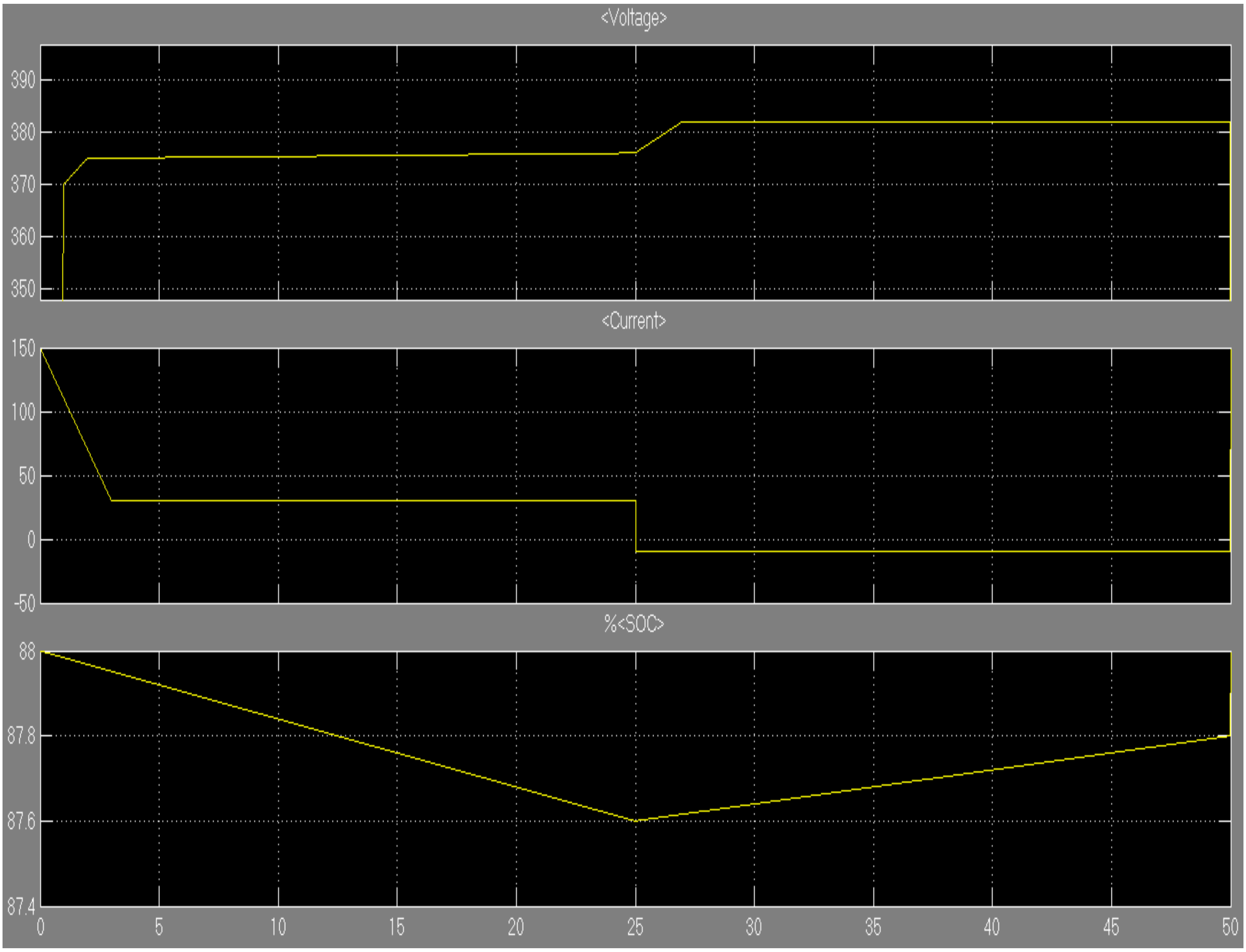


IGBT

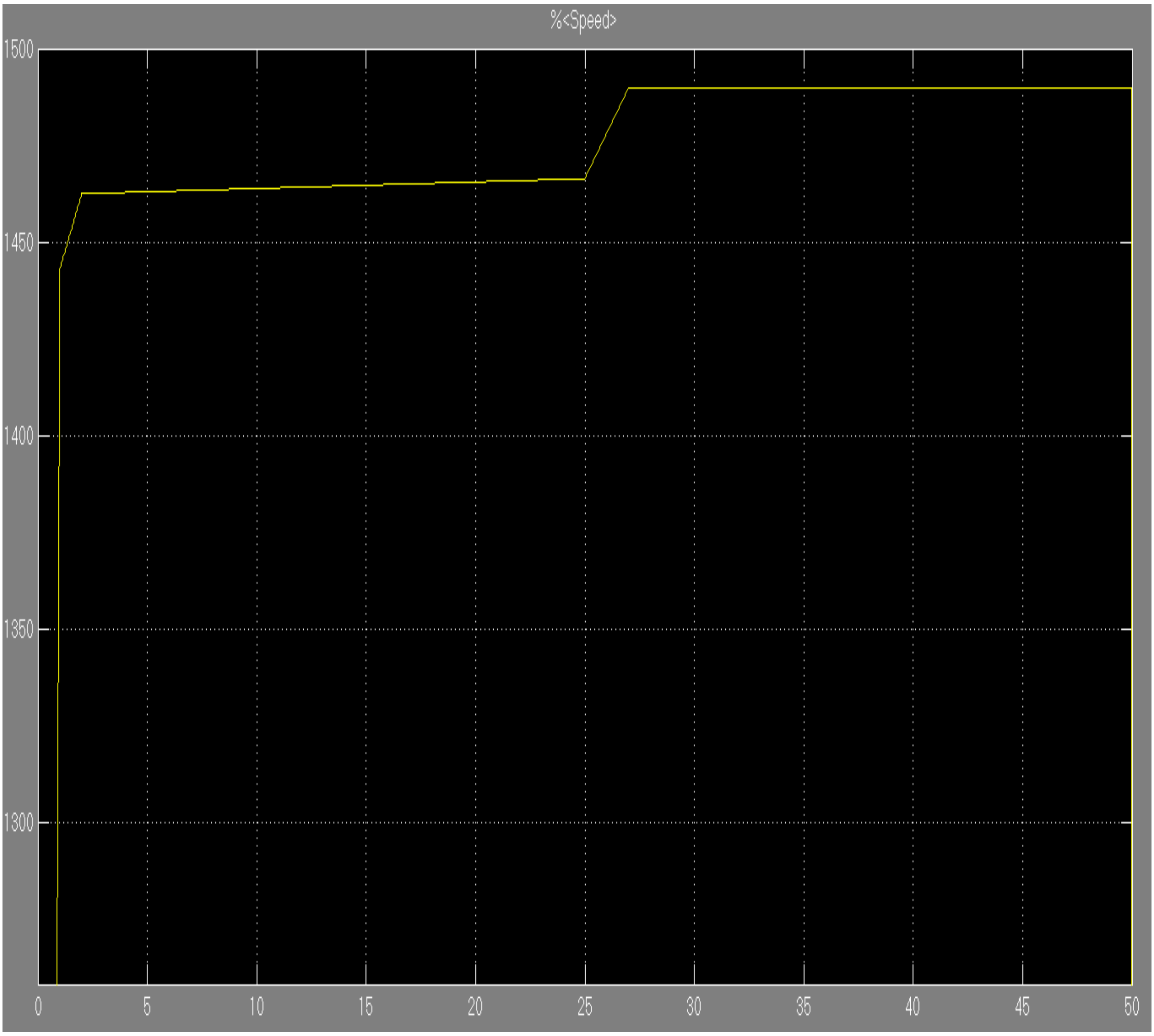
Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.



7.1.1 Proposed converter



7.1.2 Soc and current and voltage of the battery



7.1.3 Speed of proposed BLDC

CHAPTER 8

CONCLUSION

This project presents design and control bi-directional dc dc converter for all-electric vehicle. When the battery is discharged, the dc machine is operated in motor mode and bi-directional dc-dc converter is operated in boost mode. Variable positive torque values are applied to the BLDC machine and condition of the battery is observed. According to simulation result, the battery SoC is reduced from %88 to %87.337 and voltage of the dc machine is constant at 500 V.

When the battery is charged, the machine is operated generator mode and bi-directional dc-dc converter is operated in buck mode. Variable negative torque values are applied to the BLDC machine and effect on the battery is observed. According to simulation result, the battery SoC is increased from %87.337 to %87.445. In all-electric vehicle, regenerative breaking is occurred in this state. Charge and discharge states of the battery are the most essential for distance to determining.

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A

PROJECT REPORT

On

FOUR QUADRANT OPERATION & CONTROL OF THREE-PHASE BRUSHLESS DC MOTOR FOR ELECTRIC VEHICLES

Submitted by

1) LAV KUMAR	**(17K81A0229)**
2) GUBBALA MEGA SHIVA RAMA KRISHNA	**(17K81A0216)**
3) SHENNA TEJASVI	**(17K81A0238)**
4) VISLAVATH GNANESHWARI	**(17K81A0242)**

In partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

Ms.CH.NIROSHA, M.Tech

Assistant Professor

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ST.MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled '**Four Quadrant Operation & Control of Three-Phase Brushless DC Motor for Electric Vehicles'** is being submitted by **1. Lav Kumar (17K81A0229) 2. Gubbala Mega Shiva Rama Krishna (17K81A0216) 3. Shenna Tejasvi (17K81A0238) 4. Vislavath Gnaneshwari (17K81A0242)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Ms.CH. Nirosha
Assistant Professor
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DECLARATION

We, the students of **Bachelor of Technology** in Department of Electrical and Electronics Engineering, session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled "**Four Quadrant Operation & Control of Three-Phase Brushless DC Motor for Electric Vehicles"** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

This project presents the control of Brushless direct current (BLDC) motor in all four quadrants (forward/reverse motoring/braking) with the help of the bidirectional DC-DC converter. The output of the DC-DC converter is fed to the three-phase voltage source inverter (VSI) to drive the motor. During the motoring mode buck operation through the bi-directional converter of the battery takes place and during regenerative mode, the mechanical energy is converted into electrical energy and is stored in the same chargeable battery through the boost operation. As the electric vehicle operates with frequent start/stop, the scheme proposes recovery of energy for every stopping operation through regenerative braking. Also when the electric vehicle (EV) is going on a downhill, the controlled speed on downhill provides energy return to the battery. MATLAB/Simulink software is used to verify the above operations.

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NOMENCLATURE

BLDC	**:**	Brushless DC motor
EV	**:**	Electric Vehicles
ICE	**:**	Internal Combustion Engine
VSI	**:**	Voltage Source Inverter
IGBT	**:**	Insulated-Gate Bipolar Transistor
MOSFET	**:**	Metal–Oxide–Semiconductor Field-Effect Transistor
EMF	**:**	Electromotive Force
KVL	**:**	Kirchhoff's Voltage Law
SEPIC	**:**	Single-Ended Primary-Inductor Converter
PWM	**:**	Pulse Width Modulation
MPPT	:	Maximum Power Point Tracker
OFC	**:**	Optical Fiber Communication
SPWM	**:**	Sinusoidal pulse width modulation
ASD	**:**	Adjustable Speed Drives
UPS	**:**	Uninterruptable Power Supplies
FACTS	**:**	Flexible AC transmission systems
CSI	**:**	Current Source Inverters
STATCOM	**:**	The Static Synchronous Compensator
PID	:	Proportional-Integral-Derivative
GUI	:	Graphical User Interface
MATLAB	**:**	Matrix Laboratory
ODE	:	Ordinary Differential Equations
FORTRAN	**:**	Formula Translation
GTO	:	Gate Turn-Off thyristor

CHAPTER 1

1.1 INTRODUCTION

Brushless DC motors are gaining a lot of popularity whether it is aerospace, military, household or traction applications. Due to the constraint of fuel resources, the world requires highly efficient electric vehicle drives for transportation needs. The BLDC motor has a longer lifespan, higher efficiency, and compact size making it the most sought after motor in electric vehicle drive applications. The continuous attempt to reduce environmental pollution has given an impetus to the market of electric vehicles (EVs). As the fuel resources are depleting, the energy efficient electric drives are likely to replace vehicles running with fossil fuels. Being different from the ICE (Internal Combustion Engine), EVs are the least burden to the environment. Any motor drive system which can be recharged from any external electricity source is known as a plug-in electric vehicle (EV).

There are still some disadvantages of EV drives like overall lower efficiency, huge dimension, and the cost of storage devices etc. The technique of performing the four quadrant operation is proposed, where its battery is charged during the regenerative braking but the system here has two energy sources, one is driving the motor and other is storing the energy using the rectifier during braking. It is proposed in this project that only one battery is enough to drive the motor and at the same time to recover the kinetic energy of the motor using regenerative mode. This proposal reduces the cost of an extra rectifier and an additional battery.

In the four quadrant operation is performed without utilizing the kinetic energy of the motor. During braking, the motor kinetic energy is wasted in resistive losses this makes the system highly inefficient. In the world where there is fuel constraint, this system is not helping in that cause. In four quadrant sensor less control of the electronically commutated motor is done without utilizing the motor kinetic energy in regenerative braking.

The battery capacity puts a limitation to the EVs in the form of mileage or distance covered. Regenerative braking is just one of the ways to increase the efficiency of the drive. During regenerative mode, the energy of the drive system which is in the form of kinetic energy can be used to charge the battery during deceleration and downhill run to slow down the vehicle.

This project proposes a simple method of four quadrant operation in which the energy of the motor is utilized to charge the battery during braking. This method of efficient utilization of power can be done through bidirectional DC-DC converter and VSI. There is just one energy source and it is efficiently utilizing the motor kinetic energy by charging the battery using the VSI. The VSI operates as a rectifier during the braking mode and the rectified voltage is boosted to charge the battery.

The most commonly used topology for a three phase BLDC motor. The three phase inverter is fed by DC source through VSI. Depicted in the figure, the stage following the capacitor consists of six insulated gate bipolar transistors (IGBT) switches which have anti-parallel diodes connected across it. Instead of IGBTs, switch-like MOSFET can also be used as it inherently has anti-parallel diode but the problem with the MOSFET is the ON-state voltage drop. For the low voltage, application MOSFET can also be used. Typically, the BLDC motor has trapezoidal back EMF waveform. To get constant power output the current is injected during the 120° period of constant back EMF.

The injection of current is controlled through the two switches of different legs at a time in the inverter. Therefore, at a time, only two switches operate. Unlike the DC motor, the commutation is controlled here through the switches. The current injection in each phase should be properly aligned with the back EMF to get the rotor flux and stator flux angle close to 90° for maximum torque production. The switching sequences of the MOSFET switches are shown in Fig. 2 for both forward motoring and reverse motoring. These three phases produce constant dc voltage for 360° during regenerative braking. It becomes important to know the rotor position so that the energization of the stator winding is in sequence.

The position of the rotor can be detected using internal and external position sensor or it can be detected without the help of sensors. In this project, hall sensors are used to detect the rotor position. These sensors are embedded in the stator and according to the sensor output, the switches are triggered. Applying the KVL during any interval for BLDC motor as only two phases are conducting the equation becomes (1) where I_c is the phase current and R_c is the per phase resistance.

$$V_d = 2(E_b + I_C R_c)$$

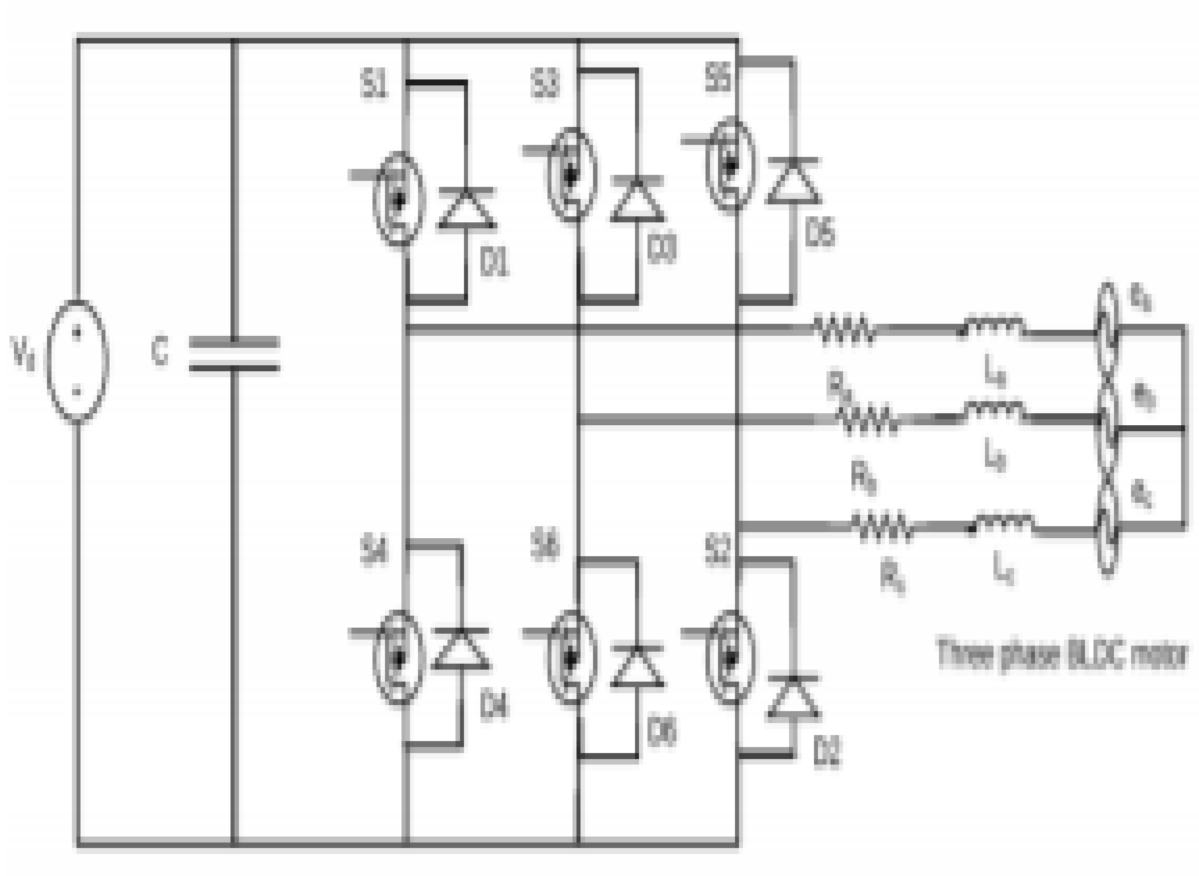


Fig 1.1: Inverter based driving circuit of BLDC motor.

The structure of the bidirectional converter is illustrated. The bi-directional performance analysis is mentioned. It consists of two switches and two diodes it behaves as a buck converter when the switch T1 and D2 are operational, these operations are utilized in the drive during motoring mode and for regenerative braking T2 and D1 are operational, thus making the converter work in boost operation by boosting the dc-link voltage to charge the battery. Diodes allow the flow of current in one particular direction depending on the operation. During the buck operation the inverter side voltage is stepped down α time of the battery voltage is the time period for which switch conducts.

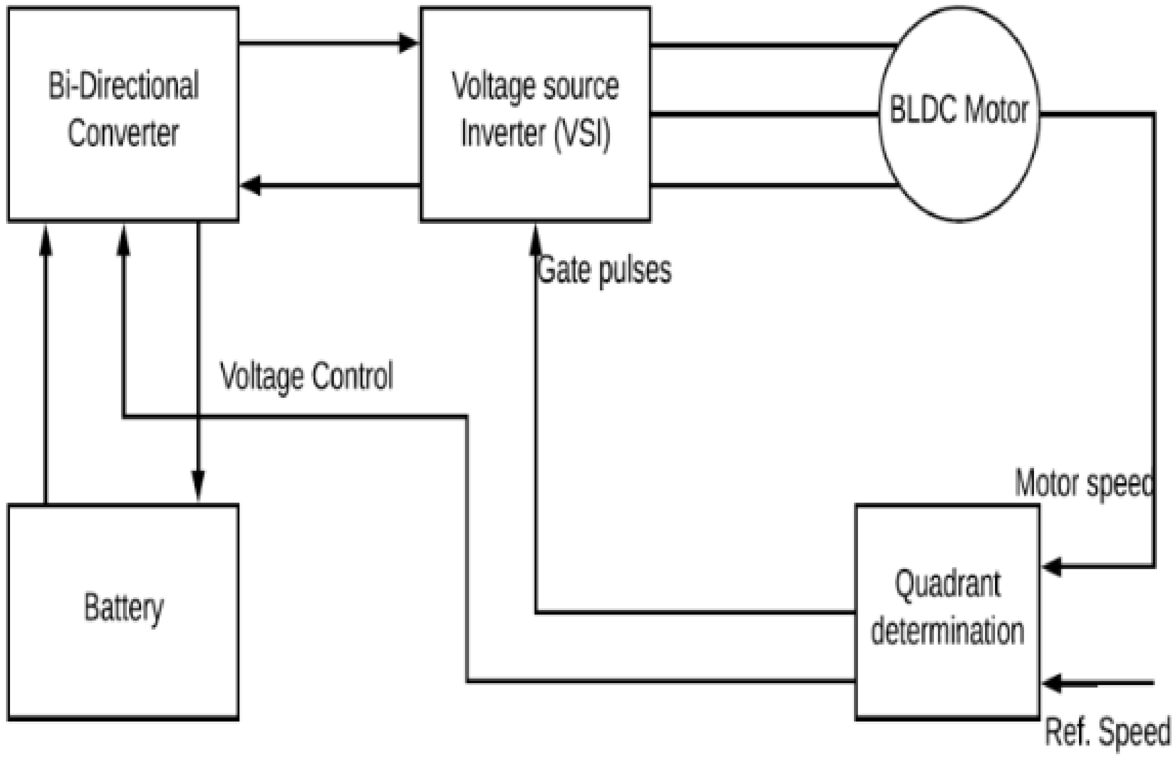


Fig.1.2 Block diagram representation of four quadrant operation.

The four-quadrant operation of BLDC motor is depicted clearly in Fig 1.2. In the first and third quadrant, both the torque and speed are having the same sign either positive or negative. The four-quadrant operation of BLDC motor is slightly different as the direction of rotation cannot be made opposite just by reversing the voltage polarity of dc link as in case of DC motor. For reversing the direction of rotation of the motor the phase sequence of the BLDC motor has to change as the voltage across the dc link is always positive and therefore current is positive. For operating the motor in the third quadrant phase sequence of BLDC should be changed. This could be achieved by changing the switching sequence of the inverter.

Braking is obtained through the bi-directional DC-DC converter. The bi-directional converter operates in two modes buck or boost mode. Motoring mode utilizes the buck operation and braking mode utilizes the boost operation.

The logic diagram of the four quadrant operation is mentioned in Fig 1.2. When the regenerative braking is required the torque and speed command are detected and the gate pulses to the switches of VSI are switched off.

As the diodes are connected across the antiparallel switches, the VSI behave as a rectifier and the alternating three-phase back EMF (e (is converted which appears across the inverter DC supply.

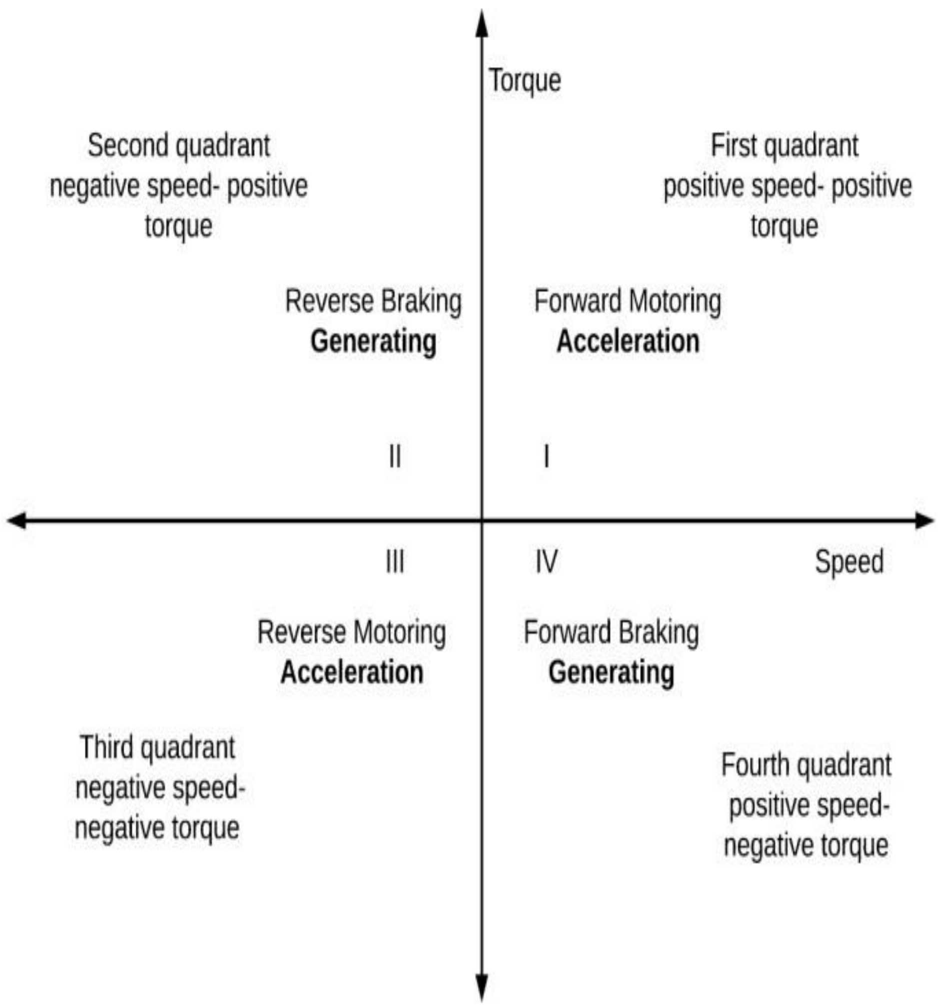


Fig 1.3: Four Quadrant Operation

But this can happen only when the diodes (D) of VSI are forward biased this is achieved by reducing the dc-link voltage making it less than the rectified back EMF voltage which is an ideal case in absence phase resistance Fig. 2, with the presence of phase resistance the equation becomes, Once the diodes are forward biased, immediately the control is transferred to switch T2 which step up the voltage and charges the battery.

The control logic is elaborated. The controlling of switch T2 is done through the current control. During vehicle downhill run the speed is more than the reference speed (higher potential energy) is converted to kinetic energy. To maintain the speed equal to the reference speed, the kinetic energy of the motor could be returned to the battery.

CHAPTER 2

PROPOSED DC -DC CONVERTER

Buck–boost converter is a type of DC--DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a fly back converter using a single inductor instead of a transformer. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, ranging from much larger (in absolute magnitude) than the input voltage, down to almost zero.

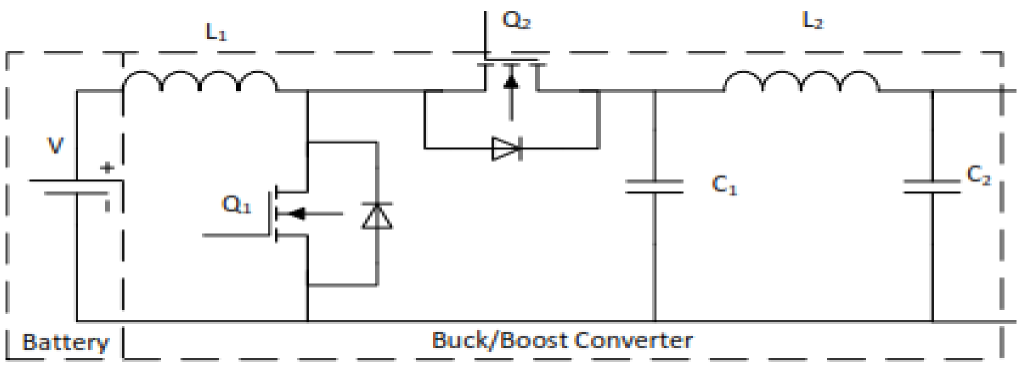


Fig 2.1: Proposed converter

The output voltage is of the opposite polarity than the input. This is a switched-mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. However, this drawback is of no consequence if the power supply is isolated from the load circuit (if, for example, the supply is a battery) because the supply and diode polarity can simply be reversed. When they can be reversed, the switch can be on either the ground side or the supply side.

A buck (step-down) converter combined with a boost (step-up) converter. The output voltage is typically of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor mode and the boost inductor mode, using switches instead of diodes, sometimes called a "four-switch buck-boost converter", it may use multiple inductors but only a single switch as in the SEPIC and Ćuk topologies. Buck boost converter principle of operation applications.

2.1 INTRODUCTION TO BUCK BOOST CONVERTER

A Buck converter is a switch mode DC to DC converter in which the output voltage can be transformed to a level less than or greater than the input voltage. The magnitude of output voltage depends on the duty cycle of the switch. It is also called as step up/step down converter. The name step up/step down converter comes from the fact that analogous to step up/step down transformer the input voltage can be stepped up/down to a level greater than/less than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

$$\text{Input power } (P_{in}) = \text{output power } (P_{out})$$

In step up mode $V_{in} < V_{out}$ in a Buck Boost converter, it follows then that the output current will be less than the input current. Therefore for a Buck Boost converter in step up mode.

$$V_{in} < V_{out} \text{ and } I_{in} > I_{out}$$

In step down mode $V_{in} > V_{out}$ in a Buck Boost converter, it follows then that the output current will be greater than the input current. Therefore for a Buck Boost converter in step down mode.

$$V_{in} > V_{out} \text{ and } I_{in} < I_{out}$$

2.2 PRINCIPLE OF OPERATION OF BUCK CONVERTER

The main working principle of Buck Boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is ON the inductor stores energy from the input in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures that in steady state a constant output voltage $V_o(t) = V_o(\text{constant})$ exists across load terminals.

2.3 CIRCUIT DIAGRAM OF BUCK BOOST CONVERTER

The circuit diagram of Typical Buck Boost converter is shown in the figure below

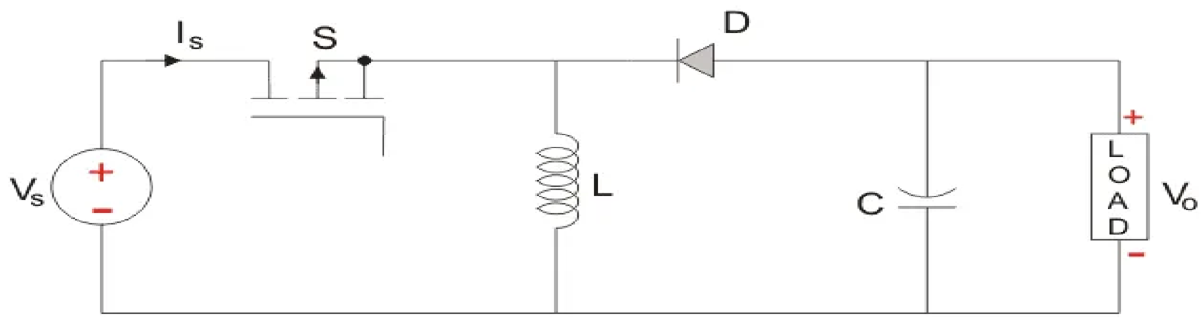


Fig 2.2: Typical buck boost converter

2.4 MODES OF OPERATION OF BUCK BOOST CONVERTER

The Buck Boost converter can be operated in two modes

a) Continuous conduction mode in which the current through inductor never goes to zero i.e. inductor partially discharges before the start of the switching cycle.

b) Discontinuous conduction mode in which the current through inductor goes to zero i.e. inductor is completely discharged at the end of switching cycle.

2.4.1 Circuit analysis of buck converter

Assume in the entire analysis that the current swing (maximum to minimum value) through inductor and voltage swing through capacitor is very less so that they vary in a linear fashion. This is to ease the analysis and the results we will get through this analysis are quite accurate compared to real values.

Continuous conduction mode

<u>Case-1:</u> When switch S is ON

When switch in ON for a time t_{on}, the diode will be open circuited since it does not allow currents in reverse direction from input to output. Hence the Buck Boost converter can be redrawn as follows.

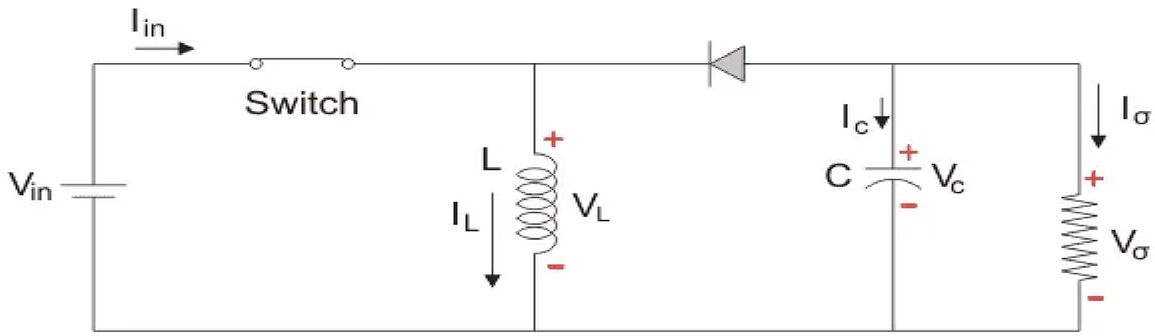


Fig 2.3: When switch S is ON

During this state the inductor charges and the inductor current increases. The current through the inductor is given as

$$I_L = (1/L) * \int V * dt$$

Assume that prior to the opening of switch the inductor current is $I'_{L,\,off}$. Since the input voltage is constant.

$$I_{L,on} = (1/L) * \int V_{in} * dt + I'_{L,on}$$

Assume the switch is open for ton seconds which is given by $D*T_s$ where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch on state is given as

$I_{L,\,on} = (1/L) *V_{in}*D*T_s + I'_{L,\,on}$ (equation 1)

Hence $\Delta I_{L\,on} = (1/L)*V_{in}*D*T_s$.

<u>Case -2</u>: When switch is off

When switch in OFF the diode will be forward biased as it allows current from output to input (p to n terminal) and the Buck Boost converter circuit can be redrawn as follows.

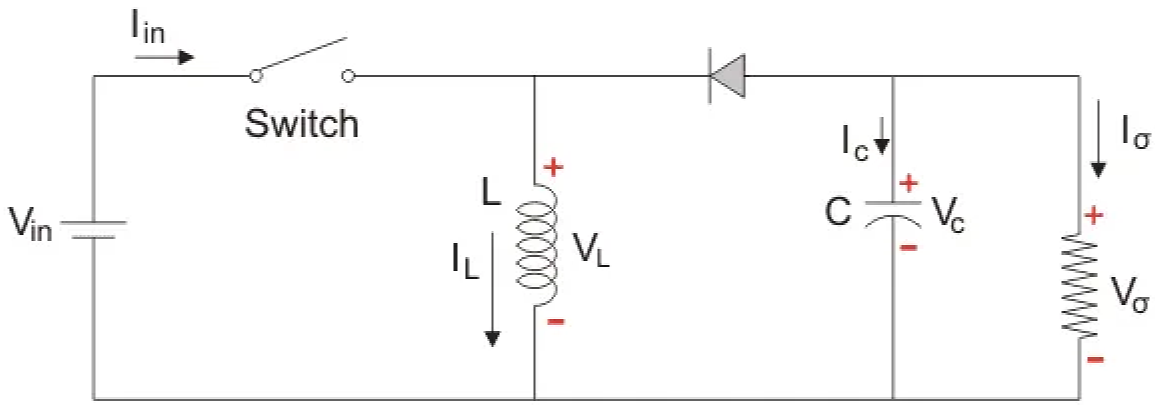


Fig 2.4: When switch is off

The inductor now discharges through the diode and RC combination. Assume that prior to the closing of switch the inductor current is $I''_{L,\ off}$. The current through the inductor is given as

$$I'''_{L,off} = -(1/L) * \int V_{out} * dt + I''_{L,off}$$

Note the negative sign at the front end of equation signifies that the inductor is discharging. Assume the switch is open for t_{off} seconds which is given by $(1-D)*T_s$ where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch off state is given as

$$I'''_{L,\ off} = -(1/L) *V_{out}*(1-D)*T_s + I''_{L,\ off} \text{ (equation 2)}$$

In steady state condition as the current through the inductor does not change abruptly, the current at the end of switch on state and the current at the end of switch off state should be equal. Also the currents at the start of switch off state should be equal to current at the end of switch on state. Hence

$$I'''_{L,\ off} = I_{L,\ on} \text{ also } I'_{L,\ off} = I''_{L,\ off}$$

Using the equations 1 and 2 we get

$(1/L) *V_{in}*D*T_s = (1/L) *V_{out}*(1-D)*T_s$

$V_{in}*D = V_{out}*(1-D)$

$V_{out}/V_{in} = D/(1-D)$

Since $D < 1$, V_{out} can be greater than or less than V_{in}. For $D>0.5$ the Buck boost converter acts as boost converter with $V_{out} > V_{in}$.

For D<0.5 the Buck boost converter acts as buck converter with $V_{out} > V_{in}$. Assuming no losses in the circuit and applying the law of conservation of energy.

$$V_{out} * I_{out} = V_{in} * I_{in}$$

This implies $I_{out}/I_{in} = (1-D)/D$, Thus $I_{out} > I_{in}$ for D<0.5 and $I_{out} < I_{in}$ for D<0.5. As the duty cycle increases the output voltage increases and output current decreases.

Discontinuous conduction mode

As mentioned before the converter when operated in discontinuous mode the inductor drains its stored energy completely before completion of switching cycle. The current and voltage wave forms of Buck Boost converter in discontinuous mode is shown in the figure below.

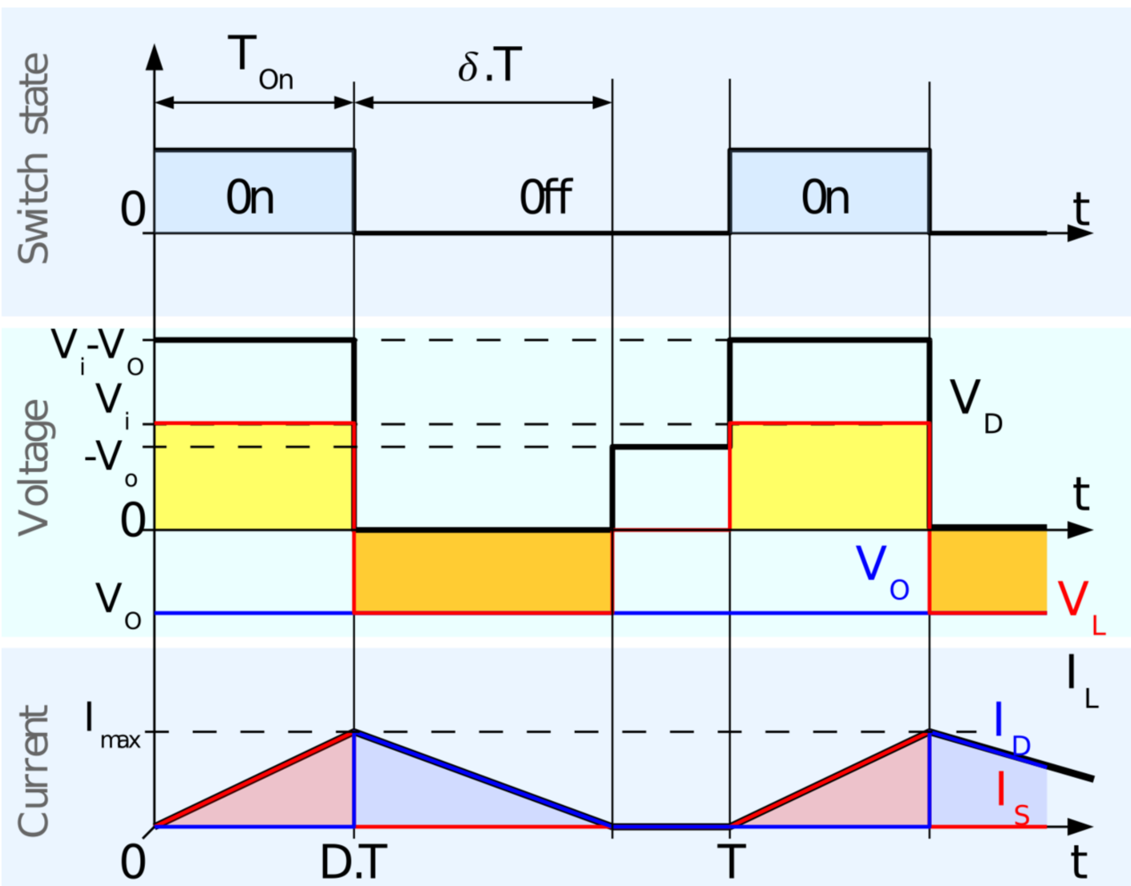


Fig 2(a): Waveforms of current and voltage in a buck–boost converter operating in discontinuous mode.

The inductor in discontinuous mode drains all the current which it piled up in charging interval of same switching cycle. The current through the inductor is given as

$$I_L = (1/L)\int V_L * dt$$ = (1/L)*area under the curve of voltage v/s time. Hence from the wave forms shown in the figure

$V_{out}*\delta*T_s = V_{in}*D*T_s$

$$V_{out}/V_{in} = D/\delta$$

and the ratio of output to input current from law of conservation of energy is $I_{out}/I_{in} = \delta/D$.

2.5 APPLICATIONS OF BUCK BOOST CONVERTER

- It is used in the self- regulating power supplies.
- It has consumer electronics.
- It is used in the Battery power systems.
- Adaptive control applications.
- Power amplifier applications.

1. Cheap to make.
2. Little heat whilst working.
3. Low power consumption.
4. Can utilize very high frequencies (40-100 Khz is not uncommon.)
5. Very energy-efficient when used to convert voltages or to dim light bulbs.
6. High power handling capability.
7. Efficiency up to 90%.

A modulation technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photovoltaic solar battery chargers, the other being MPPT.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. Typically switching has to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.An example of PWM in an idealized inductor driven by a voltage source: the voltage source (blue) is modulated as a series of pulses that results in a sine-like current/flux (red) in the inductor.

The blue rectangular pulses nonetheless result in a smoother and smoother red sine wave as the switching frequency increases. Note that the red waveform is the (definite) integral of the blue waveform.

2.6 PRINCIPLE

Pulse-width modulation uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform. If we consider a pulse waveform $f(t)$, with period T, low value y_{min}, a high value y_{max} and a duty cycle D (see figure 1), the average value of the waveform is given by:

$$\bar{y} = \frac{1}{T}\int_0^T f(t)\,dt.$$

As $f(t)$ is a pulse wave, its value is y_{max} for $0 < t < D \cdot T$ and y_{min} for $D \cdot T < t < T$. The above expression then becomes:

$$\begin{aligned}\bar{y} &= \frac{1}{T}\left(\int_0^{DT} y_{max}\,dt + \int_{DT}^{T} y_{min}\,dt\right)\\ &= \frac{D \cdot T \cdot y_{max} + T\,(1-D)\,y_{min}}{T}\\ &= D \cdot y_{max} + (1-D)\,y_{min}.\end{aligned}$$

This latter expression can be fairly simplified in many cases where $y_{min} = 0$ as $\bar{y} = D \cdot y_{max}$. From this, it is obvious that the average value of the signal ($\bar{y}$) is directly dependent on the duty cycle D.

The simplest way to generate a PWM signal is the intersective method, which requires only a sawtooth or a triangle waveform (easily generated using a simple oscillator) and a comparator.

When the value of the reference signal (the red sine wave in figure 2) is more than the modulation waveform (blue), the PWM signal (magenta) is in the high state, otherwise it is in the low state.

The **PWM** is a technique which is used to drive the inertial loads since a very long time. The simple example of an inertial load is a motor. Apply the power to a motor for a very short period of time and then turn off the power: it can be observed that the motor is still running even after the power has been cut off from it. This is due to the inertia of the motor and the significance of this factor is that the continuous power is not required for that kind of devices to operate. A burst power can save the total power supplied to the load while achieving the same performance from the device as it runs on continuous power.

The **PWM technique** is use in devices like DC motors, Loudspeakers, Class -D Amplifiers, SMPS etc. They are also used in communication field as-well. The modulation techniques like AM, FM are widely used RF communication whereas the PWM is modulation technique is mostly used in Optical Fiber Communication (OFC).

As in the case of the inertial loads mentioned previously, the PWM in a communication link greatly saves the transmitter power. The immunity of the PWM transmission against the inter-symbol interference is another advantage. This article discusses the technique of generating a PWM wave corresponding to a modulating sine wave.

2.7 DESCRIPTION:

The **Pulse Width Modulation** is a technique in which the ON time or OFF time of a pulse is varied according to the amplitude of the modulating signal.

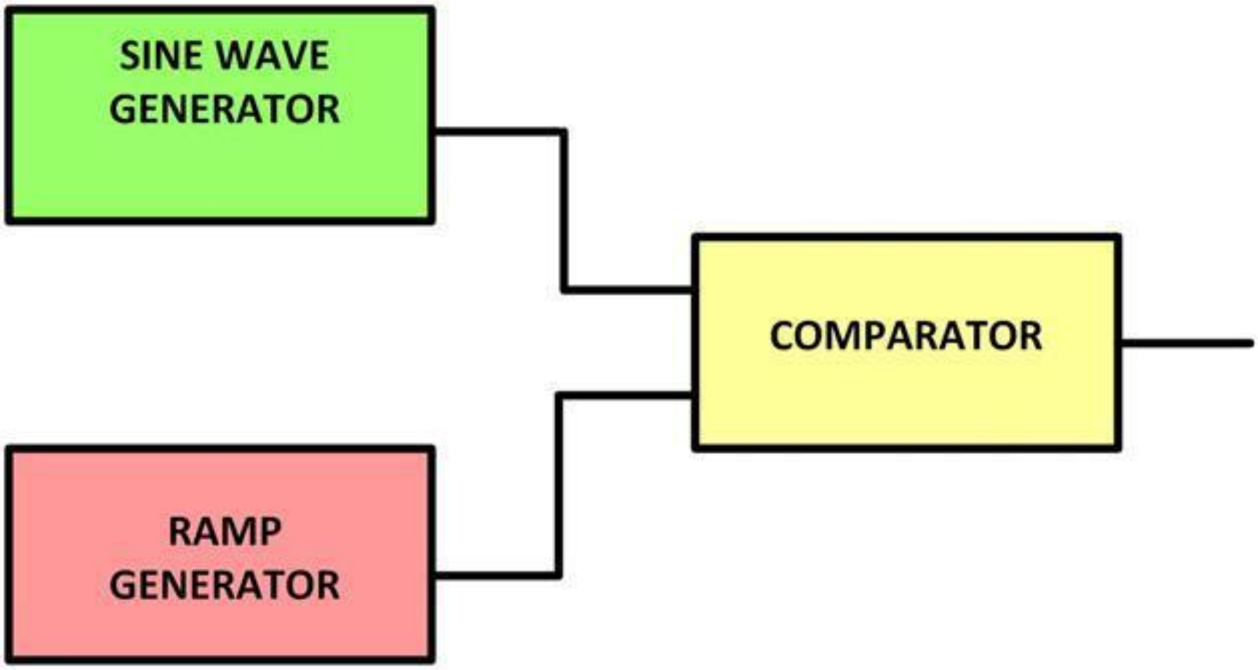


Fig 2.5: SPWM block diagram

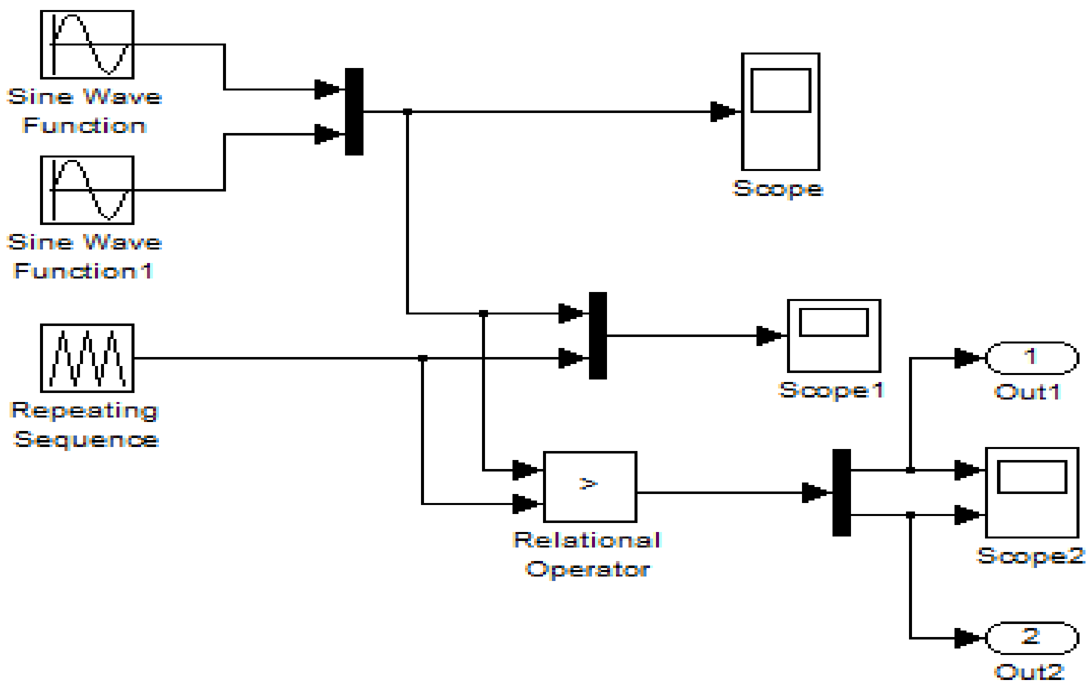
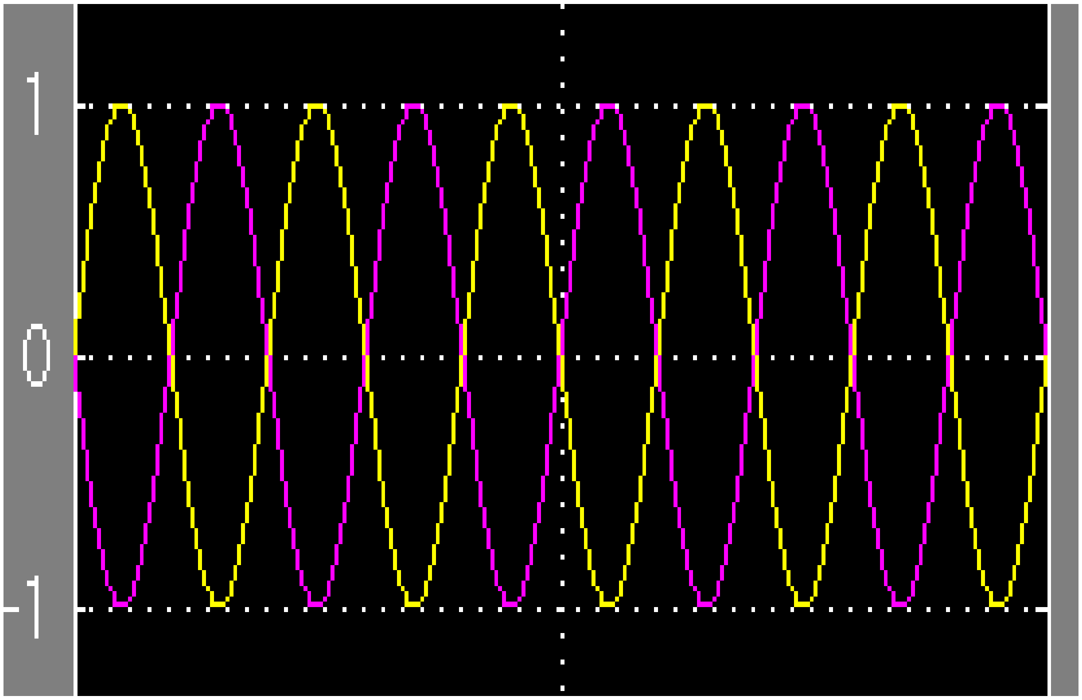
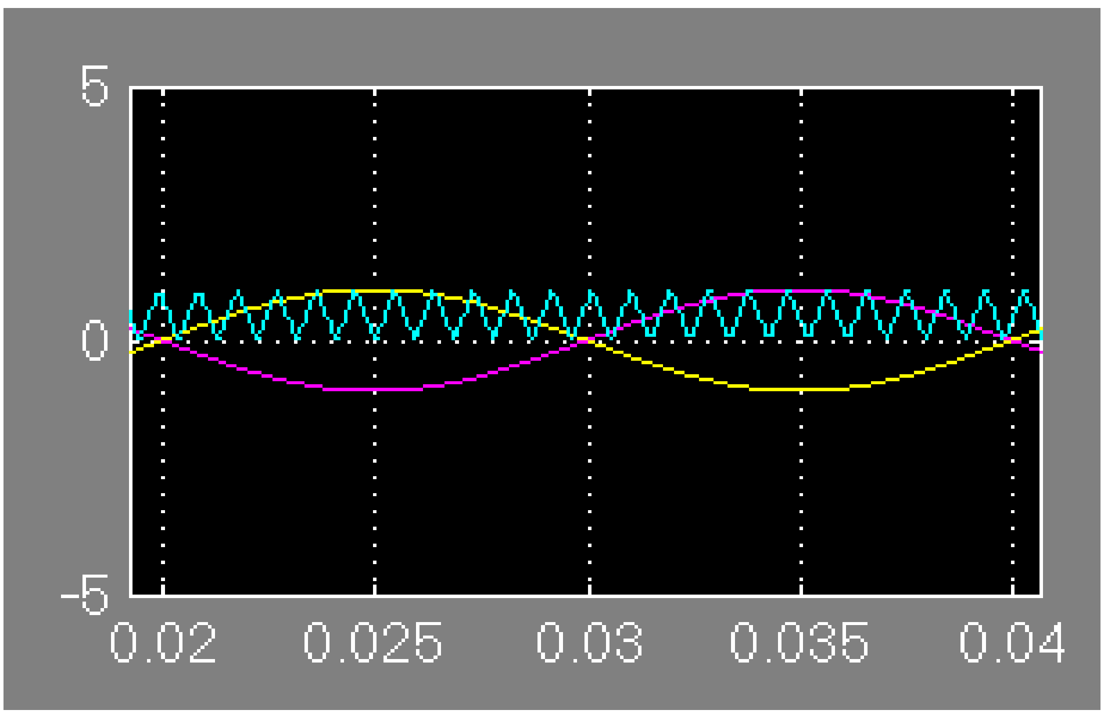


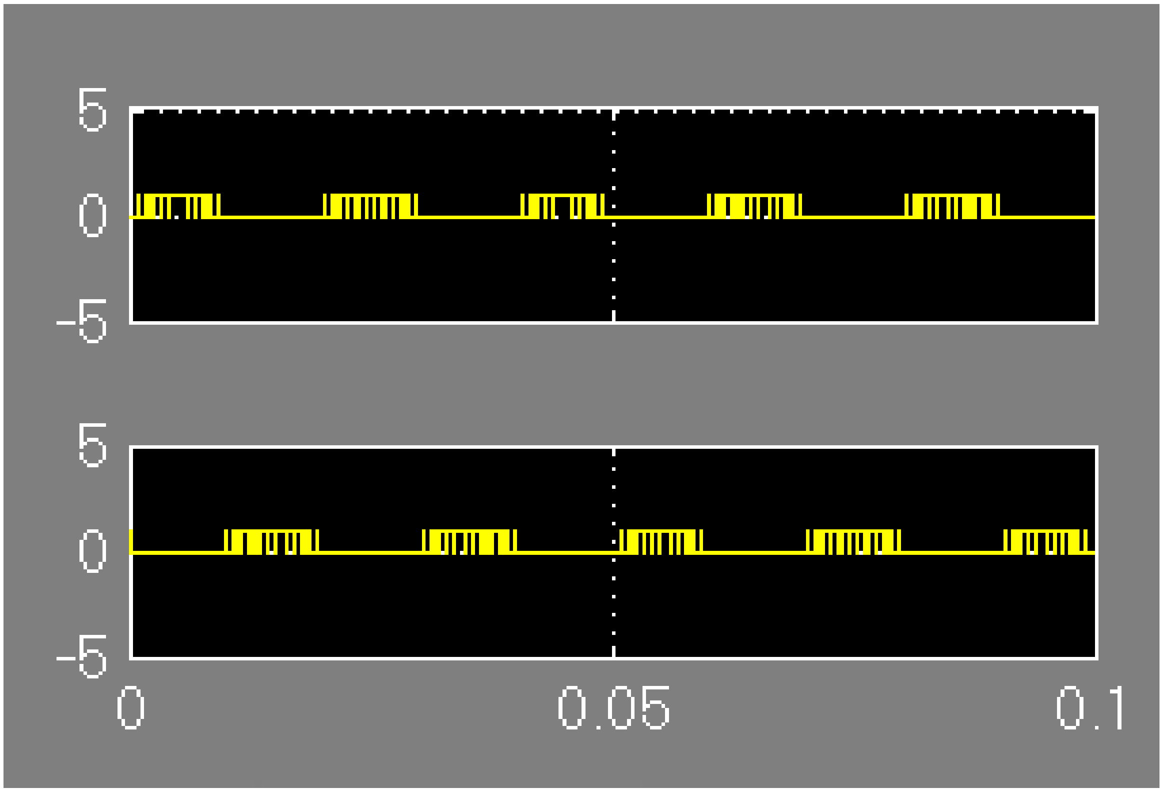
Fig 2.6: SPWM SIMULATION DIAGRAM



Graph 2(b): SCOPE view



Graph 2(c): SCOPE 1 view



Graph 2(d): SCOPE 2 view

The (ON time + OFF time) time of the pulse as constant. The (ON time + OFF time) of a pulse is called ‘Period’ of the pulse, and the ratio of the ON time or OFF time with the Period is called the ‘Duty Cycle’. Hence the PWM is a kind of modulation which keeps the Period of pulses constant but varying their duty cycle according to the amplitude of the modulating signal.

The conventional method of generating a PWM modulated wave is to compare the message signal with a ramp waveform using a comparator. The block diagram required for the generation of a simple PWM is shown.

CHAPTER 3

VOLTAGE SOURCE INVERTER

DC to AC converters produce an AC output waveform from a DC source. Applications include adjustable speed drives (ASD), uninterruptable power supplies (UPS), active filters, Flexible AC transmission systems (FACTS), voltage compensators, and photovoltaic generators. Topologies for these converters can be separated into two distinct categories: voltage source inverters and current source inverters. Voltage source inverters (VSIs) are named so because the independently controlled output is a voltage waveform. Similarly, current source inverters (CSIs) are distinct in that the controlled AC output is a current waveform.

Being static power converters, the DC to AC power conversion is the result of power switching devices, which are commonly fully controllable semiconductor power switches. The output waveforms are therefore made up of discrete values, producing fast transitions rather than smooth ones. The ability to produce near sinusoidal waveforms around the fundamental frequency is dictated by the modulation technique controlling when, and for how long, the power valves are on and off. Common modulation techniques include the carrier-based technique, or pulse width modulation, space-vector technique, and the selective-harmonic technique.

Voltage source inverters have practical uses in both single-phase and three-phase applications. Single-phase VSIs utilize half-bridge and full-bridge configurations, and are widely used for power supplies, single-phase UPSs, and elaborate high-power topologies when used in multicell configurations. Three-phase VSIs are used in applications that require sinusoidal voltage waveforms, such as ASDs, UPSs, and some types of FACTS devices such as the STATCOM. They are also used in applications where arbitrary voltages are required as in the case of active filters and voltage compensators.

Current source inverters are used to produce an AC output current from a DC current supply. This type of inverter is practical for three-phase applications in which high-quality voltage waveforms are required.

A relatively new class of inverters, called multilevel inverters, has gained widespread interest. Normal operation of CSIs and VSIs can be classified as two-level inverters, due to the fact that power switches connect to either the positive or to the negative DC bus. If more than two voltage levels were available to the inverter output terminals, the AC output could better approximate a sine wave. It is for this reason that multilevel inverters, although more complex and costly, offer higher performance.

Each inverter type differs in the DC links used, and in whether or not they require freewheeling diodes. Either can be made to operate in square-wave or pulse-width modulation (PWM) mode, depending on its intended usage. Square-wave mode offers simplicity, while PWM can be implemented several different ways and produces higher quality waveforms.

Voltage Source Inverters (VSI) feed the output inverter section from an approximately constant-voltage source. The desired quality of the current output waveform determines which modulation technique needs to be selected for a given application. The output of a VSI is composed of discrete values. In order to obtain a smooth current waveform, the loads need to be inductive at the select harmonic frequencies. Without some sort of inductive filtering between the source and load, a capacitive load will cause the load to receive a choppy current waveform, with large and frequent current spikes.

There are three main types of VSIs:

- Single-phase half-bridge inverter
- Single-phase full-bridge inverter

3.1. SINGLE-PHASE HALF-BRIDGE INVERTER

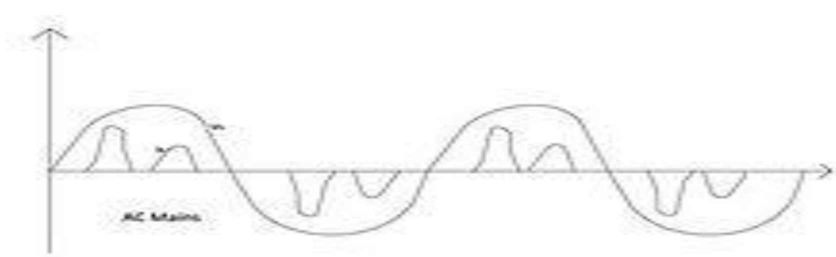


Fig 3.1: The AC input for an ASD.

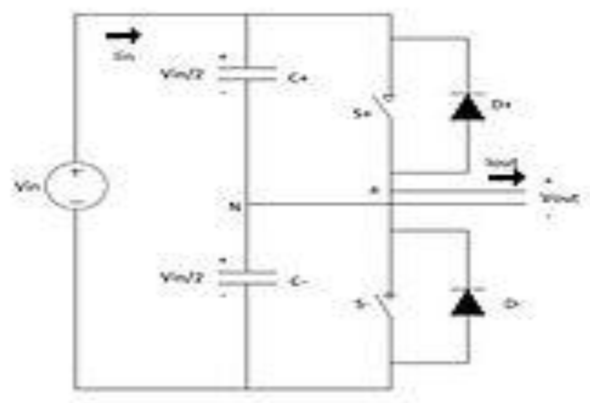


Fig 3.2: Single-Phase Half-Bridge Voltage Source Inverter

The single-phase voltage source half-bridge inverters, are meant for lower voltage applications and are commonly used in power supplies. Figure 2 shows the circuit schematic of this inverter.

Low-order current harmonics get injected back to the source voltage by the operation of the inverter. This means that two large capacitors are needed for filtering purposes in this design. As Figure 2 illustrates, only one switch can be on at time in each leg of the inverter. If both switches in a leg were on at the same time, the DC source will be shorted out.

Inverters can use several modulation techniques to control their switching schemes. The carrier-based PWM technique compares the AC output waveform, vc, to a carrier voltage signal, vΔ. When vc is greater than vΔ, S+ is on, and when vc is less than vΔ, S- is on. When the AC output is at frequency fc with its amplitude at vc, and the triangular carrier signal is at frequency fΔ with its amplitude at vΔ, the PWM becomes a special sinusoidal case of the carrier based PWM. This case is dubbed sinusoidal pulse-width modulation (SPWM).For this, the modulation index, or amplitude-modulation ratio, is defined as **ma = vc / v**Δ .

The normalized carrier frequency, or frequency-modulation ratio, is calculated using the equation **mf = f**Δ **/ fc**. If the over-modulation region, ma, exceeds one, a higher fundamental AC output voltage will be observed, but at the cost of saturation. For SPWM, the harmonics of the output waveform are at well-defined frequencies and amplitudes. This simplifies the design of the filtering components needed for the low-order current harmonic injection from the operation of the inverter.

The maximum output amplitude in this mode of operation is half of the source voltage. If the maximum output amplitude, ma, exceeds 3.24, the output waveform of the inverter becomes a square wave.

As was true for PWM, both switches in a leg for square wave modulation cannot be turned on at the same time, as this would cause a short across the voltage source. The switching scheme requires that both S+ and S- be on for a half cycle of the AC output period. The fundamental AC output amplitude is equal to **vo1 = vaN**.

Therefore, the AC output voltage is not controlled by the inverter, but rather by the magnitude of the DC input voltage of the inverter.

Using Selective Harmonic E w limination (SHE) as a modulation technique allows the switching of the inverter to selectively eliminate intrinsic harmonics. The fundamental component of the AC output voltage can also be adjusted within a desirable range. Since the AC output voltage obtained from this modulation technique has odd half and odd quarter wave symmetry, even harmonics do not exist. Any undesirable odd (N-1) intrinsic harmonics from the output waveform can be eliminated.

3.2. SINGLE-PHASE FULL-BRIDGE INVERTER

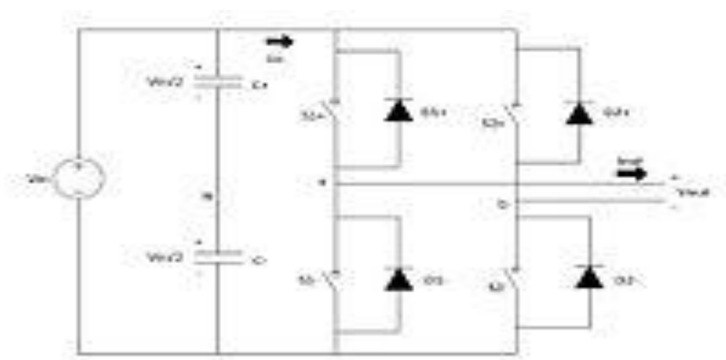


Fig 3.3: Single-Phase Voltage Source Full-Bridge Inverter

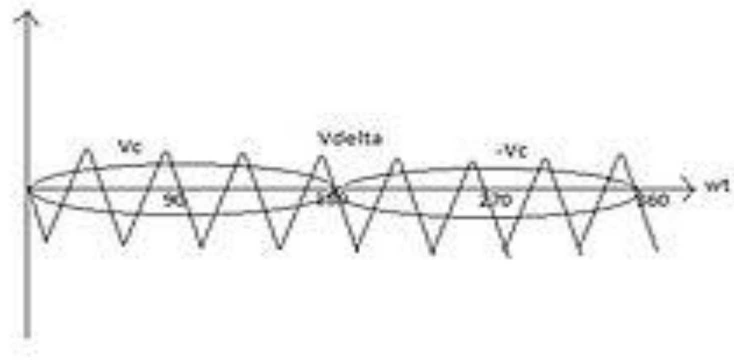


Fig 3.4: Carrier and Modulating Signals for the Bipolar Pulse width Modulation Technique

The full-bridge inverter is similar to the half bridge-inverter, but it has an additional leg to connect the neutral point to the load. Figure 3 shows the circuit schematic of the single-phase voltage source full-bridge inverter.

To avoid shorting out the voltage source, S1+ and S1- cannot be on at the same time, and S2+ and S2- also cannot be on at the same time. Any modulating technique used for the full-bridge configuration should have either the top or the bottom switch of each leg on at any given time. Due to the extra leg, the maximum amplitude of the output waveform is Vi, and is twice as large as the maximum achievable output amplitude for the half-bridge configuration.

States 1 and 2 from Table 2 are used to generate the AC output voltage with bipolar SPWM. The AC output voltage can take on only two values, either Vi or –Vi. To generate these same states using a half-bridge configuration, a carry based technique can be used. S+ being on for the half-bridge corresponds to S1+ and S2- being on for the full-bridge. Similarly, S- being on for the half-bridge corresponds to S1- and S2+ being on for the full bridge. The output voltage for this modulation technique is more or less sinusoidal, with a fundamental component that has an amplitude in the linear region of ma less than or equal to one **vo1 =vab1= vi • ma**.

Unlike the bipolar PWM technique, the unipolar approach uses states 1, 2, 3 and 4 from Table 2 to generate its AC output voltage. Therefore, the AC output voltage can take on the values Vi, 0 or –V [1] i. To generate these states, two sinusoidal modulating signals, Vc and –Vc, are needed, as seen in Figure.

Vc is used to generate VaN, while –Vc is used to generate VbN. The following relationship is called unipolar carrier-based SPWM **vo1 =2 • vaN1= vi • ma**.

The phase voltages VaN and VbN are identical, but 180 degrees out of phase with each other. The output voltage is equal to the difference of the two phase voltages, and do not contain any even harmonics. Therefore, if mf is taken, even the AC output voltage harmonics will appear at normalized odd frequencies, fh. These frequencies are centered on double the value of the normalized carrier frequency. This particular feature allows for smaller filtering components when trying to obtain a higher quality output waveform. As was the case for the half-bridge SHE, the AC output voltage contains no even harmonics due to its odd half and odd quarter wave symmetry.

Through VSI, a DC supply feeds the three phase inverter. The stage after the capacitor is depicted in the diagram has six IGBT switches with anti-parallel diodes linked across them. Switch-like MOSFETs can be used instead of IGBTs because they have an anti-parallel diode built in, although the ON-state voltage drop is a concern with MOSFETs.

MOSFETs can also be utilized for low voltage. The back Electromotive force waveform of a BLDC motor is typically trapezoidal. The current injection across the 120° duration of a constant back EMF is to achieve constant output power. The current injection is managed in the inverter by the two switches with separate legs at the same.

As a result, only two switches are active. For optimal torque output, the current injected in each phase can be correctly lined up with the back EMF to acquire the flux in the motor with angle nearer to 90°. For both forward and reverse motoring, the MOSFET switching sequences are depicted in Figure. 3.4.

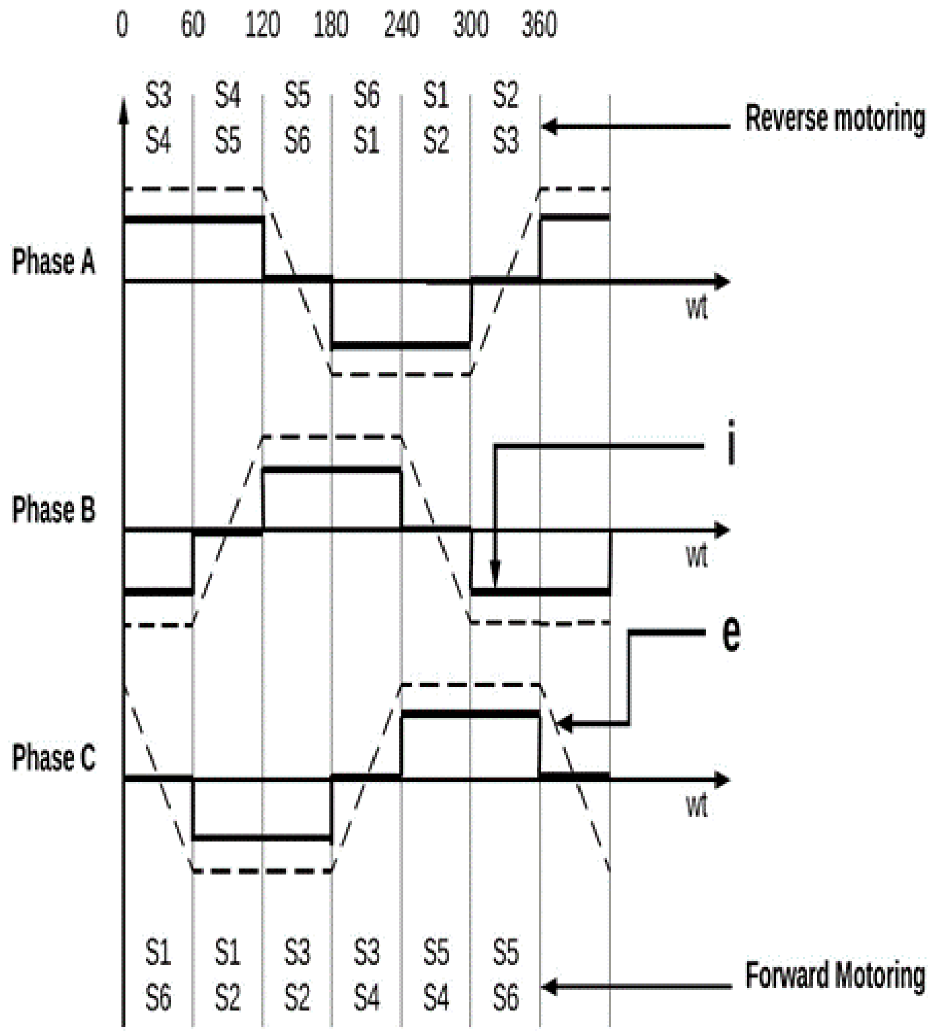


Fig 3.5: Switching sequences of switches in VSI with respect to Back EMF, phase current.

CHAPTER 4

PROPOSED BRUSHLESS DC MOTORS

Brushless DC motors (BLDC) have been a much focused area for numerous motor manufacturers as these motors are increasingly the preferred choice in many applications, especially in the field of motor control technology. BLDC motors are superior to brushed DC motors in many ways, such as ability to operate at high speeds, high efficiency, and better heat dissipation. They are an indispensable part of modern drive technology, most commonly employed for actuating drives, machine tools, electric propulsion, robotics, computer peripherals and also for electrical power generation. With the development of sensor less technology besides digital control, these motors become so effective in terms of total system cost, size and reliability.

A brushless DC motor (known as BLDC) is a permanent magnet synchronous electric motor which is driven by direct current (DC) electricity and it accomplishes electronically controlled commutation system (commutation is the process of producing rotational torque in the motor by changing phase currents through it at appropriate times) instead of a mechanically commutation system. BLDC motors are also referred as trapezoidal permanent magnet motors.

Unlike conventional brushed type DC motor, wherein the brushes make the mechanical contact with commutator on the rotor so as to form an electric path between a DC electric source and rotor armature windings, BLDC motor employs electrical commutation with permanent magnet rotor and a stator with a sequence of coils. In this motor, permanent magnet (or field poles) rotates and current carrying conductors are fixed.

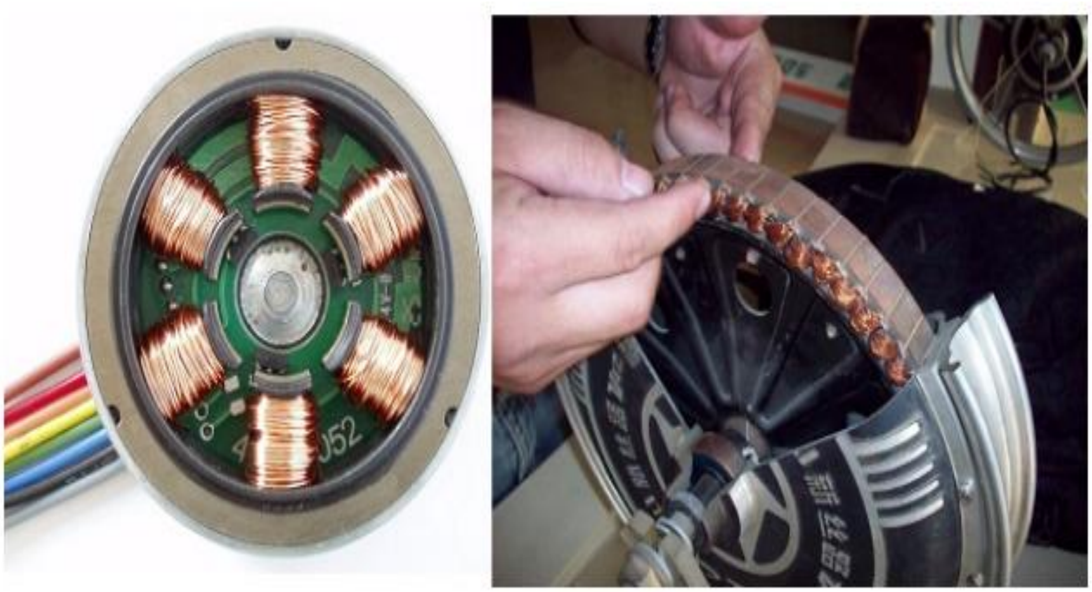


Fig:4.1 Armature coils of BLDC Motor.

The armature coils are switched electronically by transistors or silicon controlled rectifiers at the correct rotor position in such a way that armature field is in space quadrature with the rotor field poles. Hence the force acting on the rotor causes it to rotate. **Hall sensors** or rotary encoders are most commonly used to sense the position of the rotor and are positioned around the stator. The rotor position feedback from the sensor helps to determine when to switch the armature current.

This electronic commutation arrangement eliminates the commutator arrangement and brushes in a DC motor and hence more reliable and less noisy operation is achieved. Due to the absence of brushes BLDC motors are capable to run at high speeds. The efficiency of BLDC motors is typically 85 to 90 percent, whereas as brushed type DC motors are 75 to 80 percent efficient. There are wide varieties of BLDC motors available ranging from small power range to fractional horsepower, integral horsepower and large power ranges.

4.1 CONSTRUCTION OF BLDC MOTOR

BLDC motors can be constructed in different physical configurations. Depending on the stator windings, these can be configured as single-phase, two-phase, or three-phase motors. However, three-phase BLDC motors with permanent magnet rotor are most commonly used.

The construction of this motor has many similarities of three phase induction motor as well as conventional DC motor. This motor has stator and rotor parts as like all other motors.

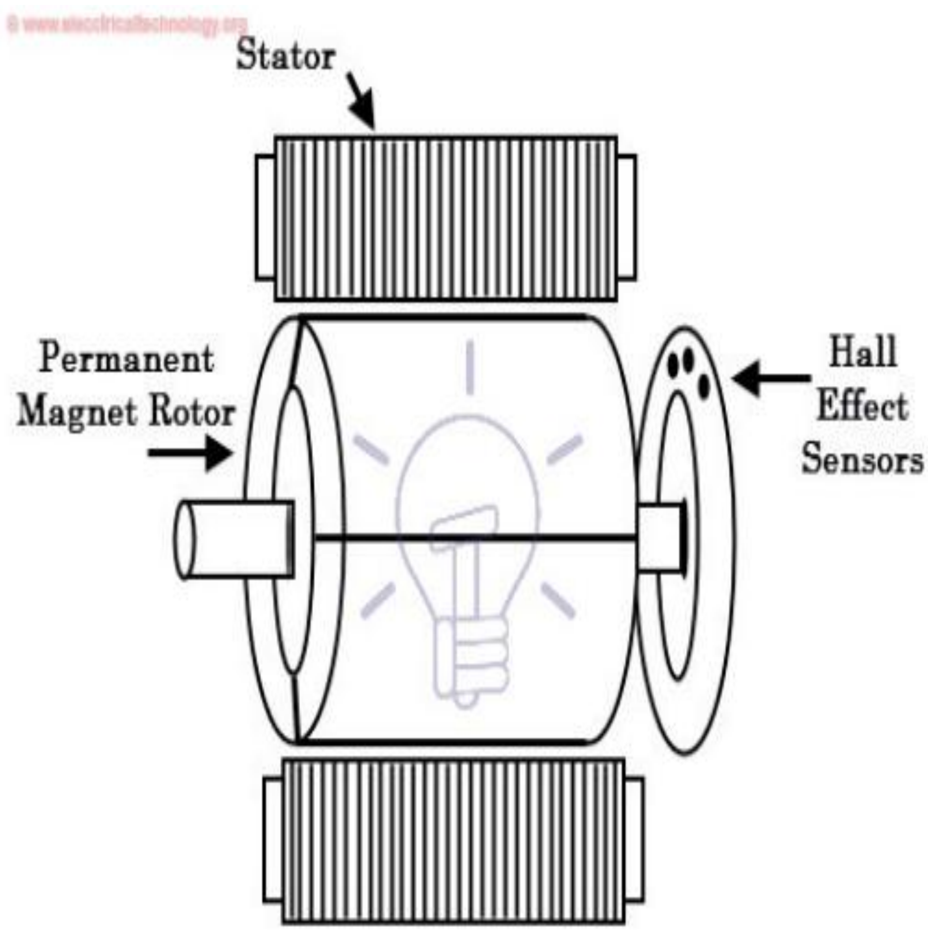


Fig 4.2: BLDC motor

Stator of a BLDC motor made up of stacked steel laminations to carry the windings. These windings are placed in slots which are axially cut along the inner periphery of the stator. These windings can be arranged in either star or delta.

However, most BLDC motors have three phase star connected stator. Each winding is constructed with numerous interconnected coils, where one or more coils are placed in each slot. In order to form an even number of poles, each of these windings is distributed over the stator periphery. The stator must be chosen with the correct rating of the voltage depending on the power supply capability. For robotics, automotive and small actuating applications, 48 V or less voltage BLDC motors are preferred. For industrial applications and automation systems, 100 V or higher rating motors are used.

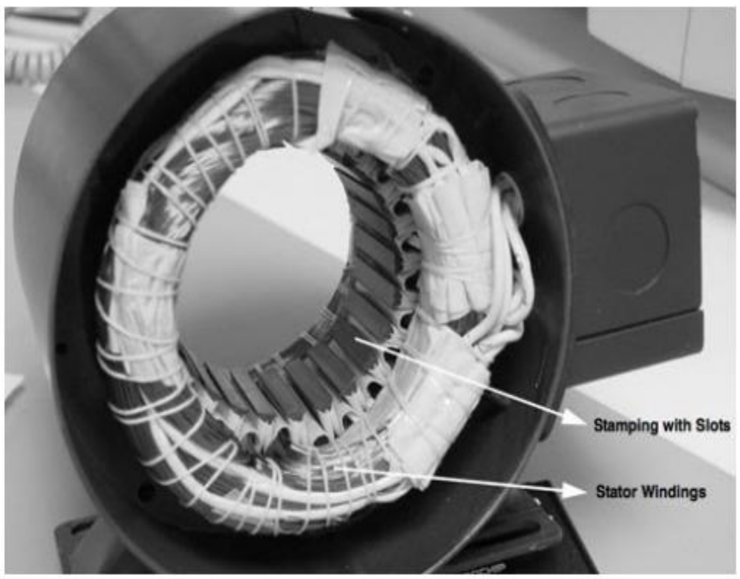


Fig 4.3: Stator of BLDC motor

4.2 ROTOR

BLDC motor incorporates a permanent magnet in the rotor. The number of poles in the rotor can vary from 2 to 8 pole pairs with alternate south and north poles depending on the application requirement. In order to achieve maximum torque in the motor, the flux density of the material should be high. A proper magnetic material for the rotor is needed to produce required magnetic field density.

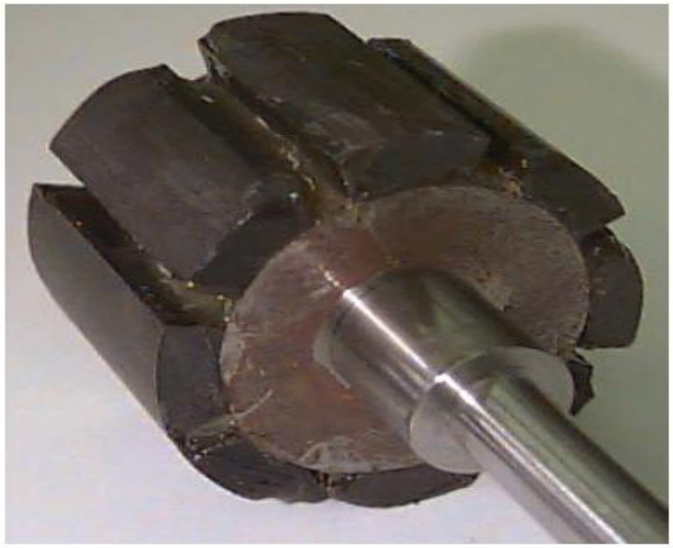


Fig 4.4: Rotor of BLDC motor

Ferrite magnets are inexpensive, however they have a low flux density for a given volume. Rare earth alloy magnets are commonly used for new designs. Some of these alloys are Samarium Cobalt (SmCo), Neodymium (Nd), and Ferrite and Boron (NdFeB). The rotor can be constructed with different core configurations such as the circular core with permanent magnet on the periphery, circular core with rectangular magnets, etc.

4.3 HALL SENSORS

Hall sensor provides the information to synchronize stator armature excitation with rotor position. Since the commutation of BLDC motor is controlled electronically, the stator windings should be energized in sequence in order to rotate the motor. Before energizing a particular stator winding, acknowledgment of rotor position is necessary.

So, the Hall Effect sensor embedded in stator senses the rotor position. Most BLDC motors incorporate three Hall sensors which are embedded into the stator. Each sensor generates Low and High signals whenever the rotor poles pass near to it. The exact commutation sequence to the stator winding can be determined based on the combination of these three sensor's response.

4.4 WORKING PRINCIPLE AND OPERATION OF BLDC MOTOR

BLDC motor works on the principle similar to that of a conventional DC motor, i.e., the Lorentz force law which states that whenever a current carrying conductor placed in a magnetic field it experiences a force. As a consequence of reaction force, the magnet will experience an equal and opposite force.

In case BLDC motor, the current carrying conductor is stationary while the permanent magnet moves. When the stator coils are electrically switched by a supply source, it becomes electromagnet and starts producing the uniform field in the air gap. Though the source of supply is DC, switching makes to generate an AC voltage waveform with trapezoidal shape. Due to the force of interaction between electromagnet stator and permanent magnet rotor, the rotor continues to rotate.

Consider the figure below in which motor stator is excited based on different switching states. With the switching of windings as High and Low signals, corresponding winding energized as North and South poles. The permanent magnet rotor with North and South poles align with stator poles causing motor to rotate.

Observe that motor produces torque because of the development of attraction forces (when North-South or South-North alignment) and repulsion forces (when North-North or South-South alignment). By this way motor moves in a clockwise direction.

Here, one might get a question that how we know which stator coil should be energized and when to do. This is because; the motor continuous rotation depends on the switching sequence around the coils. As discussed above that Hall sensors give shaft position feedback to the electronic controller unit. Based on this signal from sensor, the controller decides particular coils to energize. Hall-effect sensors generate Low and High level signals whenever rotor poles pass near to it. These signals determine the position of the shaft.

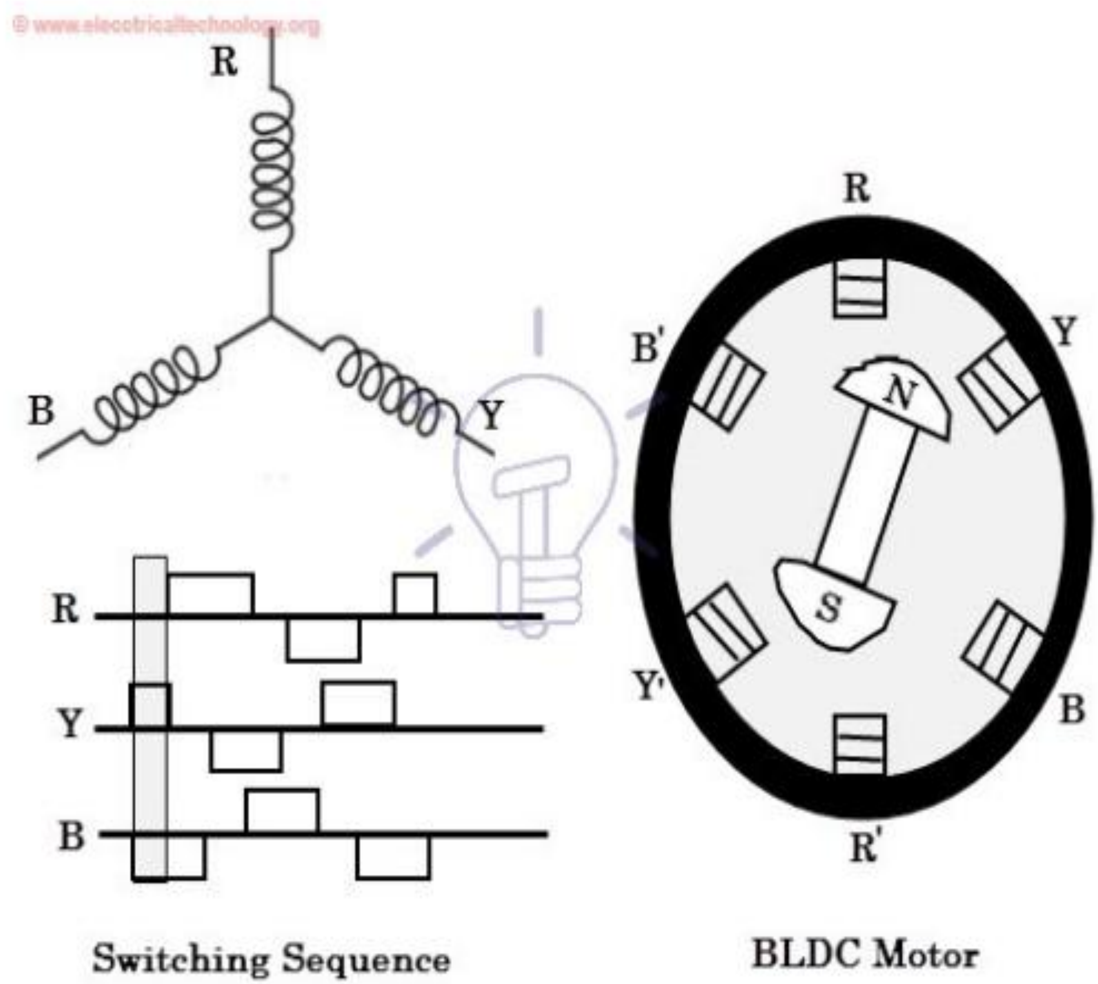


Fig 4.5: working principle of BLDC motor

4.5 BRUSHLESS DC MOTOR DRIVE

As described above that the electronic controller circuit energizes appropriate motor winding by turning transistor or other solid state switches to rotate the motor continuously. The figure below shows the **simple BLDC motor drive circuit** which consists of MOSFET bridge (also called as inverter bridge), electronic controller, hall effect sensor and BLDC motor.

Here, Hall-effect sensors are used for position and speed feedback. The electronic controller can be a microcontroller unit or microprocessor or DSP processor or FPGA unit or any other controller. This controller receives these signals, processes them and sends the control signals to the MOSFET driver circuit.

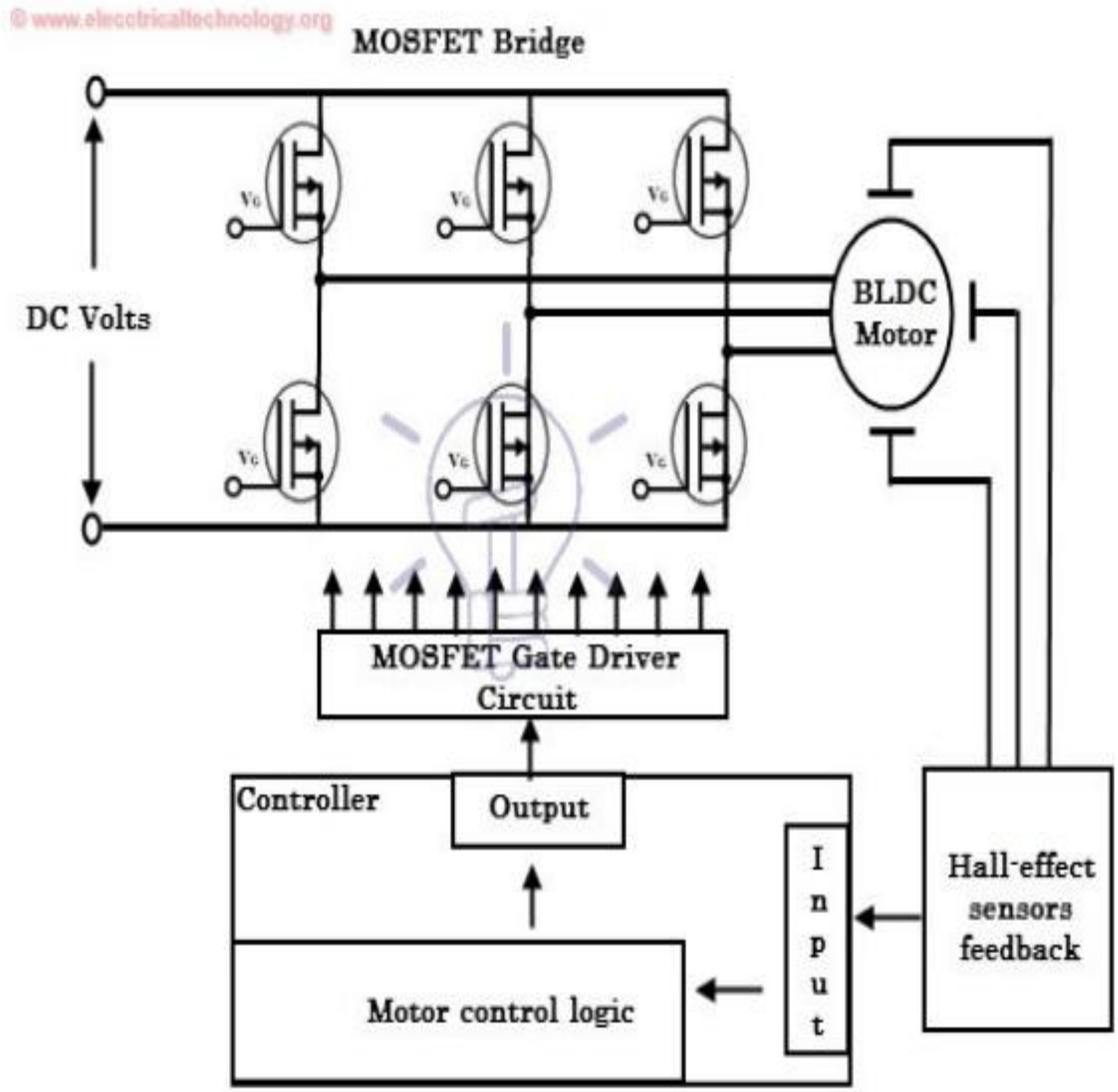


Fig 4.6: Simple BLDC motor drive circuit

In addition to the switching for a rated speed of the motor, additional electronic circuitry changes the motor speed based on required application. These speed control units are generally implemented with PID controllers to have precise control. It is also possible to produce four-quadrant operation from the motor whilst maintaining good efficiency throughout the speed variations using modern drives.

4.6 ADVANTAGES OF BLDC MOTOR

BLDC motor has several advantages over conventional DC motors and some of these are

- It has no mechanical commutator and associated problems.
- High efficiency due to the use of permanent magnet rotor.
- High speed of operation even in loaded and unloaded conditions due to the absence of brushes that limits the speed.
- Smaller motor geometry and lighter in weight than both brushed type DC and induction AC motors.
- Long life as no inspection and maintenance is required for commutator system.
- Higher dynamic response due to low inertia and carrying windings in the stator.
- Less electromagnetic interference.
- Quite operation (or low noise) due to absence of brushes.

4.7 DISADVANTAGES OF BRUSHLESS DC MOTOR

- These motors are costly.
- Electronic controller required control this motor is expensive.
- Not much availability of many integrated electronic control solutions, especially for tiny BLDC motors.
- Requires complex drive circuitry.
- Need of additional sensors.

4.8 APPLICATIONS OF BRUSHLESS DC MOTORS (BLDC)

Brushless DC Motors (BLDC) are used for a wide variety of application requirements such as varying loads, constant loads and positioning applications in the fields of industrial control, automotive, aviation, automation systems, health care equipments, etc. Some specific applications of BLDC motors are

- Computer hard drives and DVD/CD players.
- Electric vehicles, hybrid vehicles, and electric bicycles.
- Industrial robots, CNC machine tools, and simple belt driven systems.
- Washing machines, compressors and dryers.
- Fans, pumps and blowers.

4.9 SPEED CONTROLLER MODELLING

PID controllers are used for speed control. When compared to a PD controller, a PID controller allows for more precise speed tracking. Besides the error tracking of a PI controller is outstanding, but the operation period is too slow. The tuning of the controller (PID) is the issue. Through MATLAB/Simulink software the tuning of the system is very easy. The PID variable value is shown in Table below. The mentioned bi-directional converter necessitates the control of the switches T1, T2.

A PI controller will be used to control the switches. The DC- link voltage of VSI is connected to the controller or a feedback system to control the speed through the hysteresis control in the motoring mode. For turning on the switch T1 the DC link voltage is adjusted. The gate logic command of a bi – directional DC-DC converter is shown in Figure 4.6.

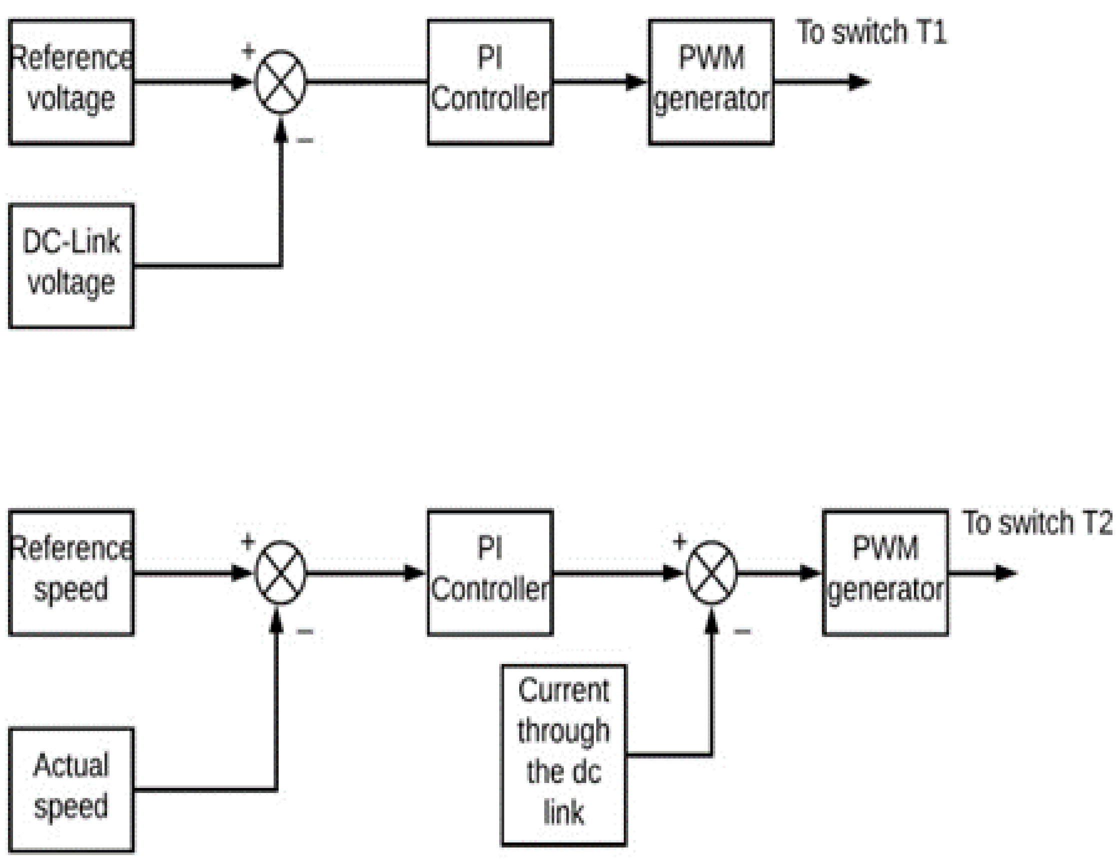


Fig 4.7: Control logics for the Bi-directional converter.

Because the actual speed must be similar to the reference speed during the regenerative mode, current control is done to control the switch T2.

TABLE I
PID CONTROLLER PARAMETERS

Proportional	0.0855
Integral	0.471
Derivative	-0.00072
Filter Coefficient	117.319

4.10 PID CONTROLLER

A proportional–integral–derivative controller (PID controller or three-term controller) is a control loop mechanism employing feedback that is widely used in industrial control systems and a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an error value {\display style e(t)}e(t) as the difference between a desired set point (SP) and a measured process variable (PV) and applies a correction based on proportional, integral, and derivative terms (denoted P, I, and D respectively).

In practical terms it automatically applies an accurate and responsive correction to a control function. An everyday example is the cruise control on a car, where ascending a hill would lower speed if only constant engine power were applied. The controller's PID algorithm restores the measured speed to the desired speed with minimal delay and overshoot by increasing the power output of the engine.

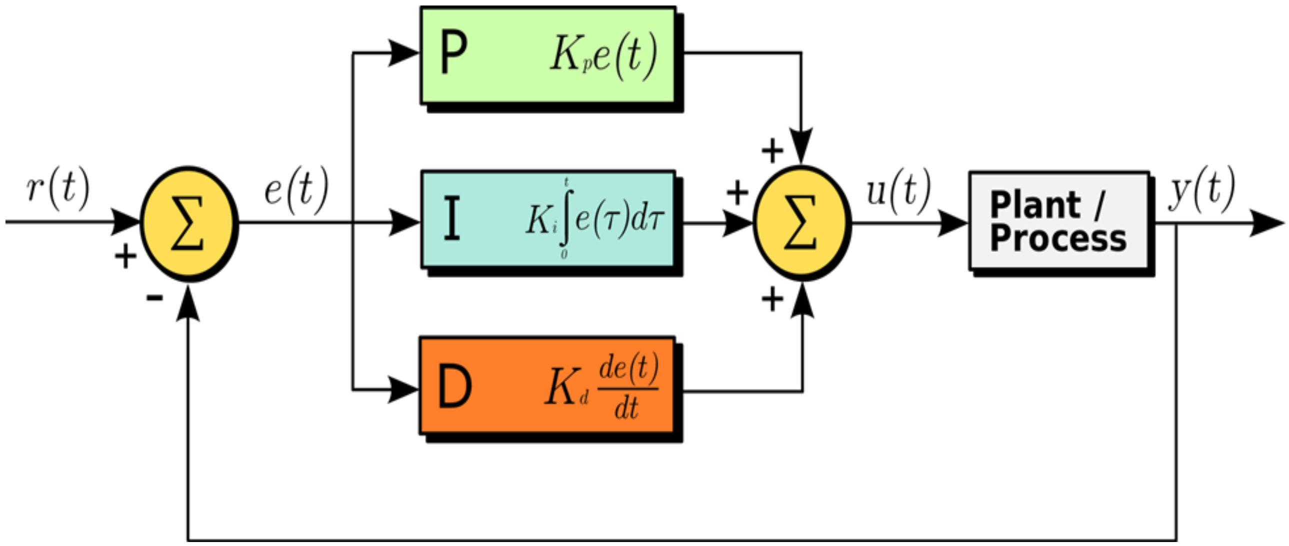


Fig 4.8: A block diagram of a PID controller in a feedback loop. *r*(*t*) is the desired process value or set point (SP), and *y*(*t*) is the measured process value (PV).

The distinguishing feature of the PID controller is the ability to use the three *control terms* of proportional, integral and derivative influence on the controller output to apply accurate and optimal control. The block diagram on the right shows the principles of how these terms are generated and applied.

It shows a PID controller, which continuously calculates an *error value* as the difference between a desired set point and a measured process variable , and applies a correction based on proportional, integral, and derivative terms. The controller attempts to minimize the error over time by adjustment of a *control variable*, such as the opening of a control valve, to a new value determined by a weighted sum of the control terms.

In this model:

- **Term P** is proportional to the current value of the SP − PV error . For example, if the error is large and positive, the control output will be proportionately large and positive, taking into account the gain factor "K". Using proportional control alone will result in an error between the set point and the actual process value because it requires an error to generate the proportional response. If there is no error, there is no corrective response.

- **<u>Term I</u>** accounts for past values of the SP – PV error and integrates them over time to produce the **I** term. For example, if there is a residual SP – PV error after the application of proportional control, the integral term seeks to eliminate the residual error by adding a control effect due to the historic cumulative value of the error. When the error is eliminated, the integral term will cease to grow. This will result in the proportional effect diminishing as the error decreases, but this is compensated for by the growing integral effect.
- **<u>Term D</u>** is a best estimate of the future trend of the SP – PV error, based on its current rate of change. It is sometimes called "anticipatory control", as it is effectively seeking to reduce the effect of the SP – PV error by exerting a control influence generated by the rate of error change. The more rapid the change, the greater the controlling or damping effect

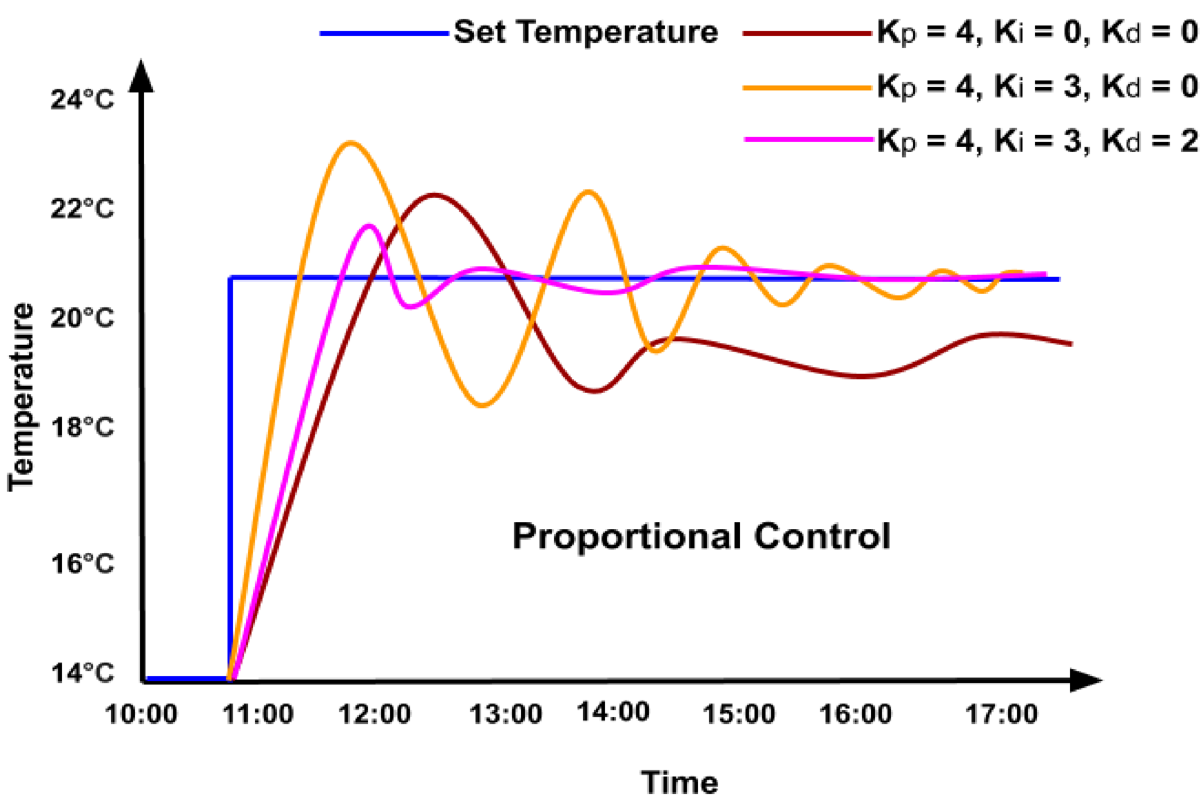


Fig 4.9: System response of PID controller

4.10.1 Applicability

The use of the PID algorithm does not guarantee optimal control of the system or its control stability . Situations may occur where there are excessive delays: the measurement of the process value is delayed, or the control action does not apply quickly enough. In these cases lead–lag compensation is required to be effective. The response of the controller can be described in terms of its responsiveness to an error, the degree to which the system overshoots a set point, and the degree of any system oscillation. But the PID controller is broadly applicable since it relies only on the response of the measured process variable, not on knowledge or a model of the underlying process.

CHAPTER 5

PROPOSED SIMULATION RESULTS

5.1 INTRODUCTION

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail.

This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.

Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor. The model depicts the time-dependent mathematical relationships among the system's inputs, states, and outputs. Then, we use Simulink to simulate the behavior of the system over a specified time span. Simulink uses information that you entered into the model to perform the simulation.

5.2. BLOCK DIAGRAM

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block).

The lines represent connections of block inputs to block outputs. Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time. A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate. A block comprises one or more of the following:

1) A set of inputs,
2) A set of states, and
3) A set of outputs.

A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance. Continuous Versus discrete Blocks Simulink's standard block set includes continuous blocks and discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only at integral multiples of a fixed interval called the block's sample time.

Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, depending on whether they are driven by continuous or discrete blocks. A block that can be either discrete or continuous is said to have an implicit sample rate. The implicit sample time is continuous if any of the block's inputs are continuous.

The implicit sample time is equal to the shortest input sample time if all the input sample times are integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times.

Simulink can optionally color code a block diagram to indicate the sample times of the blocks it contains, e.g., black (continuous), magenta (constant), yellow (hybrid), red (fastest discrete), and so on. The block contains block name, icon, and block library that contain the block, the purpose of the block.

5.3 SIMULINK BLOCK LIBRARIES

Simulink organizes its blocks into block libraries according to their behavior.

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-time components.
4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.
6) The Functions & Tables library contains blocks that describe general functions and table look-up operations.
7) The Nonlinear library contains blocks that describe nonlinear functions.
8) The Signal & Systems library contains blocks that allow multiplexing and de-multiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types of subsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

5.4 SUB SYSTEMS

Simulink allows to model a complex system as a set of interconnected subsystems each of which is represented by a block diagram. We create a subsystem using Simulink's Subsystem block and the Simulink model editor. We can embed subsystems with subsystems to any depth to create hierarchical models. We can create conditionally executed subsystems that are executed only when a transition occurs on a triggering or enabling input.

5.5 SOLVERS

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model. The process of computing the successive states of a system from its model is known as solving the model.

No single method of solving a model suffices for all systems. Accordingly, Simulink provides a set of programs, known as solvers, that each embody a particular approach to solving a model. The Simulation Parameters dialog box allows us to choose the solver most suitable for our model.

5.5.1 Fixed-Step and Variable-Step Solvers

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size. Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly and increasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time, required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

5.5.2 Continuous and Discrete Solvers

Continuous solvers use numerical integration to compute a model's continuous states at the current time step from the states at previous time steps and the state derivatives. Continuous solvers rely on the model's blocks to compute the values of the model's discrete states at each time step. Mathematicians have developed a wide variety of numerical integration techniques for solving the ordinary differential equations (ODEs) that represent the continuous states of dynamic systems. Simulink provides an extensive set of fixed-step and variable-step continuous solvers, each implementing a specific ODE solution method.

Some continuous solvers subdivide the simulation time span into major and minor steps, where a minor time step represents a subdivision of the major time step. The solver produces a result at each major time step. It use results at the minor time steps to improve the accuracy of the result at the major time step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time-step for a model and nothing else. They do not compute continuous states and they rely on the model's blocks to update the model's discrete states.We can use a continuous solver, but not a discrete solver, to solve a model that contains both continuous and discrete states. This is because a discrete solver does not handle continuous states. If you select a discrete solver for a continuous model, Simulink disregards your selection and uses a continuous solver instead when solving the model.

Simulink provides two discrete solvers, a fixed-step discrete solver and a variable-step discrete solver. The fixed-step solver by default chooses a step size and hence simulation rate fast enough to track state changes in the fastest block in our model. The variable-step solver adjusts the simulation step size to keep pace with the actual rate of discrete state changes in our model. This can avoid unnecessary steps and hence shorten simulation time for multi-rate models.

5.6 MODEL EXECUTION PHASE

In the simulation model execution phase, Simulink successively computes the states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps.

The length of time between steps is called the step size. The step size depends on the type of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states have discontinuities (Zero Crossing Detection). At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated. At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

1) Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and states to the output function as it may require these arguments to compute the block's output. Simulink updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.
2) Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's continuous states by numerically integrating the time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.
3) Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.
4) Computes the time for the next time step.

   Simulink repeats steps 1 through 4 until the simulation stop time is reached.

5.7 BLOCK SORTING RULES

Simulink uses the following basic update rules to sort the blocks:

1) Each block must be updated before any of the direct-feed through blocks that it drives. This rule ensures that the inputs to direct-feed through blocks will be valid when they are updated.
2) Non-direct feed through blocks can be updated in any order as long as they are updated before any direct-feed through blocks that they drive. This rule can be met by putting all non-direct feed through blocks at the head of the update list in any order. It thus allows Simulink to ignore non direct-feed through blocks during the sorting process.

The result of applying these rules is an update list in which non-direct feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct-feed through block is connected directly or indirectly to one of the block's inputs. Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output.

However, an algebraic loop can represent a set of simultaneous algebraic equations (hence the name) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step. The simulation is executed in order to demonstrate the behaviour of the system. In Table below, the values of the BLDC motor used are listed.

TABLE II

PARAMETERS OF THE BLDC MOTOR

DC- link voltage (V)	200
Rated speed (rpm)	1500
PM flux-linkage (Wb)	0.1194
Pole pair number	4
Phase resistance (Ω)	0.0485
Phase inductance (mH)	8.5

TABLE III

BATTERY PARAMETERS

Parameter	Value
Battery Type	Lithium-ion
Nominal Voltage	350 V
Maximum Capacity	100 Ah
Exponential Voltage	378 V
Initial State of Charge	% 88
Cut off Voltage	262.5 V
Fully Charge Voltage	407.4 V
Nominal Discharge Current	44.5 A

The voltage covering the inverter is shown in Figure. 5(h). The voltage over the dc-link can be achieved by the forward braking, where it is reducing from 3 sec. to 3.5 sec, through the rectification of the three- phase back EMF. The load torque generated with electromagnetic torque is depicted in Figure. 5(g).

For 8 seconds, the simulation results are displayed. The motor's steady-state operation in four quadrants is correctly depicted. The BLDC motor first operates in the forward motoring mode for 3 seconds, followed by 0.5 seconds of braking to lower the speed from 1000 rpm - 350 rpm. Figure 5(k) shows the variation of speed, back EMF and phase current.

TABLE IV

PARAMETERS

Motor action	Time duration (sec.)
Acceleration	0-1
Constant speed of 1000 rpm	1-3
Braking	3-3.5
Reverse motoring	Beyond 5.5

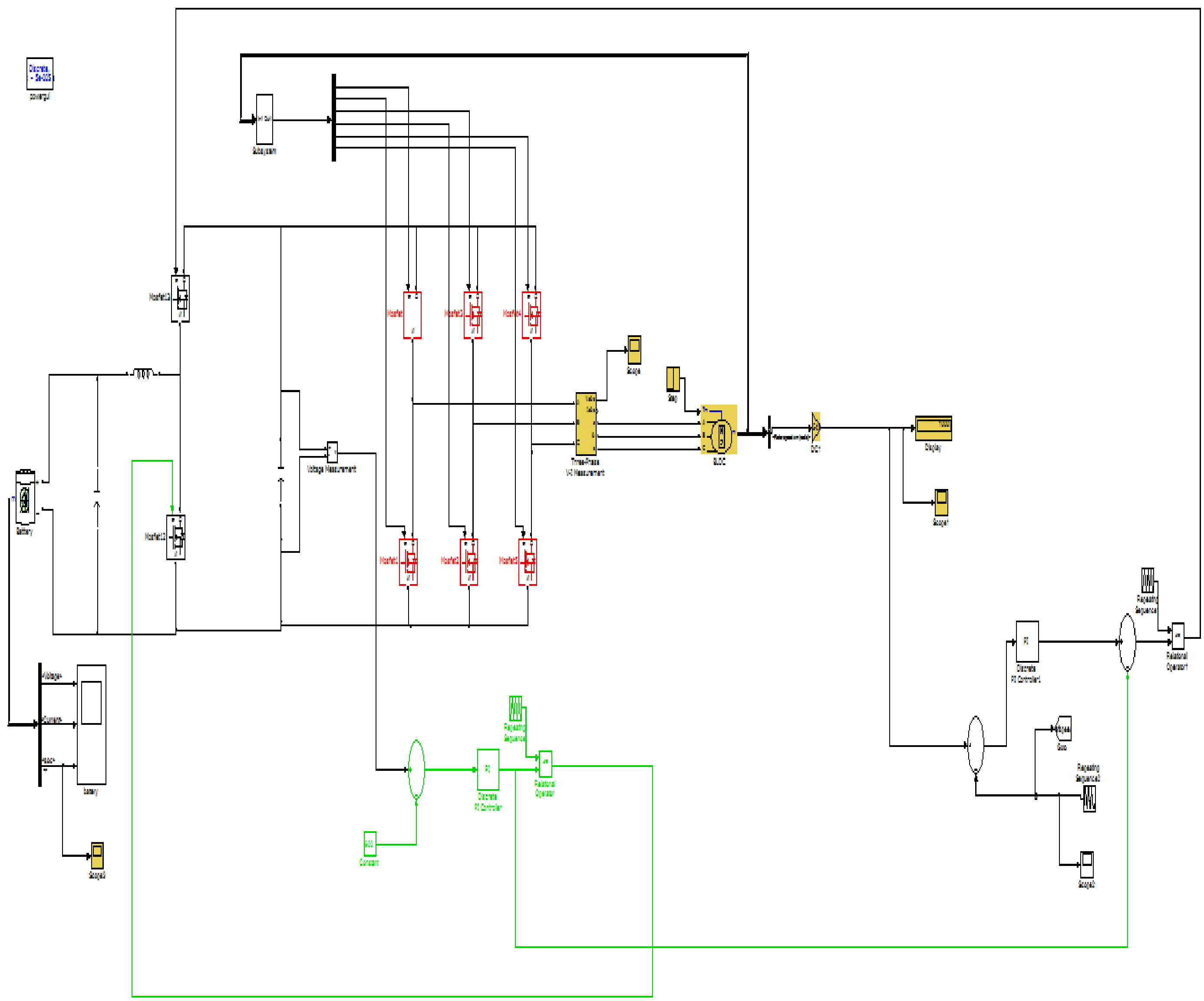
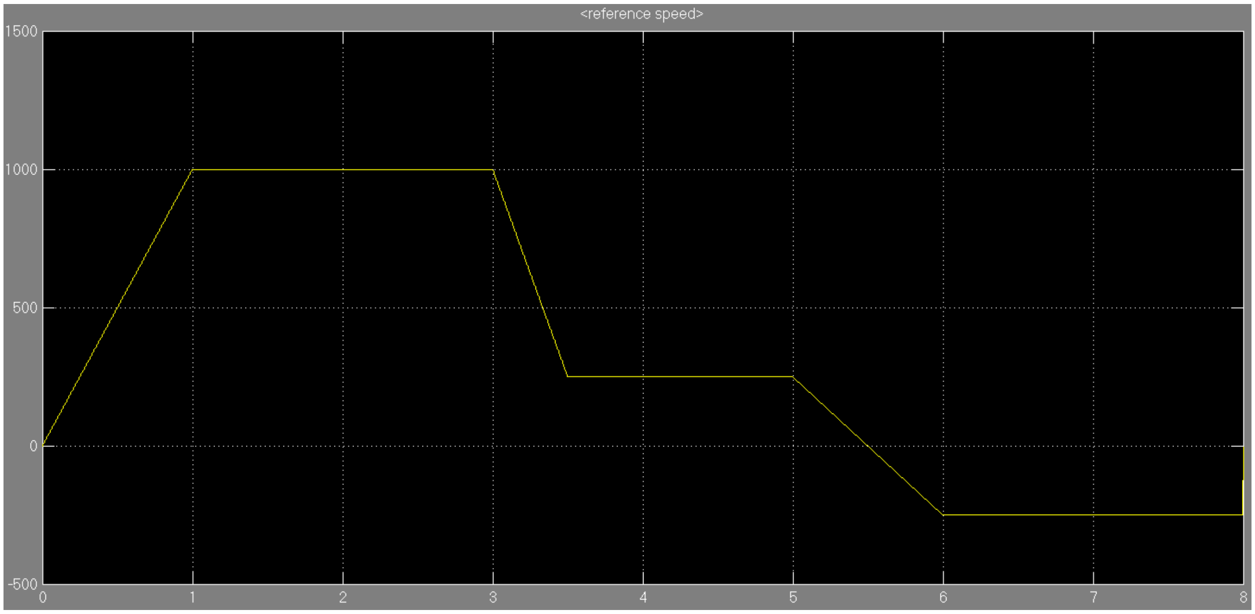
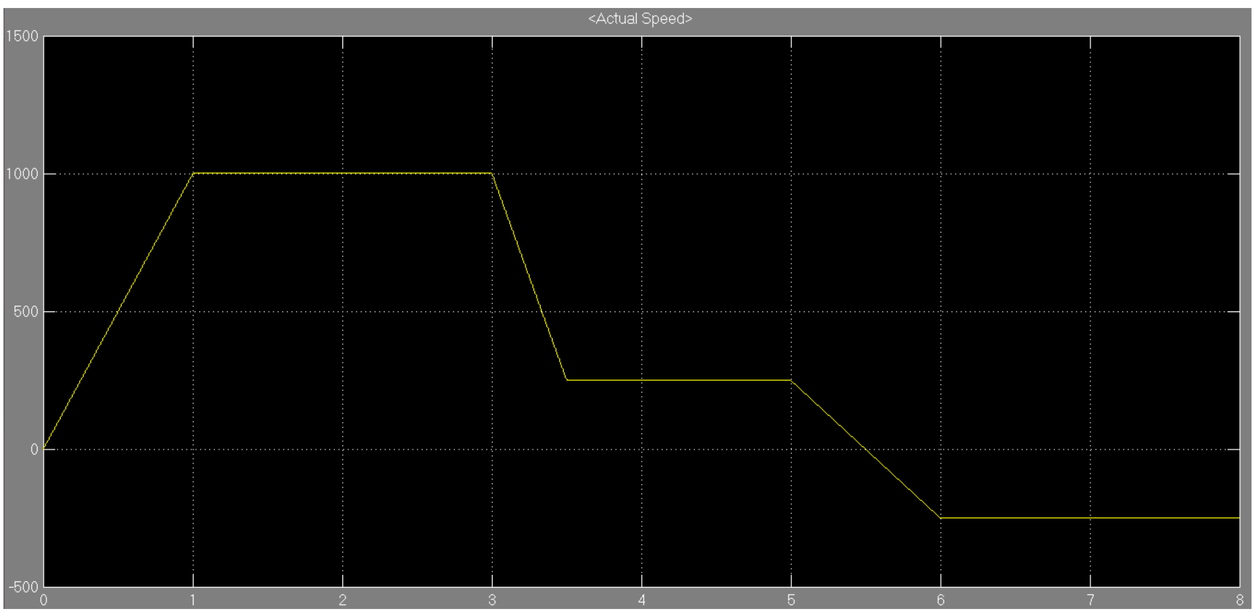


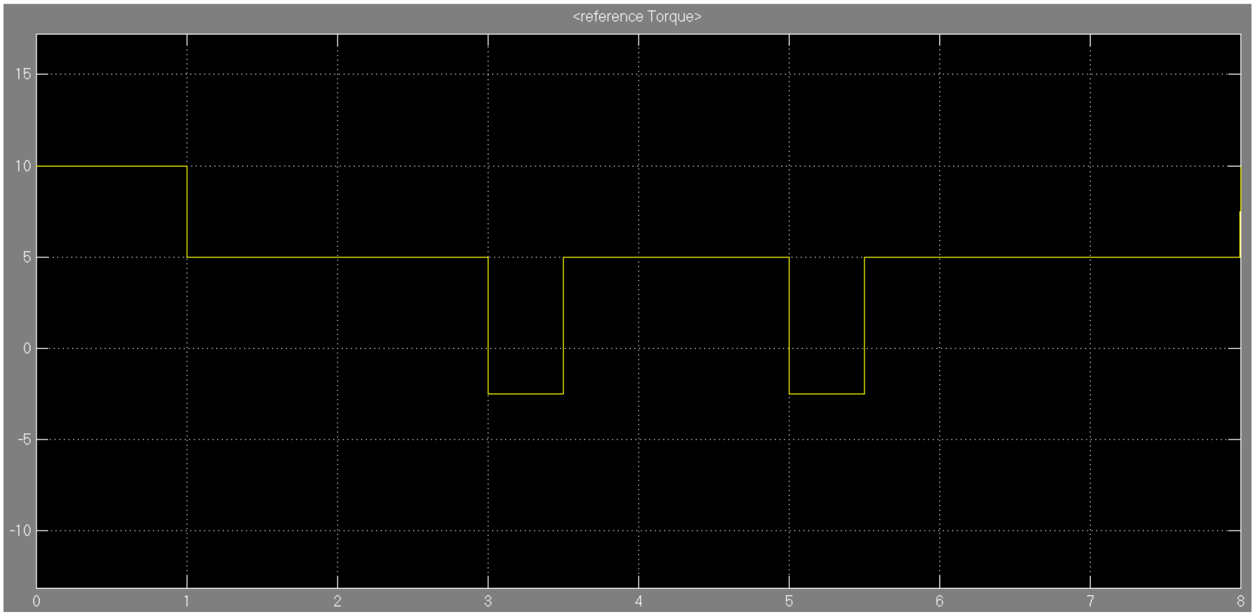
Fig 5.1: Proposed circuit configuration



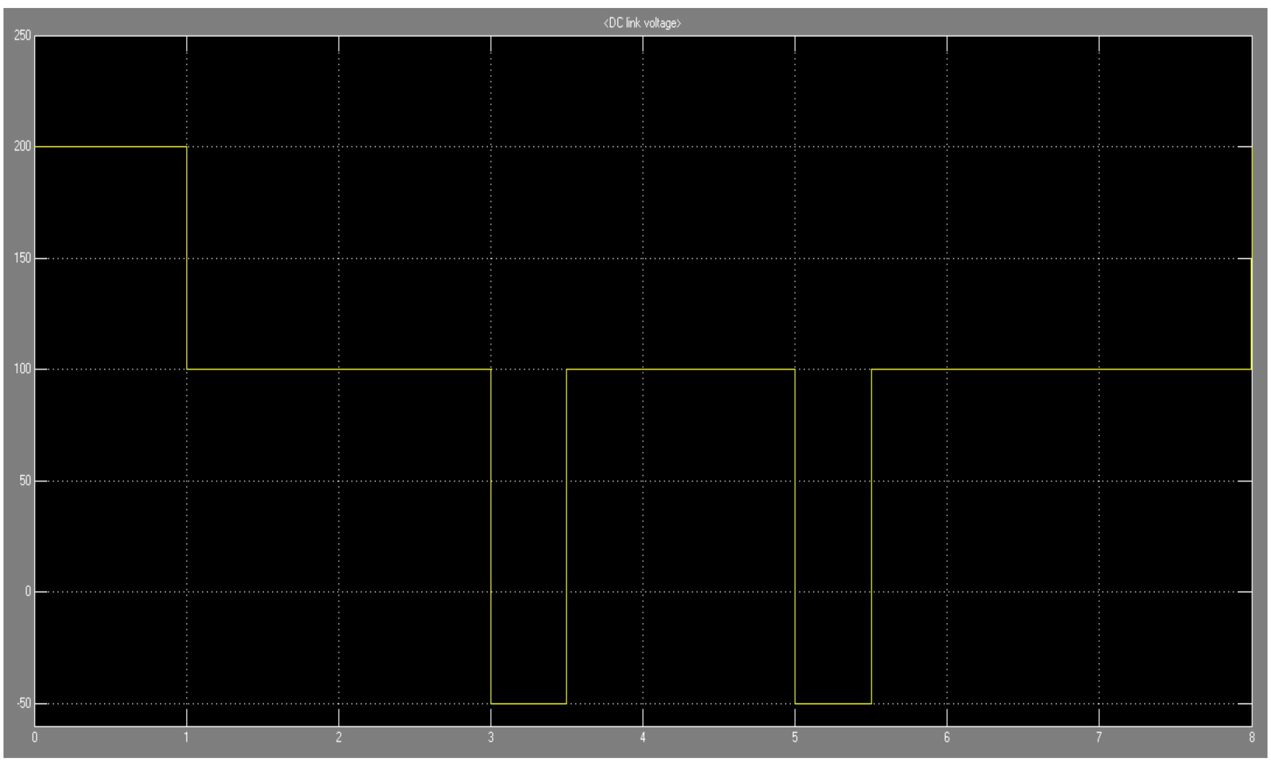
Graph 5(a): Reference speed



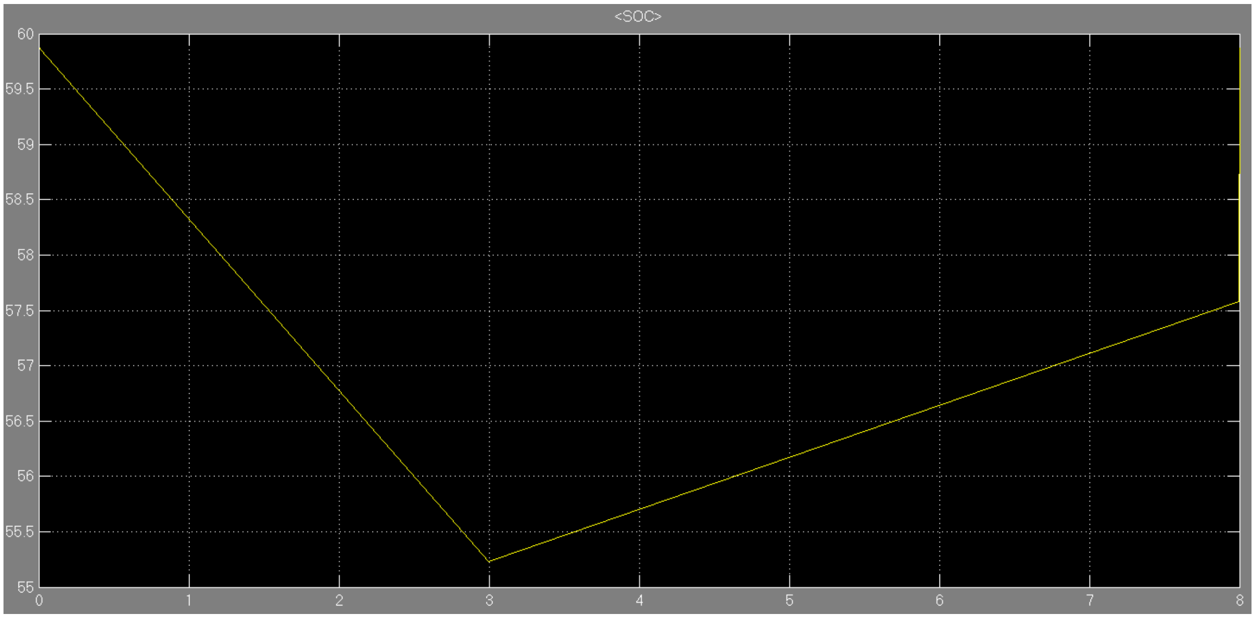
Graph 5(b): Actual speed



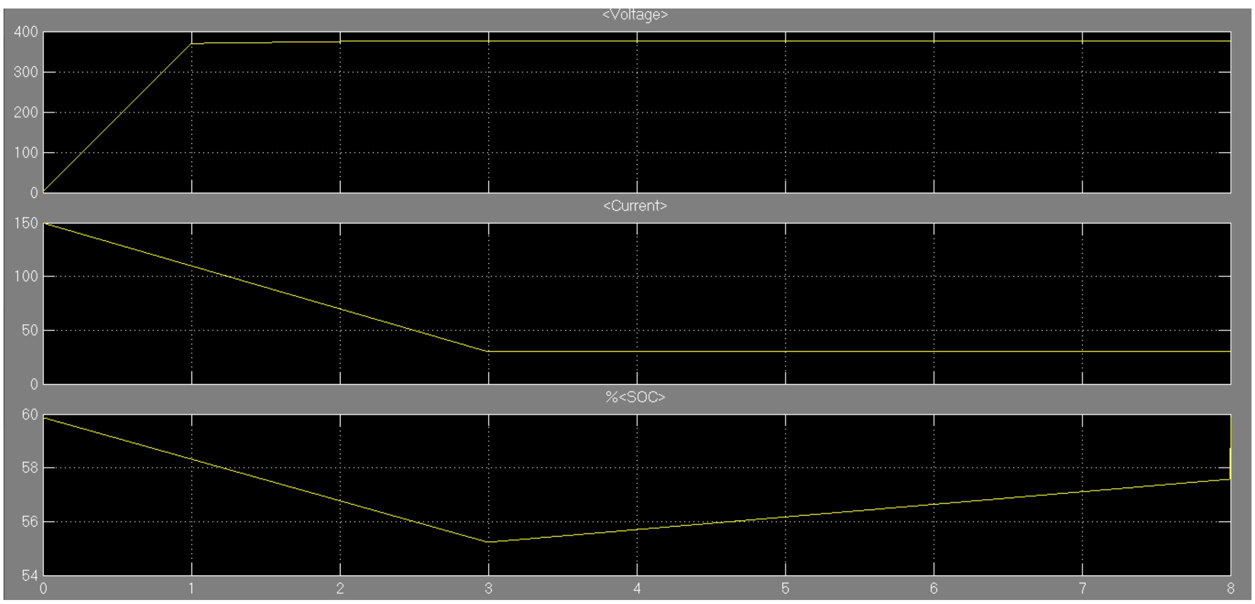
Graph 5(c): Reference torque



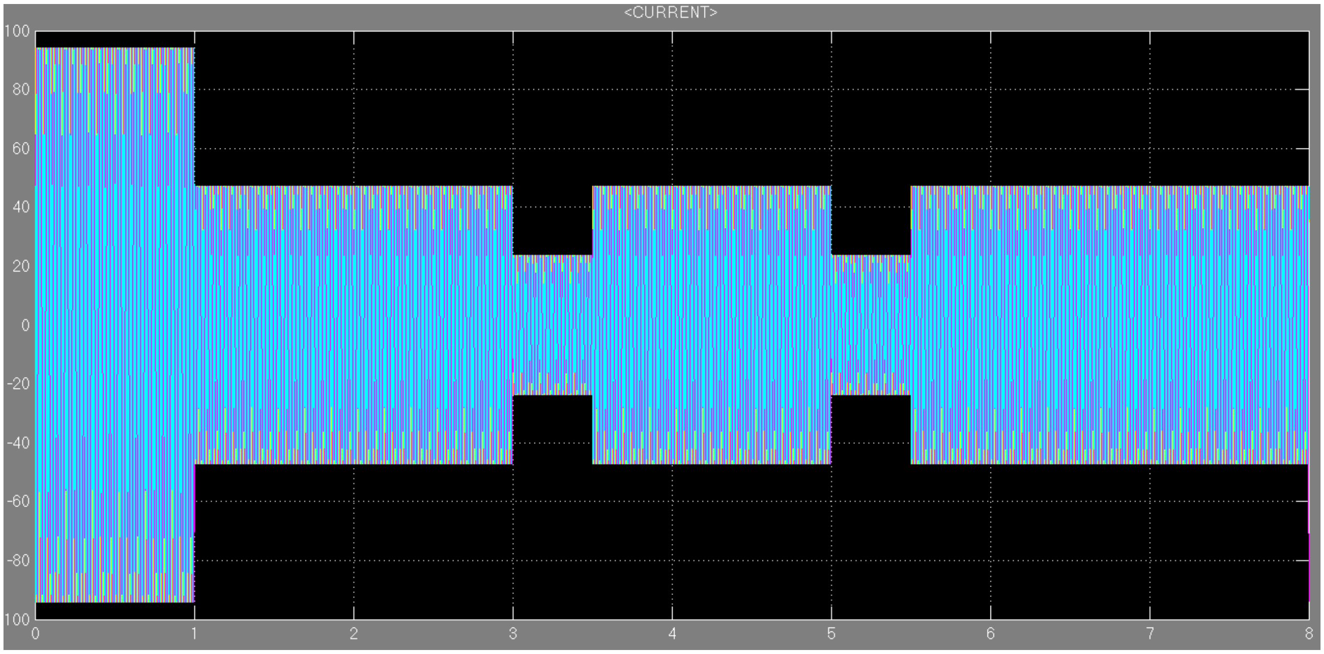
Graph 5(d): Voltage across the inverter.



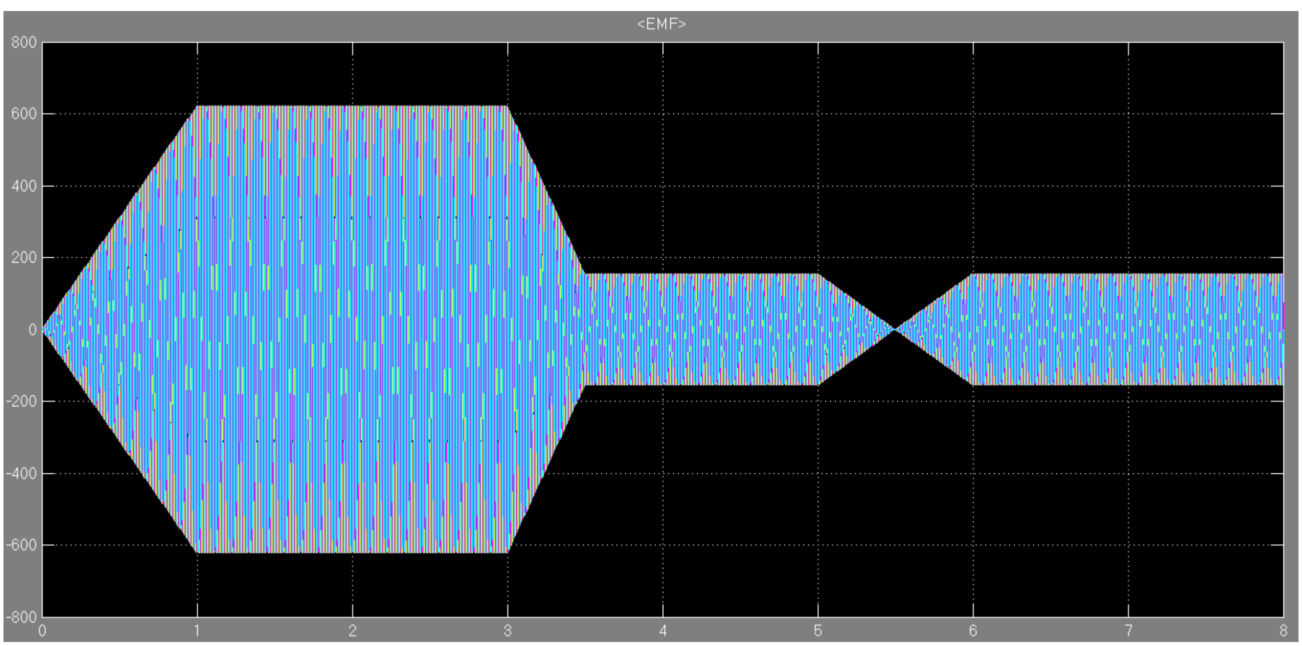
Graph 5(e): Battery State of charge



Graph 5(f): Battery voltage, current, SOC



Graph 5(g): Three-Phase current waveform and Three-phase back EMF of the motor.



Graph 5(h): Three-Phase current waveform and Three-phase back EMF of the motor.

CHAPTER 6

CONCLUSION

The four quadrant operation is simulated for the electric drive with maximum efficiency keeping in mind the fuel constraint. The battery is charged during the regenerative mode and the speed control using the closed loop control is performed. The proposed method requires the minimum hardware and the operation can be controlled in all the four quadrants. During the regenerative mode, the kinetic energy is returned via the bi-directional converter to charge the battery. The abovementioned proposal could be applied in electric vehicle downhill run by controlling the speeding in gravitational action where the speed becomes more than the reference speed. The practical implementation is under progress for the proposed method.

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APPENDIX

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

(a) Development Environment

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

(b) The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

(e) The MATLAB Application Program Interface (API)

This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

(f) MATLAB Documentation

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

(1) Three phase source block

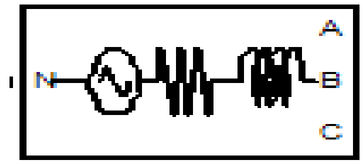

Fig 6.1: Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

(2) VI measurement block

The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents

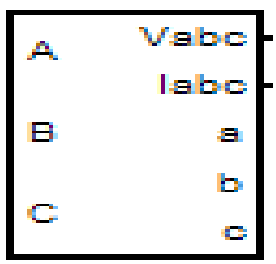

Fig 6.2: Three Phase V-I Measurement

(3) Scope

Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes.

The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation

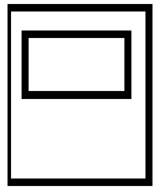

Fig 6.3: Scope

(4) Three-Phase Series RLC Load

The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

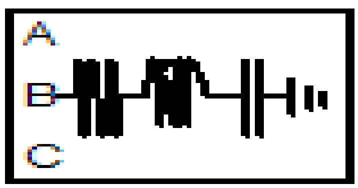

Fig 6.4: Three-Phase Series RLC Load

(5) Three-Phase Breaker block

The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.

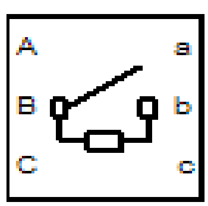

Fig 6.5: Three-Phase Breaker Block

(6) Integrator

Library: Continuous

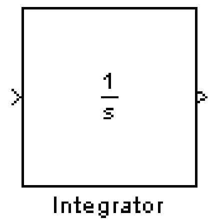

Fig 6.6: Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

(7) Breaker

Implement circuit breaker opening at current zero crossing.

Library: Elements

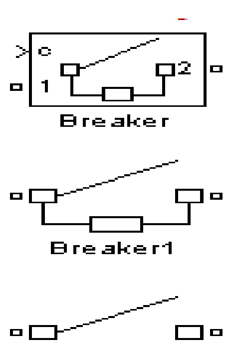

Fig 6.7: Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it).

When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

(8) Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources

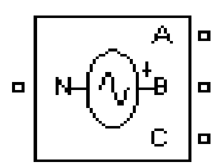

Fig 6.8: Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

(9) Trigonometric Function

Specified trigonometric function on input

Library: Math Operations

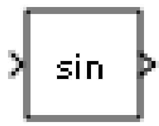

Fig 6.9: Trigonometric Function

Purpose: The Trigonometric Function block performs common trigonometric functions

(10) Three-Phase Transformer (Two Windings)

Implement three-phase transformer with configurable winding connections

Library: **Elements**

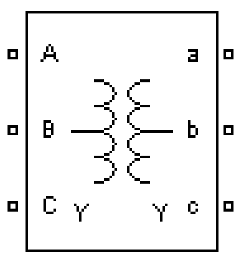

Fig 6.10: Three Phase Transformer

Purpose:

The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers.

The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

Three-Phase Transformer 12 Terminals

Implement three single-phase, two-winding transformers where all terminals are accessible

Library: Elements

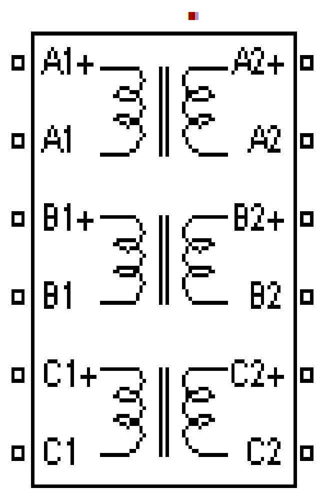

Fig 6.11: Two winding Transformer

Purpose:

The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

(11) IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: **Power Electronics**

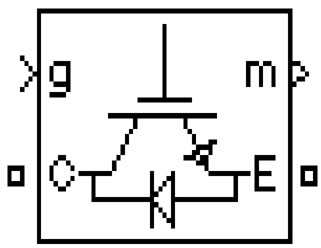

Fig 6.12: IGBT

Purpose:

The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

A

PROJECT REPORT

On

DESIGN AND ANALYSIS OF BI-DIRECTIONAL DC-DC DRIVER FOR ELECTRIC VEHICLE

Submitted by

1) Ms. J. Sanjana (17K81A0219)

2) Ms. P. Srujana (18K85A0202)

3) Ms. S. Lokeshwari (17K81A0237)

4) Mr. T. ChandraPrakash (18K85A0204)

in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

Mrs. C.N. Sangeetha, **M.Tech,(PhD)**

Assistant Professor

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ST. MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

BONAFIDE CERTIFICATE

This is to certify that the project entitled **DESIGN AND ANALYSIS OF BI-DIRECTIONAL DC-DC DRIVER FOR ELECTRICAL VEHICLE**, is being submitted by 1.**Ms.J.Sanjana(17K81A0219),2.Ms.P.Srujana(18K85A0202),3.Ms.S.Lokeshwari(17K81A0237),4.Mr.T.ChandraPrakash(18K85A0204)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN** ELECTRICAL AND ELECTRONICS ENGINEERING is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Mrs. C.N. Sangeetha
Department of EEE

Head of the Department
Dr. N. Ramchandra
Department of EEE

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of '**ELECTRICAL AND ELECTRONICS ENGINEERING'**, session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled **DESIGN AND ANALYSIS OF BI-DIRECTIONAL DC-DC DRIVER FOR ELECTRICAL VEHICLE** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

J. Sanjana (17K81A0219)
P. Srujana (18K85A0202)
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NOMENCLATURE

EV	Electrical Vehicle
HEVs	Hybrid Electrical Vehicle
ICE	Internal combustion engine
FLC	Fuzzy Logic Controller
BEVs	Battery Electrical Vehicles
VRLA	Valve regulated lead–acid battery
AGM	Absorbed Glass Mat
SOC	State of Charge

ABSTRACT

The level of exhaust gases is rising with increasing usage of internal combustion engine vehicles. In order to reduce carbon emission, researchers and industry head up for improving electric vehicle technologies in all over the word. This paper deals with design and simulation of a bi-directional power converter of electric vehicle. The power electronics block is comprised by batteries, bi-directional dc-dc converter and dc machine. The initial state of battery charge is set around 90% where the discharge current is 44.5 A during motor mode. The nominal voltage of battery stack is 350 V and maximum capacity is 100 Ah. The rated power of dc machine is set to 250 HP with 500 V armature voltage and 300 V field voltage. The operating mode of power converter is determined according to the torque values of dc machine which is operated in motor and generator modes. The charge and discharge conditions of batteries have been controlled regarding to operating modes of dc machine. The bi-directional dc-dc converter is controlled with fuzzy logic controller in both modes. The proposed converter and controller are designed to meet charge control and motor drive requirements of an all-electric vehicle.

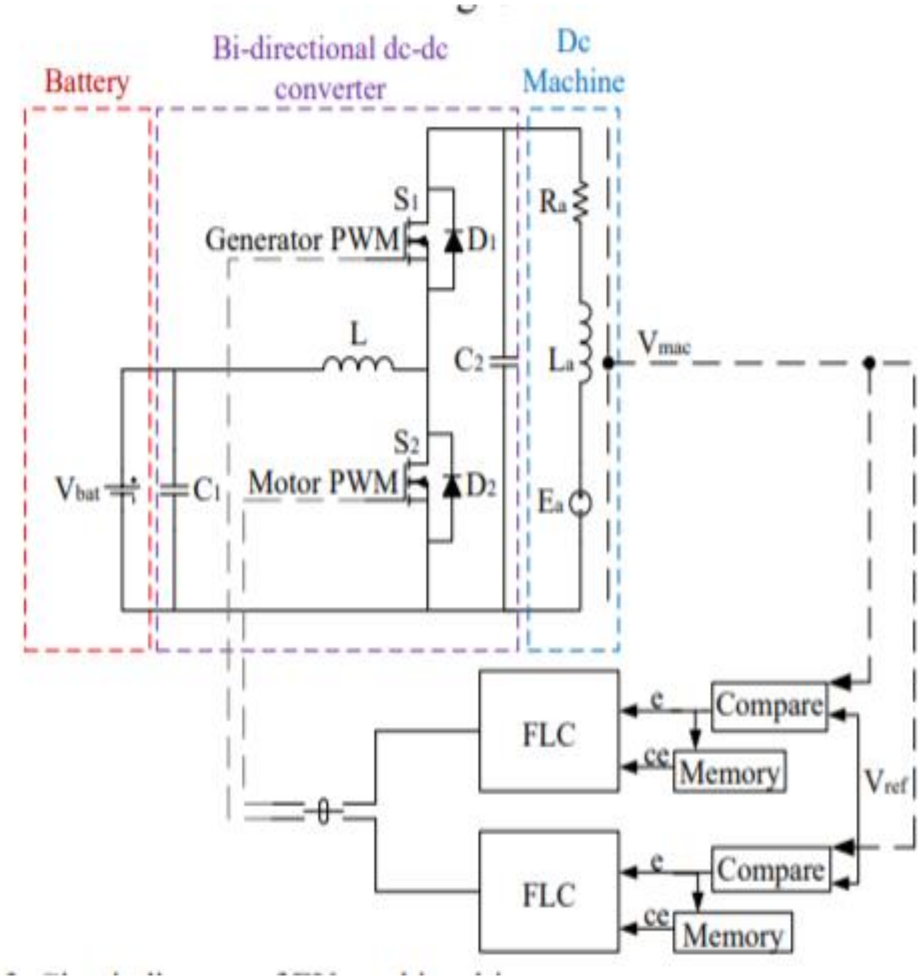
CHAPTER 1

INTRODUCTION

Transportation sector occupies a fundamental place in the world. Fossil fuels used in conventional vehicles technology emit greenhouse gases such as carbon dioxide, carbon monoxide and methane. The excessive consumption of these gases causes air pollution, climate change and global warming. In order to reduce these effects, there is a tendency to electric vehicle (EV) technology. The EV has much lower fuel cost according to fossil fueled car since they are mainly composed of battery system, power electronic circuits and electric machine. The battery system in an EV is the most crucial component in charge control time and determining distance. The electric machines of an EV are operated in both motor and generator modes due to regenerative breaking feature that enables electric machine to be operated in generator mode which is impossible in conventional internal combustion engine (ICE) vehicles. Therefore, electric machine charges the battery by operating in generator mode during the regenerative braking and it ensures recharging the batteries. EV are classified into two types as hybrid EVs (HEVs) and all-electric vehicles. The HEV technology is used in conjunction conventional vehicle technology. The main system in HEV technology includes fuel tank and ICE such as diesel or gasoline engine, and auxiliary system which is comprised by electric machine, power electronic circuits and battery. HEVs are classified as parallel and series hybrid vehicles that the parallel HEV consists ICE and electrical machine together. As the parallel electric vehicles operates at electric mode during the acceleration of electric machine, the motor operation is supplied from battery

1.1 Introduction to designed EV motor driver:

The designed EV motor driver is comprised by four sections such as battery, bi-directional dc-dc converter, FLC and dc machine as shown In this study, the starting voltage of battery is set to 378 V while the operating voltage of dc machine used in traction system is 500 V dc. The battery voltage is increased up to 500 V with bi-directional dc-dc converter in generator mode. The battery is discharged when dc machine is started acceleration. The motor mode simulation with various torque values are performed to observe battery parameters such as state of charge (SoC), current, voltage and voltage of the dc machine. The voltage of the dc machine is decreased to 500 V with bidirectional dc-dc converter which is controlled with FLC. The battery is charged during the generator mode operation of dc machine. The FLC determines duty cycle of S1 and S2 to ensure charge and discharge of battery. The dc machine is comprised by brushes, armature core and windings, commutator, field core and windings. Armature circuit is comprised by series structure with inductor, resistance and counter-electromotive source. Similarly, battery parameters such as SoC, current, voltage and voltage of the dc machine are observed in the generator mode simulation regarding to various torque values applied to dc machine.



1.1 Proposed circuit configuration

The electrical energy is converted to mechanical energy or vice versa by dc machine that operates regarding to electromechanical energy conversion theory. If a conductor is moved within the magnetic field, the voltage is induced on it which is known as generator operating mode. If alternating current passes through the conductor, magnetic field is created around it which explains the motor mode operation. When the dc machine is started acceleration, the resultant positive torque is achieved. On the other hand, negative torque is generated at the dc machine when it is operated in generator mode

1.2 Introduction to FLC:

FLC is comprised by fuzzification, rule base, interface mechanism, defuzzification. Fuzzification is used to convert digital signals received through the system into linguistic variable. Rule base is comprised by the conditions to set for controlling the system at desired location. Interface mechanism makes inferences according to the rules of system by establishing a relationship between inputs. Defuzzification is used to convert linguistic variable received through the system into digital signals

1.3 Introduction to Electric Propulsion Systems:

The European new vehicle CO2 regulation (with a mandatory target value of 95 grams of CO2 per kilometer by 2021 for passenger cars) is currently in the process of being extended to 2025. In this context, one of the key questions is at what point a significant uptake of the electric vehicle market is to be expected. In order to help inform this debate about how electric vehicle technology could fit in a lower-carbon 2020–2030 new vehicle fleet in Europe, this paper focuses on collecting, analyzing, and aggregating the available research literature on the underlying technology costs and carbon emissions. In terms of technologies, it concentrates on the three electric propulsion systems: battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hydrogen fuel cell electric vehicles (HFCEVs).

The collected cost data is used to estimate the technology cost for automotive lithium-ion (Li-ion) batteries and fuel cells. The cost of battery packs for BEVs declined to an estimated €250 per kWh for industry leaders in 2015. Further cost reductions down to as low as €130–€180 per kWh are anticipated in the 2020–25 time frame. The costs of fuel cell systems are also expected to decrease considerably, but cost estimates are highly uncertain. Furthermore, the application of fuel cells and batteries in HFCEVs, BEVs, and PHEVs is approximated using a bottom-up cost approach. Overall, the different power train costs largely depend on battery and fuel cell costs.

It concludes that the costs of all power trains will decrease significantly between 2015 and 2030 (Figure S 1). As shown, power trains for PHEVs will achieve about a 50% cost reduction, compared with approximate cost reductions of 60% for BEVs and

70% for HFCEVs. Costs for hydrogen and electricity chargers are estimated separately. Greenhouse gas (GHG) emissions and energy demand for electric and conventional vehicles are presented on a well-to-wheel (WTW) basis, capturing all direct and indirect emissions of fuel and electricity production and vehicle operation. The results are based on former analyses, and are updated and refined with real-world fuel consumption levels. Real-world fuel consumption is commonly about 20%–40% higher than official type approval measurements.

Finally, WTW estimates for electric and conventional vehicles are put in the context of the 2021 CO2 standard for European passenger vehicles. It is found that carbon emissions of BEVs using European grid-mix electricity are about half of average European vehicle emissions, whereas HFCEVs and PHEVs have a lower emissions reduction potential. In the 2020 context, electric vehicle WTW emissions are expected to continue offering greater carbon benefits due to more efficient power trains and increasing low-carbon electric power. A lower-carbon grid and higher power train efficiency by 2020 could cut average electric vehicle emissions by one-third again. However, the expected cost reductions and potential CO2 emission cuts will not be achieved without targeted policy intervention. More stringent CO2 standards, and fiscal and non-fiscal incentives for electric vehicles, can help the electric vehicle market to grow and costs to fall. Also, efforts need to be combined with activities to decarbonize the grid, or emission reductions will not be as great as they could be. Although the analysis is focused on the European context, similar dynamics with electric vehicle technology, policy, and market development are prevalent across major markets in North America and Asia.

1.4 Introduction to EVs:

The first EVs were introduced as early as 1838—or 52 years before internal combustion engine vehicles (ICEVs) entered the market. Despite recent growing interest, EVs have remained a relatively small market until today (IEA, 2015). However, the global share of EVs is expected to increase significantly, driven by substantial battery technology improvements and a variety of policies that are accelerating the development of the electric vehicle market. Overall, the market has grown from just hundreds of EV sales in 2010 to more than 500,000 sales worldwide in 2015 (EV Sales, 2016). The early development of markets for electric vehicles is seen predominantly in parts of China, Europe, and the United States, where electric vehicle support policies are helping promote the technology, while costs are still relatively high compared with conventional vehicles. Table 1 shows the global and regional estimated stock of BEV and PHEV passenger cars as of 2015, and electric vehicle supply equipment (EVSE) as of 2014. EVSE includes semipublic or public charging points or outlets, but not private charging points. Most of the electric vehicles on the road today are registered in the United States, with about half of those in the state of California. The United States also has the largest number of electric vehicle charging points. The Netherlands is the European country with the highest electric vehicle passenger car and charging-plug stock in terms of absolute sales. The following countries have achieved relatively high market sales shares of passenger electric vehicles, as a percentage of all 2014 passenger vehicle sales: Norway (13.7%), the Netherlands (3.9%), Sweden (1.5%) (Mock, 2015), and the United States (1.5%) (Lutsey, 2015b). Most other major automobile markets have EV sales shares at or below 1%.

1.5 Introduction to BEVs:

Pure battery electric vehicles (BEVs) are also referred to as battery-only electric vehicles (BOEVs). BEVs have no engine and are propelled by electricity that comes from one or several onboard high-energy batteries. Modern models use a regenerative braking system to save energy. Examples include the Renault Zoe and the Nissan Leaf. The Zoe has a 22 kWh Li-ion battery, and an energy consumption of 14.6 kWh per 100 km, which yields a range of about 140 km to 210 km per battery charge on the New European Driving Cycle (NEDC). The 2015 Leaf comes with a 24 kWh battery (plus a 30 KWh option for the 2016 model), and an official consumption of 15 kWh per 100 km. 3.2. PHEVs Plug-in hybrid electric vehicles (PHEVs) allow electric driving on batteries (in charge-depleting mode), but also conventional combustion fueled driving (in charge-sustaining mode).

Usually, they are equipped with an electric motor and a high energy battery, which can be charged from the power grid. Modern PHEVs can be driven in electric mode over varying distances before the combustion engine is required. In electric-driving mode, the energy efficiency of the propulsion system is much higher, and is comparable to that of a BEV. Available models include the Chevrolet Volt in U.S. markets (which is the Opel Ampera in EU markets), and the Toyota Prius Plug-in

Hybrid. The 2015 Opel Ampera uses a 16 kWh Li-ion battery and consumes 16.9 kWh per 100 km in electric mode on the NEDC. The 2015 Chevrolet Volt has a 16.5 kWh battery, and the 2016 model has an 18.4 kWh battery

PHEVs and BEVs use similar batteries, with Li-ion being the most common chemistry. There are two primary ways to extract the lithium used in batteries: mining spodumene and petalite ore using evaporation ponds on salt lakes. The majority of lithium is obtained from brine operation (USGS, 2015). The battery system is the key technology of electric vehicles and defines their range and performance characteristics. The battery works like a transducer by turning chemical energy into electrical energy. Li-ion is expected to be the dominant chemistry for BEVs and PHEVs for the foreseeable future, as most research is done in the field of Li-ion batteries. They provide relatively high power and energy for a given weight or size, and can significantly reduce costs compared with other battery concepts. Energy density of the battery pack is estimated to roughly double, up to about 300 Wh per kg, between 2007 and 2030 (Kromer & Heywood, 2007; Ricardo-AEA, 2015; NAS, 2013). Also, they have a relatively long life cycle and low self discharging losses.

One of their few drawbacks is their sensitivity to overcharging, which is why they require a battery management system. Other automotive battery concepts include nickel-metal hydride (Ni-MH), sodium-nickel chloride (Na/NiCl2), and non-electrochemical alternatives such as supercapacitors, which allow fast charging but provide low energy density. As a result, batteries with higher energy and power densities are being developed, such as lithiumair (Li-air), lithium-metal or lithiumsulphur (Li-S), but these are far from commercialization (Cookson, 2015; Hacker, Harthan, Matthes & Zimmer, 2009). Li-air batteries may reach energy densities of up to 11,680Wh per kg (Imanishi & Yamamoto, 2014), which approximates the energetic content of gasoline.

CHAPTER 2

LITERATURE SURVEY

2.1 Literature survey

R. Goutham Govind Raju et al., formulated a zero voltage switching (ZVS) bidirectional isolated DC- DC converter. This is used in high power application especially for power supply in fuel cell vehicles electric vehicle driving system and power generation where a high power density is required. This technique has the advantages of low cost, light weight and high reliability power converter where the power semiconductor devices (MOSFET, IGBT, etc) and packaging of the individual units and the system integration play a major role in isolated DC/DC converter hybrid/fuel cell vehicles.

Zhe Zhang et al., designed a bidirectional isolated DC-DC converter controlled by phase-shift and duty cycle for the fuel cell hybrid energy system is analysed and designed. The proposed topology minimizes the number of switches and their associated gate driver components by using two high frequency transformers which combine a half-bridge circuit and a full-bridge circuit together on the primary side.

Hyun-Wook Seong et al., describes non-isolated high step-up DC-DC converters using zero voltage switching (ZVS) boost integration technique (BIT) and their light-load frequency modulation (LLFM) control. The proposed ZVS BIT integrates a bidirectional boost converter with a series output module as a parallel-input and series-output (PISO) configuration.

Lisheng Shi et al., presented the basic requirements and specifications for PHEV bidirectional ac dc converter designs. Generally, there are two types of topologies used for PHEVs: an independent topology and a combination topology that utilizes the drive motor's inverter. Evaluations of the two converter topologies are analysed in detail. The combination topology analysis is emphasized because it has more advantages in PHEVs, in respect to savings in cost, volume and weight.

Tanmoy Bhattacharya et al., proposed a multi power-port topology which is capable of handling multiple power sources and still maintains simplicity and features like obtaining high gain, wide load variations, lower output-current ripple, and capability of parallel battery energy due to the modular structure. The scheme incorporates a transformer winding technique which drastically reduces the leakage inductance of the coupled inductor.

CHAPTER 3

BATTERY STORAGE SYSTEM

3.1 Introduction of Battery

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to include devices composed of a single cell.

3.2 Battery characteristics

Primary (single-use or "disposable") batteries are used once and discarded, as the electrode materials are irreversibly changed during discharge; a common example is the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and mobile phones.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smartphones, to large lead acid batteries or lithium-ion batteries in vehicles, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centers.

Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. In automobiles, this is somewhat offset by the higher efficiency of electric motors in converting chemical energy to mechanical work, compared to combustion engines.

3.3 History of Battery

The usage of "battery" to describe a group of electrical devices dates to Benjamin Franklin, who in 1748 described multiple Leyden jars by analogy to a battery of cannon (Benjamin Franklin borrowed the term "battery" from the military, which refers to weapons functioning together).

Italian physicist Alessandro Volta built and described the first electrochemical battery, the voltaic pile, in 1800.This was a stack of copper and zinc plates, separated by brine-soaked paper disks, that could produce a steady current for a considerable length of time. Volta did not understand that the voltage was due to chemical reactions. He thought that his cells were an inexhaustible source of energy, and that the associated corrosion effects at the electrodes were a mere nuisance, rather than an unavoidable consequence of their operation, as Michael Faraday showed in 1834.

Although early batteries were of great value for experimental purposes, in practice their voltages fluctuated and they could not provide a large current for a sustained period. The Daniell cell, invented in 1836 by British chemist John Frederic Daniell, was the first practical source of electricity, becoming an industry standard and seeing widespread adoption as a power source for electrical telegraph networks. It consisted of a copper pot filled with a copper sulfate solution, in which was immersed an unglazed earthenware container filled with sulfuric acid and a zinc electrode. These wet cells used liquid electrolytes, which were prone to leakage and spillage if not handled correctly. Many used glass jars to hold their components, which made them fragile and potentially dangerous. These characteristics made wet cells unsuitable for portable appliances. Near the end of the nineteenth century, the invention of dry cell batteries, which replaced the liquid electrolyte with a paste, made portable electrical devices practical

3.4 Basic Battery Operation

Batteries convert chemical energy directly to electrical energy. In many cases, the electrical energy released is the difference in the cohesive or bond energies of the metals, oxides, or molecules undergoing the electrochemical reaction. For instance, energy can be stored in Zn or Li, which are high-energy metals because they are not stabilized by d-electron bonding, unlike transition metals. Batteries are designed such that the energetically favorable redox reaction can occur only if electrons move through the external part of the circuit.

A battery consists of some number of voltaic cells. Each cell consists of two half-cells connected in series by a conductive electrolyte containing metal cations. One half-cell includes electrolyte and the negative electrode, the electrode to which anions (negatively charged ions) migrate; the other half-cell includes electrolyte and the positive electrode, to which cations (positively charged ions) migrate. Cations are reduced (electrons are added) at the cathode, while metal atoms are oxidized (electrons are removed) at the anode.[14] Some cells use different electrolytes for each half-cell; then a separator is used to prevent mixing of the electrolytes while allowing ions to flow between half-cells to complete the electrical circuit.

3.5 Battery voltage

half-cell has an electromotive force (emf, measured in volts) relative to a standard. The net emf of the cell is the difference between the emfs of its half-cells. Thus, if the electrodes have emfs then the net emf in other words, the net emf is the difference between the reduction potentials of the half-reactions.

The electrical driving force or across the terminals of a cell is known as the terminal voltage (difference) and is measured in volts. The terminal voltage of a cell that is neither charging nor discharging is called the open-circuit voltage and equals the emf of the cell. Because of internal resistance, the terminal voltage of a cell that is discharging is smaller in magnitude than the open-circuit voltage and the terminal voltage of a cell that is charging exceeds the open-circuit voltage. An ideal cell has negligible internal resistance, so it would maintain a constant terminal voltage of until exhausted, then dropping to zero. If such a cell maintained 1.5 volts and produce a charge of one coulomb then on complete discharge it would have performed 1.5 joules of work. In actual cells, the internal resistance increases under discharge and the open-circuit voltage also decreases under discharge. If the voltage and resistance are plotted against time, the resulting graphs typically are a curve; the shape of the curve varies according to the chemistry and internal arrangement employed.

The voltage developed across a cell's terminals depends on the energy release of the chemical reactions of its electrodes and electrolyte. Alkaline and zinc–carbon cells have different chemistries, but approximately the same emf of 1.5 volts; likewise NiCd and NiMH cells have different chemistries, but approximately the same emf of 1.2 volts. The high electrochemical potential changes in the reactions of lithium compounds give lithium cells emfs of 3 volts or more.

3.6 Classification of Batteries

Batteries are classified into primary and secondary forms:

Primary batteries are designed to be used until exhausted of energy then discarded. Their chemical reactions are generally not reversible, so they cannot be recharged. When the supply of reactants in the battery is exhausted, the battery stops producing current and is useless.

Secondary batteries can be recharged; that is, they can have their chemical reactions reversed by applying electric current to the cell. This regenerates the original chemical reactants, so they can be used, recharged, and used again multiple times.

Some types of primary batteries used, for example, for telegraph circuits, were restored to operation by replacing the electrodes. Secondary batteries are not indefinitely rechargeable due to dissipation of the active materials, loss of electrolyte and internal corrosion.

3.6.1 Primary

Main article: Primary cell

Primary batteries, or primary cells, can produce current immediately on assembly. These are most commonly used in portable devices that have low current drain, are used only intermittently, or are used well away from an alternative power source, such as in alarm and communication circuits where other electric power is only intermittently available. Disposable primary cells cannot be reliably recharged, since the chemical reactions are not easily reversible and active materials may not return to their original forms. Battery manufacturers recommend against attempting to recharge primary cells. In general, these have higher energy densities than rechargeable batteries, but disposable batteries do not fare well under high-drain applications with loads under 75 ohms (75 Ω). Common types of disposable batteries include zinc–carbon batteries and alkaline batteries.

3.6.2 Secondary

Main article: Rechargeable battery

Secondary batteries, also known as secondary cells, or rechargeable batteries, must be charged before first use; they are usually assembled with active materials in the discharged state. Rechargeable batteries are (re)charged by applying electric current, which reverses the chemical reactions that occur during discharge/use. Devices to supply the appropriate current are called chargers.

3.7 Types of Batteries

3.7.1 Lead Acid Battery

The oldest form of rechargeable battery is the lead–acid battery, which are widely used in automotive and boating applications. This technology contains liquid electrolyte in an unsealed container, requiring that the battery be kept upright and the area be well ventilated to ensure safe dispersal of the hydrogen gas it produces during overcharging. The lead–acid battery is relatively heavy for the amount of electrical energy it can supply. Its low manufacturing cost and its high surge current levels make it common where its capacity (over approximately 10 Ah) is more important than weight and handling issues. A common application is the modern car battery, which can, in general, deliver a peak current of 450 amperes.

3.7.2 VRLA Battery

The sealed valve regulated lead–acid battery (VRLA battery) is popular in the automotive industry as a replacement for the lead–acid wet cell. The VRLA battery

uses an immobilized sulfuric acid electrolyte, reducing the chance of leakage and extending shelf life. VRLA batteries immobilize the electrolyte. The two types are:
Gel batteries (or "gel cell") use a semi-solid electrolyte. Absorbed Glass Mat (AGM) batteries absorb the electrolyte in a special fiberglass matting.

Other portable rechargeable batteries include several sealed "dry cell" types, that are useful in applications such as mobile phones and laptop computers. Cells of this type (in order of increasing power density and cost) include nickel–cadmium (NiCd), nickel–zinc (NiZn), nickel metal hydride (NiMH), and lithium-ion (Li-ion) cells. Li-ion has by far the highest share of the dry cell rechargeable market. NiMH has replaced NiCd in most applications due to its higher capacity, but NiCd remains in use in power tools, two-way radios, and medical equipment.

In the 2000s, developments include batteries with embedded electronics such as USBCELL, which allows charging an AA battery through a USB connector, nanoball batteries that allow for a discharge rate about 100x greater than current batteries, and smart battery packs with state-of-charge monitors and battery protection circuits that prevent damage on over-discharge. Low self-discharge (LSD) allows secondary cells to be charged prior to shipping.

3.8 Cell Types

Many types of electrochemical cells have been produced, with varying chemical processes and designs, including galvanic cells, electrolytic cells, fuel cells, flow cells and voltaic piles.

3.8.1 Wet Cell

A wet cell battery has a liquid electrolyte. Other names are flooded cell, since the liquid covers all internal parts, or vented cell, since gases produced during operation can escape to the air.

Wet cells were a precursor to dry cells and are commonly used as a learning tool for electrochemistry. They can be built with common laboratory supplies, such as beakers, for demonstrations of how electrochemical cells work. A particular type of wet cell known as a concentration cell is important in understanding corrosion. Wet cells may be primary cells (non-rechargeable) or secondary cells (rechargeable).

Originally, all practical primary batteries such as the Daniell cell were built as open-top glass jar wet cells. Other primary wet cells are the Leclanche cell, Grove cell, Bunsen cell, Chromic acid cell, Clark cell, and Weston cell. The Leclanche cell chemistry was adapted to the first dry cells. Wet cells are still used in automobile batteries and in industry for standby power for switchgear, telecommunication or large uninterruptible power supplies, but in many places batteries with gel cells have been used instead. These applications commonly use lead–acid or nickel–cadmium cells.

3.8.2 Dry Cell

A dry cell uses a paste electrolyte, with only enough moisture to allow current to flow. Unlike a wet cell, a dry cell can operate in any orientation without spilling, as it contains no free liquid, making it suitable for portable equipment. By comparison, the first wet cells were typically fragile glass containers with lead rods hanging from the open top and needed careful handling to avoid spillage. Lead–acid batteries did not achieve the safety and portability of the dry cell until the development of the gel battery.

A common dry cell is the zinc–carbon battery, sometimes called the dry Leclanché cell, with a nominal voltage of 1.5 volts, the same as the alkaline battery (since both use the same zinc–manganese dioxide combination). A standard dry cell comprises a zinc anode, usually in the form of a cylindrical pot, with a carbon cathode in the form of a central rod. The electrolyte is ammonium chloride in the form of a paste next to the zinc anode. The remaining space between the electrolyte and carbon cathode is taken up by a second paste consisting of ammonium chloride and manganese dioxide, the latter acting as a depolariser. In some designs, the ammonium chloride is replaced by zinc chloride.

3.8.3 Molten Salt

Molten salt batteries are primary or secondary batteries that use a molten salt as electrolyte. They operate at high temperatures and must be well insulated to retain heat.

3.8.4 Reserve

A reserve battery can be stored unassembled (un activated and supplying no power) for a long period (perhaps years). When the battery is needed, then it is assembled (e.g., by adding electrolyte); once assembled, the battery is charged and ready to work. For example, a battery for an electronic artillery fuse might be activated by the impact of firing a gun. The acceleration breaks a capsule of electrolyte that activates the battery and powers the fuse's circuits. Reserve batteries are usually designed for a short service life (seconds or minutes) after long storage (years). A water-activated battery for oceanographic instruments or military applications becomes activated on immersion in water.

3.9 Cell Performance

A battery's characteristics may vary over load cycle, over charge cycle, and over lifetime due to many factors including internal chemistry, current drain, and temperature. At low temperatures, a battery cannot deliver as much power. As such, in cold climates, some car owners install battery warmers, which are small electric heating pads that keep the car battery warm.

A battery's capacity is the amount of electric charge it can deliver at the rated voltage. The more electrode material contained in the cell the greater its capacity. A small cell has less capacity than a larger cell with the same chemistry, although they develop the same open-circuit voltage.[30] Capacity is measured in units such as amp-hour (A·h). The rated capacity of a battery is usually expressed as the product of 20 hours multiplied by the current that a new battery can consistently supply for 20 hours at 68 °F (20 °C), while remaining above a specified terminal voltage per cell. For example, a battery rated at 100 A·h can deliver 5 A over a 20-hour period at room temperature. The fraction of the stored charge that a battery can deliver depends on multiple factors, including battery chemistry, the rate at which the charge is delivered (current), the required terminal voltage, the storage period, ambient temperature and other factors.

The higher the discharge rate, the lower the capacity. The relationship between current, discharge time and capacity for a lead acid battery is approximated (over a typical range of current values) by Peukert's law:

where

is the capacity when discharged at a rate of 1 amp.

is the current drawn from battery (A).

is the amount of time (in hours) that a battery can sustain.

is a constant around 1.3.

Batteries that are stored for a long period or that are discharged at a small fraction of the capacity lose capacity due to the presence of generally irreversible side reactions that consume charge carriers without producing current. This phenomenon is known as internal self-discharge. Further, when batteries are recharged, additional side reactions can occur, reducing capacity for subsequent discharges. After enough recharges, in essence all capacity is lost and the battery stops producing power.

Internal energy losses and limitations on the rate that ions pass through the electrolyte cause battery efficiency to vary. Above a minimum threshold, discharging at a low rate delivers more of the battery's capacity than at a higher rate. Installing batteries with varying A·h ratings does not affect device operation (although it may affect the operation interval) rated for a specific voltage unless load limits are exceeded. High-drain loads such as digital cameras can reduce total capacity, as happens with alkaline batteries. For example, a battery rated at 2 A·h for a 10- or 20-hour discharge would not sustain a current of 1 A for a full two hours as its stated capacity implies.

The C-rate is a measure of the rate at which a battery is being charged or discharged. It is defined as the current through the battery divided by the theoretical current draw under which the battery would deliver its nominal rated capacity in one hour.[32] It has the units h^{-1}.

C-rate is used as a rating on batteries to indicate the maximum current that a battery can safely deliver on a circuit. Standards for rechargeable batteries generally rate the capacity over a 4-hour, 8 hour or longer discharge time. Types intended for special purposes, such as in a computer uninterruptible power supply, may be rated by manufacturers for discharge periods much less than one hour. Because of internal resistance loss and the chemical processes inside the cells, a battery rarely delivers nameplate rated capacity in only one hour.

3.9.1 Fast-charging, large and light batteries

As of 2017, the world's largest battery was built in South Australia by Tesla. It can store 129 MWh. A battery in Hebei Province, China which can store 36 MWh of electricity was built in 2013 at a cost of $500 million. Another large battery, composed

of Ni–Cd cells, was in Fairbanks, Alaska. It covered 2,000 square metres (22,000 sq ft)—bigger than a football pitch—and weighed 1,300 tonnes. It was manufactured by ABB to provide backup power in the event of a blackout. The battery can provide 40 MW of power for up to seven minutes. Sodium–sulfur batteries have been used to store wind power. A 4.4 MWh battery system that can deliver 11 MW for 25 minutes stabilizes the output of the Auwahi wind farm in Hawaii.
Lithium–sulfur batteries were used on the longest and highest solar-powered flight.

3.9.2 Lifetime

Battery life (and its synonym battery lifetime) has two meanings for rechargeable batteries but only one for non-chargeables. For rechargeables, it can mean either the length of time a device can run on a fully charged battery or the number of charge/discharge cycles possible before the cells fail to operate satisfactorily. For a non-rechargeable these two lives are equal since the cells last for only one cycle by definition. (The term shelf life is used to describe how long a battery will retain its performance between manufacture and use.) Available capacity of all batteries drops with decreasing temperature. In contrast to most of today's batteries, the Zamboni pile, invented in 1812, offers a very long service life without refurbishment or recharge, although it supplies current only in the nanoamp range. The Oxford Electric Bell has been ringing almost continuously since 1840 on its original pair of batteries, thought to be Zamboni piles.

3.9.3 Self-discharge

Disposable batteries typically lose 8 to 20 percent of their original charge per year when stored at room temperature (20–30 °C). This is known as the "self-discharge" rate, and is due to non-current-producing "side" chemical reactions that occur within the cell even when no load is applied. The rate of side reactions is reduced for batteries stored at lower temperatures, although some can be damaged by freezing.

Old rechargeable batteries self-discharge more rapidly than disposable alkaline batteries, especially nickel-based batteries; a freshly charged nickel cadmium (NiCd) battery loses 10% of its charge in the first 24 hours, and thereafter discharges at a rate of about 10% a month. However, newer low self-discharge nickel metal hydride (NiMH) batteries and modern lithium designs display a lower self-discharge rate (but still higher than for primary batteries).

3.9.4 Corrosion

Internal parts may corrode and fail, or the active materials may be slowly converted to inactive forms.

3.9.5 Physical component changes

The active material on the battery plates changes chemical composition on each charge and discharge cycle; active material may be lost due to physical changes of volume, further limiting the number of times the battery can be recharged. Most nickel-based batteries are partially discharged when purchased, and must be charged before first use. Newer NiMH batteries are ready to be used when purchased, and have only 15% discharge in a year.

Some deterioration occurs on each charge–discharge cycle. Degradation usually occurs because electrolyte migrates away from the electrodes or because active material detaches from the electrodes. Low-capacity NiMH batteries (1,700–2,000 mA·h) can be charged some 1,000 times, whereas high-capacity NiMH batteries (above 2,500 mA·h) last about 500 cycles. NiCd batteries tend to be rated for 1,000 cycles before their internal resistance permanently increases beyond usable values.

3.10 Lithium-ion battery

A lithium-ion battery or Li-ion battery is a type of rechargeable battery. Lithium-ion batteries are commonly used for portable electronics and electric vehicles and are growing in popularity for military and aerospace applications. A prototype Li-ion battery was developed by Akira Yoshino in 1985, based on earlier research by John Goodenough, M. Stanley Whittingham, Rachid Yazami and Koichi Mizushima during the 1970s–1980s, and then a commercial Li-ion battery was developed by a Sony and Asahi Kasei team led by Yoshio Nishi in 1991.

In the batteries, lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. Li-ion batteries use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode. The batteries have a high energy density, no memory effect (other than LFP cells) and low self-discharge. They can however be a safety hazard since they contain flammable electrolytes, and if damaged or incorrectly charged can lead to explosions and fires. Samsung was forced to recall Galaxy Note 7 handsets following lithium-ion fires, and there have been several incidents involving batteries on Boeing 787s.

Chemistry, performance, cost and safety characteristics vary across types of lithium-ion batteries. Handheld electronics mostly use lithium polymer batteries (with a polymer gel as electrolyte), a lithium cobalt oxide ($LiCoO_2$) cathode material, and a graphite anode, which together offer a high energy density. Lithium iron phosphate ($LiFePO_4$), lithium manganese oxide ($LiMn_2O_4$ spinel, or Li_2MnO_3-based lithium rich layered materials (LMR-NMC)), and lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$ or NMC) may offer longer lives and may have better rate capability. Such batteries are widely used for electric tools, medical equipment, and other roles. NMC and its derivatives are widely used in electric vehicles.

Research areas for lithium-ion batteries include extending lifetime, increasing energy density, improving safety, reducing cost, and increasing charging speed,[18] among others. Research has been under way in the area of non-flammable electrolytes as a pathway to increased safety based on the flammability and volatility of the organic solvents used in the typical electrolyte. Strategies include aqueous lithium-ion batteries, ceramic solid electrolytes, polymer electrolytes, ionic liquids, and heavily fluorinated systems.

CHAPTER 4

PROPOSED DC-DC CONVERTER

4.1 Buck–boost converter

Buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, ranging from much larger (in absolute magnitude) than the input voltage, down to almost zero.

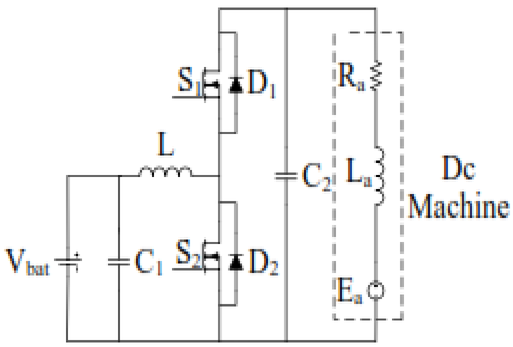


Fig 4.1 Proposed converter

The output voltage is of the opposite polarity than the input. This is a switched-mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. However, this drawback is of no consequence if the power supply is isolated from the load circuit (if, for example, the supply is a battery) because the supply and diode polarity can simply be reversed. When they can be reversed, the switch can be on either the ground side or the supply side.

A buck (step-down) converter combined with a boost (step-up) converter

The output voltage is typically of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor mode and the boost inductor mode, using switches instead of diodes,[2][3] sometimes called a "four-switch buck-boost converter", it may use multiple inductors but only a single switch as in the SEPIC and Ćuk topologies.

Buck Boost converter-principle of operation-applications

4.1.1 Introduction to Buck Boost converter

A Buck converter is a switch mode DC to DC converter in which the output voltage can be transformed to a level less than or greater than the input voltage. The magnitude of output voltage depends on the duty cycle of the switch.It is also called as step up/step down converter. The name step up/step down converter comes from the fact that analogous to step up/step down transformer the input voltage can be stepped up/down to a level greater than/less than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

$$\text{Input power } (P_{in}) = \text{output power } (P_{out})$$

In step up mode $V_{in} < V_{out}$ in a Buck Boost converter, it follows then that the output current will be less than the input current. Therefore for a Buck Boost converter in step up mode

$$V_{in} < V_{out} \text{ and } I_{in} > I_{out}$$

In step down mode $V_{in} > V_{out}$ in a Buck Boost converter, it follows then that the output current will be greater than the input current. Therefore for a Buck Boost converter in step down mode

$$V_{in} > V_{out} \text{ and } I_{in} < I_{out}$$

4.1.2 Principle of operation of Buck converter

The main working principle of Buck Boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is ON the inductor stores energy from the input in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures that in steady state a constant output voltage.

4.1.3 Modes of operation of Buck Boost converter

This type of converter nowadays is mainly used in electric vehicles. It is also called a Half-Bridge DC-DC converter. When the Buck and the boost converters are connected in antiparallel across each other with the resulting circuit is primarily having the same structure as the basic Boost and Buck structure but with the combined feature of bidirectional power flow is called Bi directional dc-dc converter. It works in both directions.

The above circuit can work in buck or boost mode depending on the switching of the Mosfets Q1 and Q2. The switches Q1 or Q2 in sequence with the anti-parallel diodes D1 or D2 (acting as a freewheeling diode) respectively, which makes the circuit step up or step down the voltage connected across them. The bidirectional operation of the above circuit can be described in the below two modes as follows:

Mode 1 (Boost Mode):

In this mode switch Q2 and diode D1 begin into conduction depending on the duty cycle whereas the switch Q1 and diode D2 are off all the time. This mode can moreover be divided into two intervals depending on the conduction on the switch Q1 and diode D2.

Interval 1 (Q2-on, D2-off; Q1-off, D2-Off):

In this mode Q2 is on and hence can be examined to be short-circuited, hence the lower voltage battery charges the inductor and the inductor current goes on rising till not the gate pulse is separated from the Q2. Also since the diode D1 is reversed biased in this mode and the switch Q1 is off, no current flows into the switch Q1.

Interval 2 (Q1-off, D1-off; Q2-off, D2-on):

In this mode, Q2 and Q1 both are off and therefore can be considered to be opened circuited. Now since the current flowing into the inductor cannot change immediately, the polarity of the voltage across it reverses and hence it starts acting in series with the input voltage. Therefore the diode D1 is forward biased and so the inductor current charges the output capacitor C2 to a greater voltage. Therefore the output voltage boosts up.

Mode 2 (Buck Mode):

In this mode switch Q1 and diode D2 begin into conduction depending on the duty cycle whereas the switch Q2 and diode D1 are off all the time. This mode can moreover be divided into two intervals depending on the conduction on the switch Q2 and diode D1.

Interval 1 (Q2-on, D2-off; Q1-off, D2-Off):

In this mode, Q1 is on and Q2 is off. The greater voltage battery will charge the inductor and the o/p capacitor will get charged by battery.

Interval 2 (Q1-off, D1-off; Q2-off, D2-on): In this mode, Q2 and Q1 both are off. Again as the inductor current cannot change instantaneously, it gets discharged via the freewheeling diode D2. The voltage across the load is stepped down as correlated to the input voltage.

A comparison between the features of the non-isolated bidirectional topologies have been explained below:

The Buck Boost converter can be operated in two modes

a) Continuous conduction mode in which the current through inductor never goes to zero. i.e inductor partially discharges before the start of the switching cycle.

b) Discontinuous conduction mode in which the current through inductor goes to zero i.e. inductor is completely discharged at the end of switching cycle.

4.2 Circuit analysis of Buck converter

Assume in the entire analysis that the current swing (maximum to minimum value) through inductor and voltage swing through capacitor is very less so that they vary in a linear fashion. This is to ease the analysis and the results we will get through this analysis are quite accurate compared to real values.

4.2.1 Continuous conduction mode

case-1: When switch S is ON

When switch in ON for a time t_{on}, the diode will be open circuited since it does not allow currents in reverse direction from input to output. Hence the Buck Boost converter can be redrawn as follows

During this state the inductor charges and the inductor current increases. The current through the inductor is given as

$$I_L = (1/L) * \int V * dt$$

Assume that prior to the opening of switch the inductor current is $I'_{L, off}$. Since the input voltage is constant

$$I_{L,on} = (1/L) * \int V_{in} * dt + I'_{L,on}$$

Assume the switch is open for ton seconds which is given by $D*T_s$ where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch on state is given as

$I_{L, on} = (1/L) *V_{in}*D*T_s + I'_{L, on}$ (equation 1)

Hence $\Delta I_{L,on} = (1/L)*V_{in}*D*T_s$.

case 2: When switch is off

When switch in OFF the diode will be forward biased as it allows current from output to input (p to n terminal) and the Buck Boost converter circuit can be redrawn as follows

The inductor now discharges through the diode and RC combination. Assume that prior to the closing of switch the inductor current is $I''_{L, off}$. The current through the inductor is given as

$$I'''_{L,off} = -(1/L) * \int V_{out} * dt + I''_{L,off}$$

Note the negative sign at the front end of equation signifies that the inductor is discharging. Assume the switch is open for t_{off} seconds which is given by (1-

D)*T_s where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch off state is given as

$$I'''_{L,\,off} = -(1/L) * V_{out}*(1-D)*T_s + I''_{L,\,off} \text{ (equation 2)}$$

In steady state condition as the current through the inductor does not change abruptly, the current at the end of switch on state and the current at the end of switch off state should be equal. Also the currents at the start of switch off state should be equal to current at the end of switch on state. Hence

$$I'''_{L,\,off} = I_{L,\,on} \text{ also } I'_{L,\,off} = I''_{L,\,off}$$

Using the equations 1 and 2 we get

$(1/L) * V_{in}*D*T_s = (1/L) * V_{out}*(1-D)*T_s$

$V_{in}*D = V_{out}*(1-D)$

$V_{out}/V_{in} = D/(1-D)$

Since D < 1, V_{out} can be greater than or less than V_{in}.For D>0.5 the Buck boost converter acts as boost converter with $V_{out} > V_{in}$.

For D<0.5 the Buck boost converter a as buck converter with $V_{out} > V_{in}$.

Assuming no losses in the circuit and applying the law of conservation of energy

$$V_{out}*I_{out} = V_{in}*I_{in}$$

This implies $I_{out}/I_{in} = (1-D)/D$, Thus $I_{out} > I_{in}$ for D<0.5 and $I_{out} < I_{in}$ for D<0.5 . As the duty cycle increases the output voltage increases and output current decreases.

4.2.2 Discontinuous conduction mode

As mentioned before the converter when operated in discontinuous mode the inductor drains its stored energy completely before completion of switching cycle. The current and voltage wave forms of Buck Boost converter in discontinuous mode is shown in the figure below

The inductor in discontinuous mode drains all the current which it piled up in charging interval of same switching cycle. The current through the inductor is given as

$I_L = (1/L)\int V_L * dt$ = (1/L)*area under the curve of voltage v/s time. Hence from the wave forms shown in the figure

$V_{out}*\delta*T_s = V_{in}*D*T_s$

$$V_{out}/V_{in} = D/\delta$$

and the ratio of output to input current from law of conservation of energy is $I_{out}/I_{in} = \delta/D$.

4.3 Applications of Buck boost converter

- It is used in the self regulating power supplies.
- It has consumer electronics.
- It is used in the Battery power systems.
- Adaptive control applications.
- Power amplifier applications.

CHAPTER-5

PULSE WIDTH MODULATION

5.1 WHY PULSE WIDTH MODULATION

1. Cheap to make.

2. Little heat whilst working.

3. Low power consumption.

4. Can utilize very high frequencies (40-100 Khz is not uncommon.)

5. Very energy-efficient when used to convert voltages or to dim light bulbs.

6. High power handling capability

7. Efficiency up to 90%

5.2 Modulation technique

A modulation technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photovoltaic solar battery chargers, the other being MPPT.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

5.3 PWM technique

The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. Typically switching has to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

5.3.1 Advantage of PWM

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

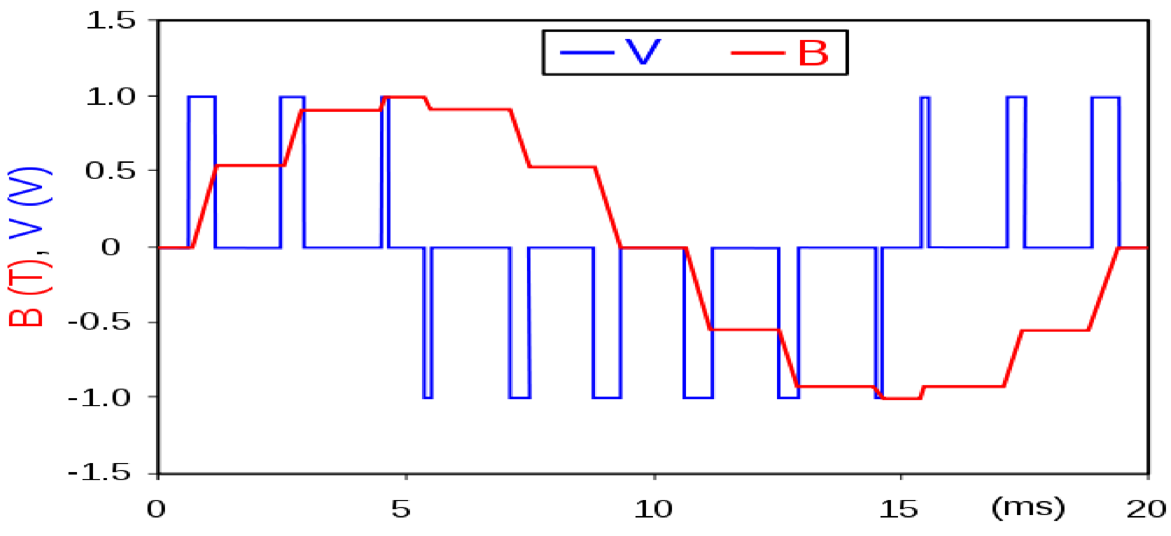


Fig 5.1 wave for combined positive and negative pulse

An example of PWM in an idealized inductor driven by a voltage source: the voltage source (blue) is modulated as a series of pulses that results in a sine-like current/flux (red) in the inductor. The blue rectangular pulses nonetheless result in a smoother and smoother red sine wave as the switching frequency increases. Note that the red waveform is the (definite) integral of the blue waveform.

5.3.2 Principle of PWM

Pulse-width modulation uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform. If we consider a pulse waveform $f(t)$, with period T, low value y_{min}, a high value y_{max} and a duty cycle D (see figure 1), the average value of the waveform is given by:

$$\bar{y} = \frac{1}{T}\int_0^T f(t)\,dt.$$

As $f(t)$ is a pulse wave, its value is y_{max} for $0 < t < D \cdot T$ and y_{min} for $D \cdot T < t < T$. The above expression then becomes:

$$\begin{aligned}\bar{y} &= \frac{1}{T}\left(\int_0^{DT} y_{max}\,dt + \int_{DT}^{T} y_{min}\,dt\right)\\ &= \frac{D \cdot T \cdot y_{max} + T\,(1-D)\,y_{min}}{T}\\ &= D \cdot y_{max} + (1-D)\,y_{min}.\end{aligned}$$

This latter expression can be fairly simplified in many cases where $y_{min} = 0$ as $\bar{y} = D \cdot y_{max}$. From this, it is obvious that the average value of the signal ($\bar{y}$) is directly dependent on the duty cycle D.

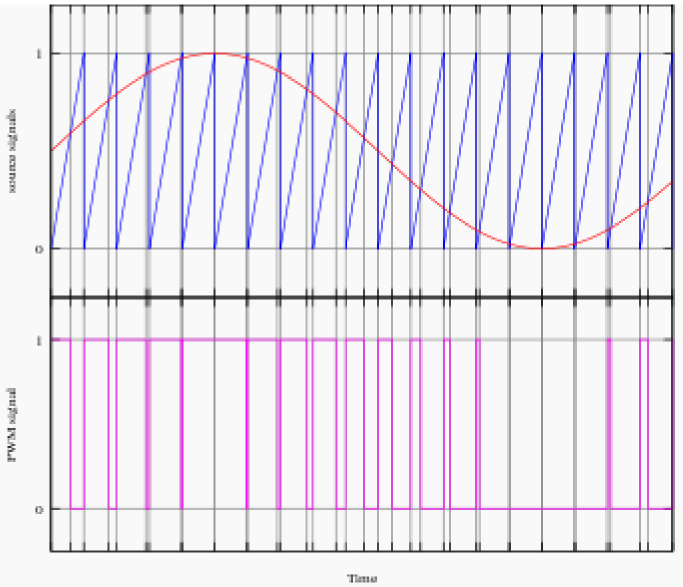


Fig. 5.2: A simple method to generate the PWM pulse train corresponding to a given signal is the intersective PWM

the signal (here the red sinewave) is compared with a sawtooth waveform (blue). When the latter is less than the former, the PWM signal (magenta) is in high state (1). Otherwise it is in the low state (0).

The simplest way to generate a PWM signal is the intersective method, which requires only a sawtooth or a triangle waveform (easily generated using a simple oscillator) and a comparator. When the value of the reference signal (the red sine wave in figure 2) is more than the modulation waveform (blue), the PWM signal (magenta) is in the high state, otherwise it is in the low state.

5.3.3 Applications of PWM Technique

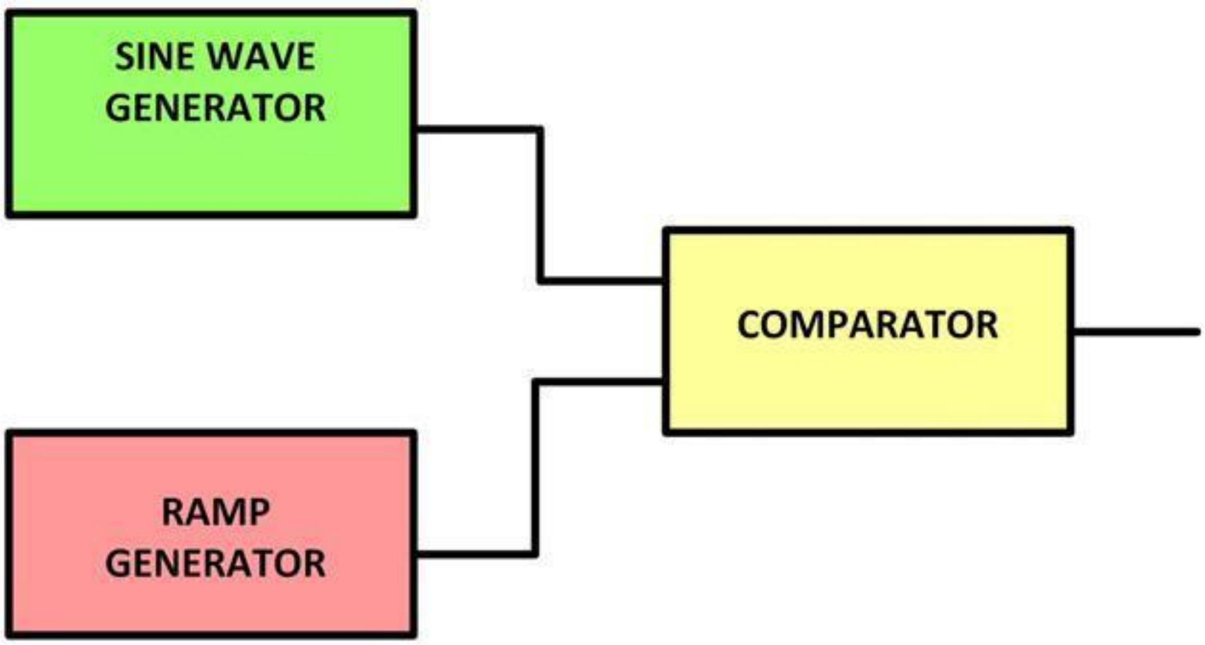
The **PWM** is a technique which is used to drive the inertial loads since a very long time.The simple example of an inertial load is a motor. Apply the power to a motor for a very short period of time and then turn off the power: it can be observed that the motor is still running even after the power has been cut off from it. This is due to the inertia of the motor and the significance of this factor is that the continuous power is not required for that kind of devices to operate. A burst power can save the total power supplied to the load while achieving the same performance from the device as it runs on continuous power.

The **PWM technique** is use in devices like DC motors, Loudspeakers, Class -D Amplifiers, SMPS etc. They are also used in communication field as-well. The modulation techniques like AM, FM are widely used RF communication whereas the PWM is modulation technique is mostly used in Optical Fiber Communication (OFC).

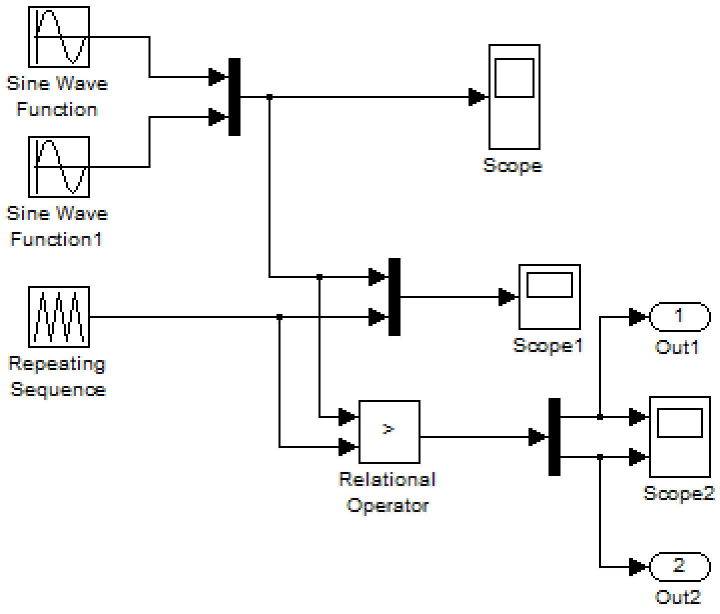
As in the case of the inertial loads mentioned previously, the PWM in a communication link greatly saves the transmitter power. The immunity of the PWM transmission against the inter-symbol interference is another advantage. This article discusses the technique of generating a PWM wave corresponding to a modulating sine wave.

5.3.4 Description of PWM :

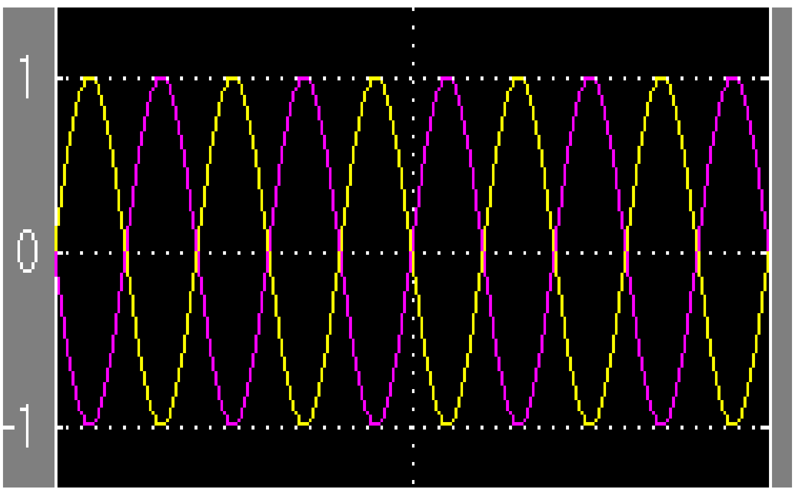
The **Pulse Width Modulation** is a technique in which the ON time or OFF time of a pulse is varied according to the amplitude of the modulating signal, keeping t



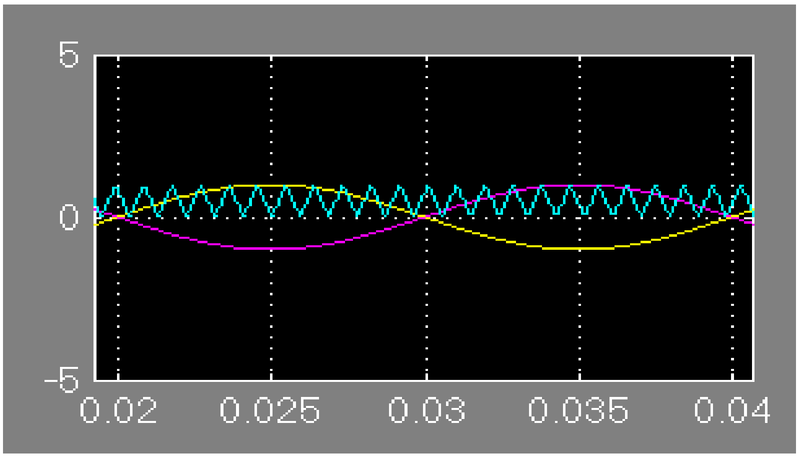
5.3 SPWM block diagram



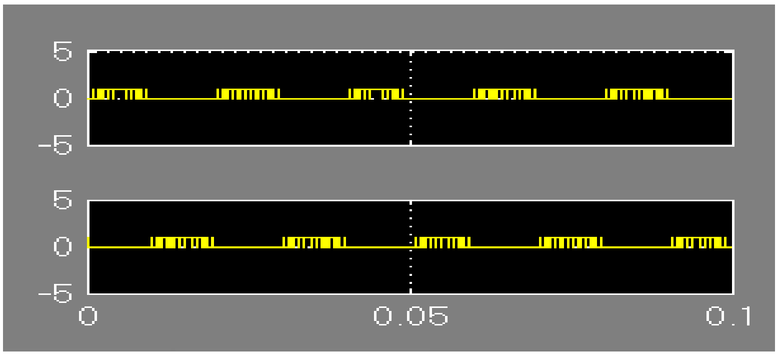
5.4 SPWM SIMULATION DIAGRAM



5.5 SCOPE view



5.6 SCOPE 1 view



5.7 SCOPE 2 view

the (ON time + OFF time) time of the pulse as constant. The (ON time + OFF time) of a pulse is called 'Period' of the pulse, and the ratio of the ON time or OFF time with the Period is called the 'Duty Cycle'. Hence the PWM is a kind of modulation which keeps the Period of pulses constant but varying their duty cycle according to the amplitude of the modulating signal.

The conventional method of generating a PWM modulated wave is to compare the message signal with a ramp waveform using a comparator. The block diagram required for the generation of a simple PWM is shown

CHAPTER 6

PROPOSED BRUSHLESS DC MOTORS

6.1 BRUSHLESS DC MOTOR:

Brushless DC motors (BLDC) have been a much focused area for numerous motor manufacturers as these motors are increasingly the preferred choice in many applications, especially in the field of motor control technology. BLDC motors are superior to brushed DC motors in many ways, such as ability to operate at high speeds, high efficiency, and better heat dissipation. They are an indispensable part of modern drive technology, most commonly employed for actuating drives, machine tools, electric propulsion, robotics, computer peripherals and also for electrical power generation. With the development of sensorless technology besides digital control, these motors become so effective in terms of total system cost, size and reliability.

A brushless DC motor (known as BLDC) is a permanent magnet synchronous electric motor which is driven by direct current (DC) electricity and it accomplishes electronically controlled commutation system (commutation is the process of producing rotational torque in the motor by changing phase currents through it at appropriate times) instead of a mechanically commutation system. BLDC motors are also referred as trapezoidal permanent magnet motors.

Unlike conventional brushed type DC motor, wherein the brushes make the mechanical contact with commutator on the rotor so as to form an electric path between a DC electric source and rotor armature windings, BLDC motor employs electrical commutation with permanent magnet rotor and a stator with a sequence of coils. In this motor, permanent magnet (or field poles) rotates and current carrying conductors are fixed.

Fig 6.1 Brushless DC motor

The armature coils are switched electronically by transistors or silicon controlled rectifiers at the correct rotor position in such a way that armature field is in space quadrature with the rotor field poles. Hence the force acting on the rotor causes it to rotate. Hall sensors or rotary encoders are most commonly used to sense the position of the rotor and are positioned around the stator. The rotor position feedback from the sensor helps to determine when to switch the armature current.

This electronic commutation arrangement eliminates the commutator arrangement and brushes in a DC motor and hence more reliable and less noisy operation is achieved. Due to the absence of brushes BLDC motors are capable to run at high speeds. The efficiency of BLDC motors is typically 85 to 90 percent, whereas as brushed type DC motors are 75 to 80 percent efficient. There are wide varieties of BLDC motors available ranging from small power range to fractional horsepower, integral horsepower and large power ranges.

6.1.1 Construction of BLDC Motor

BLDC motors can be constructed in different physical configurations. Depending on the stator windings, these can be configured as single-phase, two-phase, or three-phase motors. However, three-phase BLDC motors with permanent magnet rotor are most commonly used.

The construction of this motor has many similarities of three phase induction motor as well as conventional DC motor. This motor has stator and rotor parts as like all other motors.

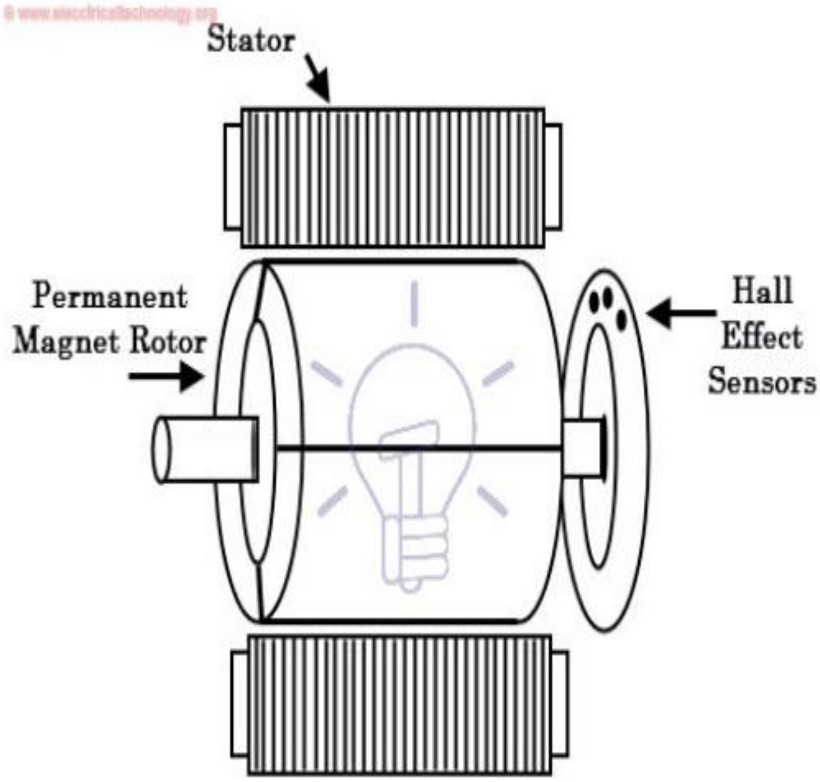


Fig 6.2 BLDC motor

Stator of a BLDC motor made up of stacked steel laminations to carry the windings. These windings are placed in slots which are axially cut along the inner periphery of the stator. These windings can be arranged in either star or delta. However, most BLDC motors have three phase star connected stator. Each winding is constructed with numerous interconnected coils, where one or more coils are placed in each slot. In order to form an even number of poles, each of these windings is distributed over the stator periphery. The stator must be chosen with the correct rating of the voltage depending on the power supply capability. For robotics, automotive and small actuating applications, 48 V or less voltage BLDC motors are preferred. For industrial applications and automation systems, 100 V or higher rating motors are used.

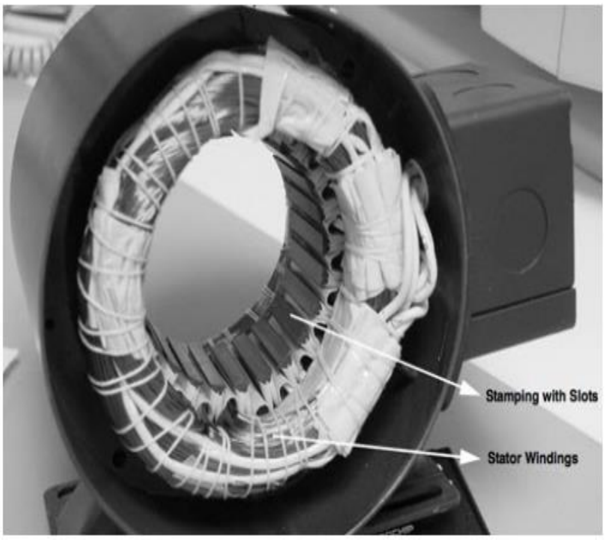


Fig 6.3 stator diagram

6.2 Rotor Description

BLDC motor incorporates a permanent magnet in the rotor. The number of poles in the rotor can vary from 2 to 8 pole pairs with alternate south and north poles depending on the application requirement. In order to achieve maximum torque in the motor, the flux density of the material should be high. A proper magnetic material for the rotor is needed to produce required magnetic field density.

Fig 6.4 Rotor diagram

Ferrite magnets are inexpensive, however they have a low flux density for a given volume. Rare earth alloy magnets are commonly used for new designs. Some of these alloys are Samarium Cobalt (SmCo), Neodymium (Nd), and Ferrite and Boron (NdFeB). The rotor can be constructed with different core configurations such as the circular core with permanent magnet on the periphery, circular core with rectangular magnets, etc.

6.3 Hall Sensors

Hall sensor provides the information to synchronize stator armature excitation with rotor position. Since the commutation of BLDC motor is controlled electronically, the stator windings should be energized in sequence in order to rotate the motor. Before energizing a particular stator winding, acknowledgment of rotor position is necessary. So the Hall Effect sensor embedded in stator senses the rotor position. Most BLDC motors incorporate three Hall sensors which are embedded into the stator. Each sensor generates Low and High signals whenever the rotor poles pass near to it. The exact commutation sequence to the stator winding can be determined based on the combination of these three sensor’s response.

6.4 Working Principle and Operation of BLDC Motor

BLDC motor works on the principle similar to that of a conventional DC motor, i.e., the Lorentz force law which states that whenever a current carrying conductor placed in a magnetic field it experiences a force. As a consequence of reaction force, the magnet will experience an equal and opposite force. In case BLDC motor, the current carrying conductor is stationary while the permanent magnet moves. When the stator coils are electrically switched by a supply source, it becomes electromagnet and starts producing the uniform field in the air gap. Though the source of supply is DC, switching makes to generate an AC voltage waveform with trapezoidal shape. Due to the force of interaction between electromagnet stator and permanent magnet rotor, the rotor continues to rotate. Consider the figure below in which motor stator is excited based on different switching states. With the switching of windings as High and Low signals, corresponding winding energized as North and South poles. The permanent magnet rotor with North and South poles align with stator poles causing motor to rotate. Observe that motor produces torque because of the development of attraction forces (when North-South or South-North alignment) and repulsion forces (when North-North or South-South alignment). By this way motor moves in a clockwise direction.

Here, one might get a question that how we know which stator coil should be energized and when to do. This is because; the motor continuous rotation depends on the switching sequence around the coils. As discussed above that Hall sensors give shaft position feedback to the electronic controller unit. Based on this signal from sensor, the controller decides particular coils to energize. Hall-effect sensors generate Low and High level signals whenever rotor poles pass near to it. These signals determine the position of the shaft.

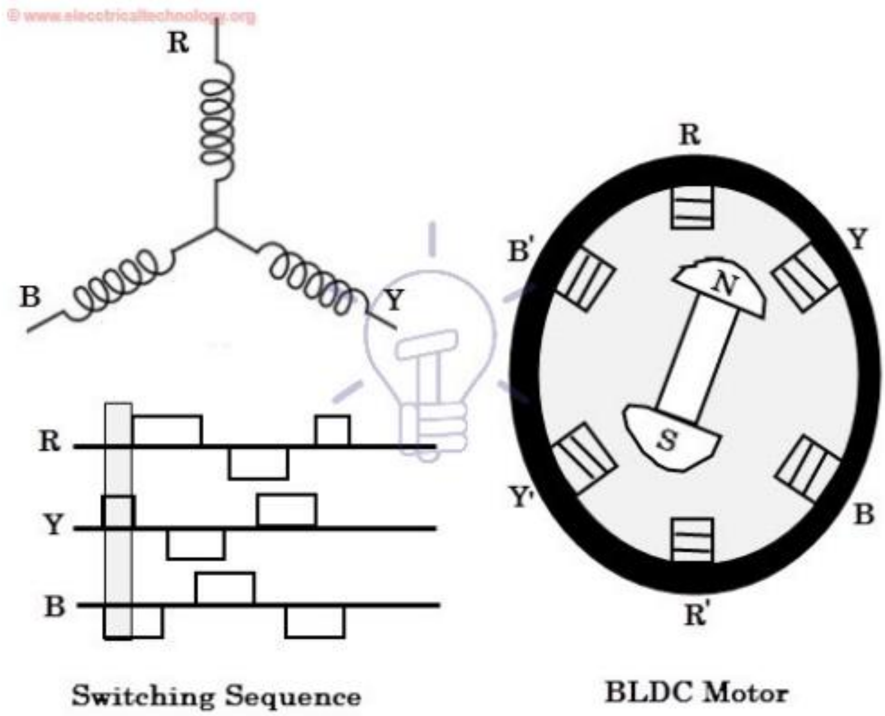


Fig 6.5 Switching sequence and BLDC Motor

6.5 Brushless DC Motor Drive

As described above that the electronic controller circuit energizes appropriate motor winding by turning transistor or other solid state switches to rotate the motor continuously. The figure below shows the simple BLDC motor drive circuit which consists of MOSFET bridge (also called as inverter bridge), electronic controller, hall effect sensor and BLDC motor.
Here, Hall-effect sensors are used for position and speed feedback. The electronic controller can be a microcontroller unit or microprocessor or DSP processor or FPGA unit or any other controller. This controller receives these signals, processes them and sends the control signals to the MOSFET driver circuit.

6.6 Mosfet Bridge:

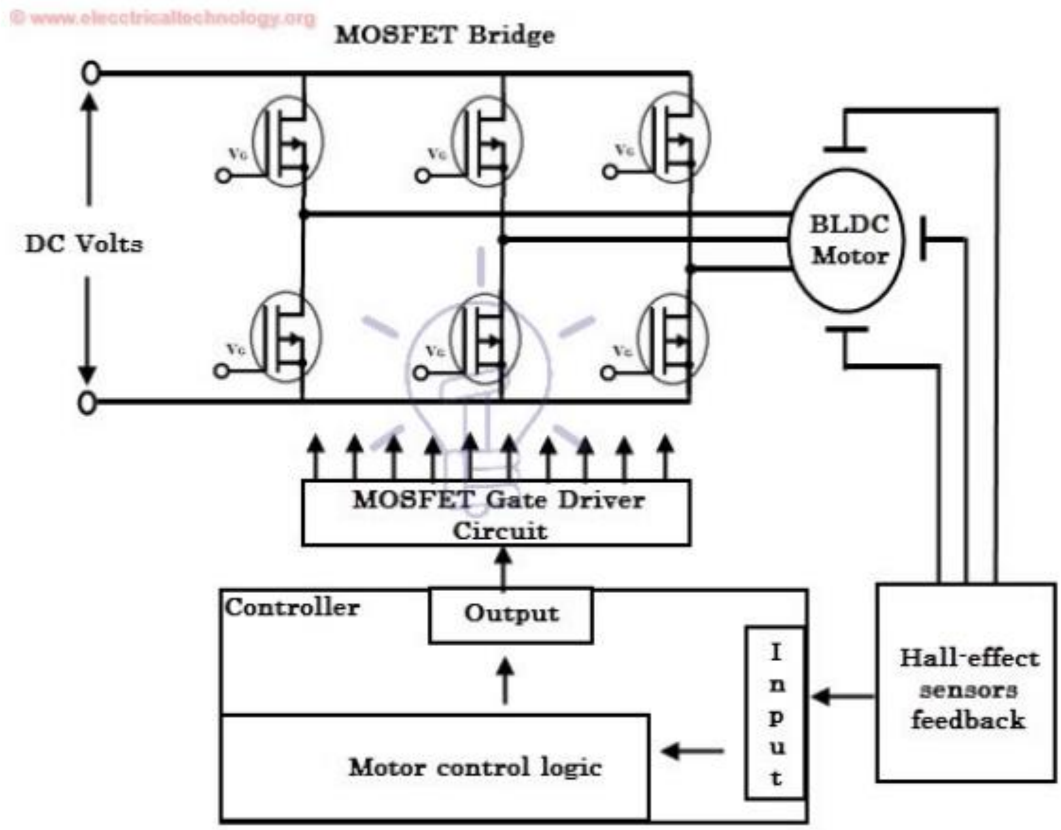


Fig 6.6 Mosfet Bridge

In addition to the switching for a rated speed of the motor, additional electronic circuitry changes the motor speed based on required application. These speed control units are generally implemented with PID controllers to have precise control. It is also possible to produce four-quadrant operation from the motor whilst maintaining good efficiency throughout the speed variations using modern drives.

6.7Advantages of BLDC Motor

BLDC motor has several advantages over conventional DC motors and some of these are

- It has no mechanical commutator and associated problems
- High efficiency due to the use of permanent magnet rotor.
- High speed of operation even in loaded and unloaded conditions due to the absence of brushes that limits the speed
- Smaller motor geometry and lighter in weight than both brushed type DC and induction AC motors
- Long life as no inspection and maintenance is required for commutator system
- Higher dynamic response due to low inertia and carrying windings in the stator
- Less electromagnetic interference
- Quite operation (or low noise) due to absence of brushes

6.8 Disadvantages of Brushless Motor

- These motors are costly
- Electronic controller required control this motor is expensive
- Not much availability of many integrated electronic control solutions, especially for tiny BLDC motors
- Requires complex drive circuitry
- Need of additional sensors

6.9 Applications of Brushless DC Motors (BLDC)

Brushless DC Motors (BLDC) are used for a wide variety of application requirements such as varying loads, constant loads and positioning applications in the fields of industrial control, automotive, aviation, automation systems, health care equipments, etc. Some specific applications of BLDC motors are

- Computer hard drives and DVD/CD players
- Electric vehicles, hybrid vehicles, and electric bicycles
- Industrial robots, CNC machine tools, and simple belt driven systems
- Washing machines, compressors and dryers
- Fans, pumps and blowers

CHAPTER 7

PROPOSED CONTROLLER

7.1 Introduction about Fuzzy Logic Technique

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection.

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalve logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with un-sharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of fl. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalve logical systems.

The basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if-then rule or, simply, fuzzy rule. Although rule-based systems have a long history of use in Artificial Intelligence (AI), what is missing in such systems is a mechanism for dealing with fuzzy consequents and fuzzy antecedents. In fuzzy logic, this mechanism is provided by the calculus of fuzzy rules. The calculus of fuzzy rules serves as a basis for what might be called the Fuzzy Dependency and Command Language (FDCL). Although FDCL is not used explicitly in the toolbox, it is effectively one of its principal constituents. In most of the applications of fuzzy logic, a fuzzy logic solution is, in reality, a translation of a human solution into FDCL.

A trend that is growing in visibility relates to the use of fuzzy logic in combination with neuro computing and genetic algorithms. More generally, fuzzy logic, neuro-computing, and genetic algorithms may be viewed as the principal constituents of what might be called soft computing. Unlike the traditional, hard computing, soft computing accommodates the imprecision of the real world.

The guiding principle of soft computing is: Exploit the tolerance for imprecision, uncertainty, and partial truth to achieve tractability, robustness, and low solution cost. In the future, soft computing could play an increasingly important role in the conception and design of systems who's MIQ (Machine IQ) is much higher than that of systems designed by conventional methods.

Among various combinations of methodologies in soft computing, the one that has highest visibility at this juncture is that of fuzzy logic and neuro computing, leading to neuro-fuzzy systems. Within fuzzy logic, such systems play a particularly important role in the induction of rules from observations.

Fuzzy logic is a fascinating area of research because it does a good job of trading off between significance and precision. something that humans have been managing for a very long time. In this sense, fuzzy logic is both old and new because, although the modern and methodical science of fuzzy logic is still young, the concept of fuzzy logic relies on age-old skills of human reasoning.

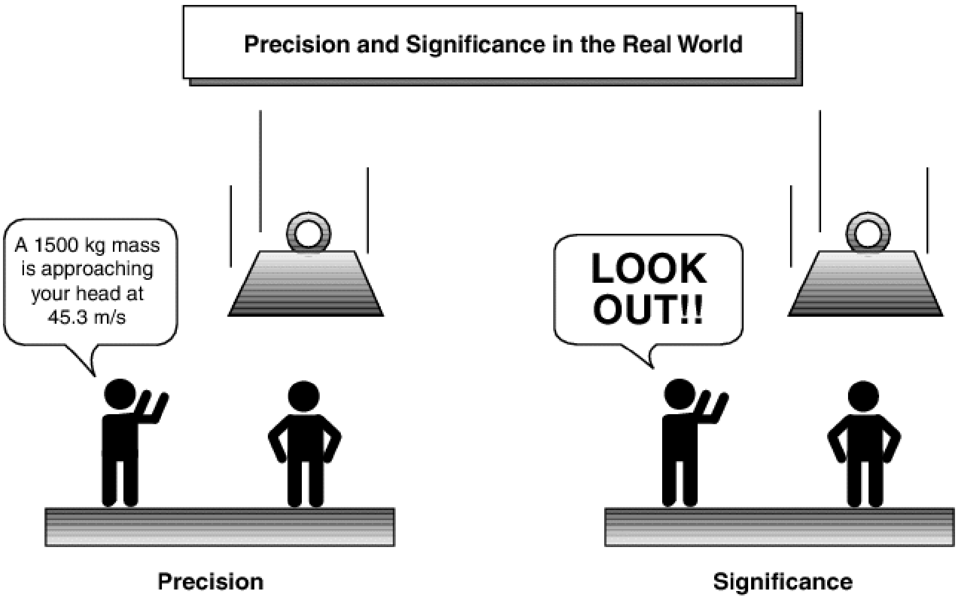


Fig. 7.1 Fuzzy Description

7.2. Uses of fuzzy logic

Fuzzy logic is a convenient way to map an input space to an output space. Mapping input to output is the starting point for everything. Consider the following examples:

- With information about how good your service was at a restaurant, a fuzzy logic system can tell you what the tip should be.

- With your specification of how hot you want the water, a fuzzy logic system can adjust the faucet valve to the right setting.
- With information about how far away the subject of your photograph is, a fuzzy logic system can focus the lens for you.
- With information about how fast the car is going and how hard the motor is working, a fuzzy logic system can shift gears for you.

To determine the appropriate amount of tip requires mapping inputs to the appropriate outputs. Between the input and the output, the preceding figure shows a black box that can contain any number of things: fuzzy systems, linear systems, expert systems, neural networks, differential equations, interpolated multidimensional lookup tables, or even a spiritual advisor, just to name a few of the possible options. Clearly the list could go on and on. Fuzzy is faster and cheaper.

7.3. Fuzzy Logic Controller

7.3.1. Simple Fuzzy Logic Controllers

First-generation simple fuzzy logic controllers can generally be depicted by a block diagram.

The knowledge-base module contains knowledge about all the input and output fuzzy partitions. It will include the term set and the corresponding membership functions defining the input variables to the fuzzy rule-base system and the output variables, or control actions, to the plant under control.

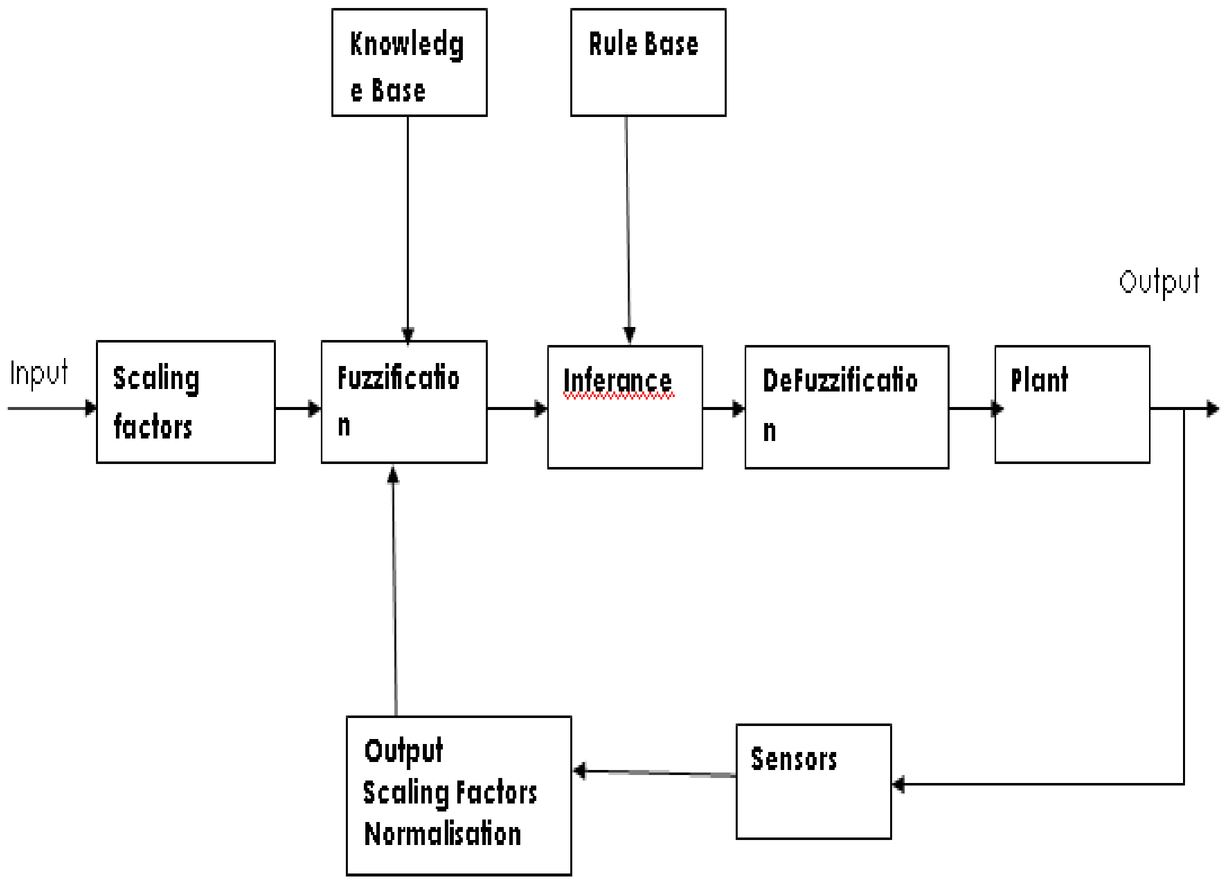


Fig. 7.2 A Simple Fuzzy Logic Control System

- The steps in designing a simple fuzzy logic control system are as follows:
- Identify the variables (inputs, states and outputs) of the plant. Partition the universe of discourse or the interval spanned by each variable into a number of fuzzy subsets, assigning each a linguistic label (subsets include all the elements in the universe).
- Assign or determine a membership function for each fuzzy subset.
- Assign the fuzzy relationships between the inputs or states fuzzy subsets on the one hand and the outputs fuzzy subsets on the other hand, thus forming the rule-base.
- Choose appropriate scaling factors for the input and output variables in order to normalize the variables to the [0, 1] or the [-1, 1] interval.
- Fuzzily the inputs to the controller.
- Use fuzzy approximate reasoning to infer the output contributed from each rule.

- Aggregate the fuzzy outputs recommended by each rule.
- Apply defuzzification to form a crisp output.

In a nonadaptive simple fuzzy logic controller, the methodology used and the results of the nine steps mentioned above are fixed, whereas in an adaptive fuzzy logic controller, they are adaptively modified based on some adaptation law in order to optimize the control.

A simple fuzzy logic control system has the following features:

- Fixed and uniform input- and output- scaling factors.
- Flat, single-partition rule-base with fixed and noninetractive rules. All the rules have the same degree of certainty and confidence, equal to unity.
- Fixed membership functions.
- Limited number of rules, which increase exponentially with the number of input variables.
- Fixed metaknowledge including the methodology for approximate reasoning, rules-aggregation, and output defuzzification.
- Low-level control and no hierarchical rule structure.

7.3.2. General Fuzzy Logic Controllers

The principal design elements in a general fuzzy logic control system are as follows:

1. Fuzzification strategies and the interpretation of a fuzzification operator, or fuzzifier.

2. Knowledge base:

   a. Discrimination/normalization of the universe of discourse.

   b. Fuzzy partitions of the input and output spaces.

   c. Completeness of the partitions.

d. Choice of the membership functions of a primary fuzzy set.

3. Rule-base:

a. Choice of process state (input) variables and control (output) variables.

b. Source of derivation of fuzzy control rules.

c. Types of fuzzy control rules.

d. Consistency, interactivity, and completeness of fuzzy control rules.

4. Decision-making logic:

a. Definition of a fuzzy implication.

b. Interpretation of sentence connective and

c. Interpretation of sentence connective or.

d. Inference mechanism.

5. Defuzzification strategies and the interpretation of a defuzzification operator (defuzzifier).

Adaptation or change in any of the five design parameters above creates an adaptive fuzzy logic control system. If all are fixed, the fuzzy logic control system is simple and nonadaptive.

7.4. Membership Functions

Definition: A graph that defines how each point in the input space is mapped to membership value between 0 and 1. Input space is often referred as the universe of discourse or universal set (u), which contain all the possible elements of concern in each particular application.

7.4.1. Types of membership functions

Before we start defining different types of membership functions, let us consider a Fuzzy IF-THEN rule for a car:

IF the speed of a car is high, THEN apply less force to the accelerator

IF the speed is low, THEN apply more force to the accelerator

Straight line:

The simplest membership function is formed by straight line. We consider the speed of car in Fig. 7.3 and plot the membership function for high. Where the horizontal represent the speed of the car and vertical axis represent the membership value for high.

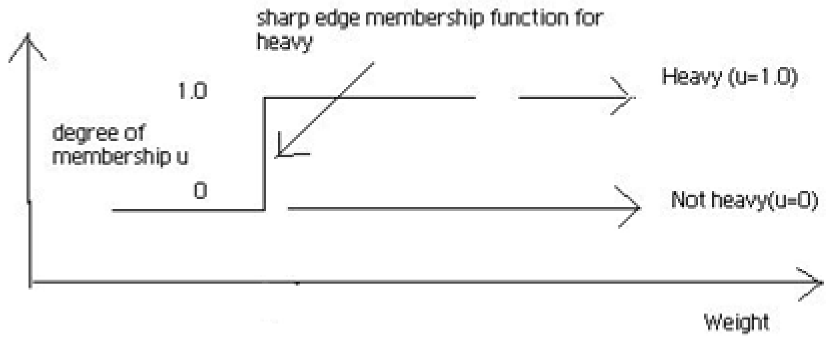


Fig. 7.3 Straight Line Membership Function

Trapezoidal:

If we consider the case 7.3 and plot the membership function for "less", we get a trapezoidal membership function. Fig. 7.3 shows a graphical representation, where the horizontal axis represent the force applied to the accelerator and the vertical shows membership value for "less". The function is often represented by "trapmf".

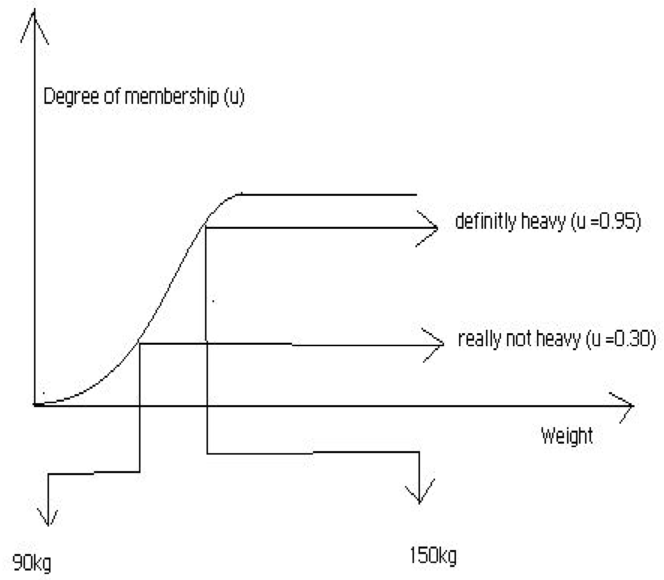


Fig. 7.4 Trapezoidal Membership Function

Gaussian:

Let say a fuzzy set Z which represent "number close to zero". The possible membership function for Z is

$$\mu_Z(x) = e^{-x^2} \qquad (5.1)$$

If we plot this function we get a graph shown in Fig 5.5 and are refer as Gaussian membership function.

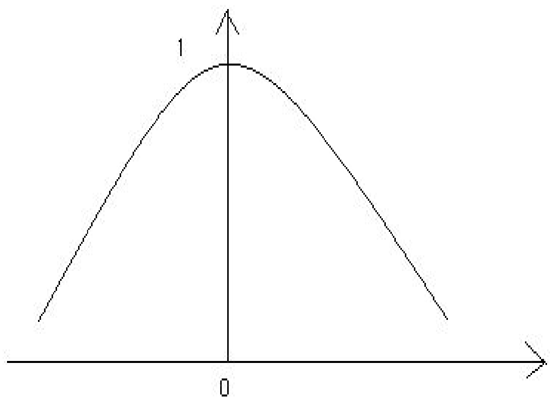


Fig. 7.5 Gaussian Membership Function

Triangular:

This is formed by the combination of straight lines. The function is name as "trimf" .We considers the above case i.e. fuzzy set Z to represent the "number close to zero". So mathematically we can also represent it as

0 if X<-1

$\mu_Z(x)$ = X + 1 if -1 ≤ X <0

(5.2)

=1–X if 0 ≤ X <1

=0 if 1≤ X

Fig. 7.6 called "triangular membership function"

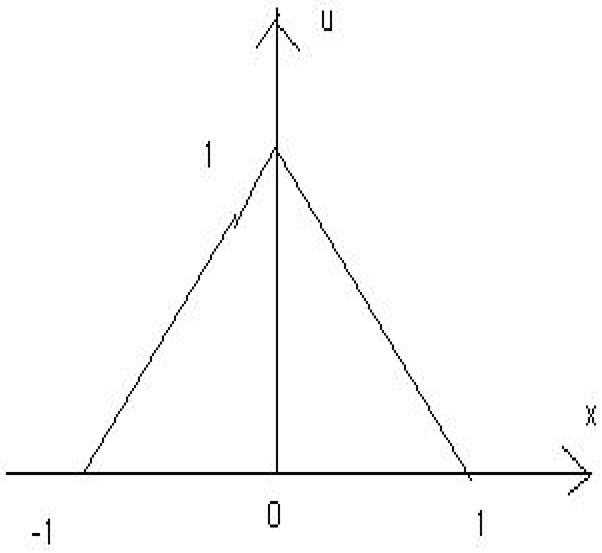


Fig. 7.6 Traingular Membership Function

7.5 Fuzzy Logic Tool Box:

In fuzzy Logic Toolbox software, fuzzy logic should be interpreted as FL, that is, fuzzy logic in its wide sense. The basic ideas underlying FL are explained very clearly and insightfully in Foundations of Fuzzy Logic. What might be added is that the basic concept underlying FL is that of a linguistic variable, that is, a variable whose values are words rather than numbers. In effect, much of FL may be viewed as a methodology for computing with words rather than numbers. Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution

The fuzzy logic toolbox is highly impressive in all respects. It makes fuzzy logic an effective tool for the conception and design of intelligent systems. The fuzzy logic toolbox is easy to master and convenient to use. And last, but not least important, it provides a reader friendly and up-to-date introduction to methodology of fuzzy logic and its wide ranging applications.

You can create and edit fuzzy inference systems with Fuzzy Logic Toolbox software. You can create these systems using graphical tools or command-line functions, or you can generate them automatically using either clustering or adaptive neuro-fuzzy techniques.

If you have access to SIMULINK software, you can easily test your fuzzy system in a block diagram simulation environment.

The toolbox also lets you run your own stand-alone C programs directly. This is made possible by a stand-alone Fuzzy Inference Engine that reads the fuzzy systems saved from a MATLAB session. You can customize the stand-alone engine to build fuzzy inference into your own code. All provided code is ansi compliant.

Because of the integrated nature of the MATLAB environment, you can create your own tools to customize the toolbox or harness it with another toolbox, such as the Control System Toolbox, Neural Network Toolbox, or Optimization Toolbox software.

The Fuzzy Logic Toolbox extends the MATLAB technical computing environment with tools for designing systems based on fuzzy logic. Graphical user interfaces (GUIs) guide you through the steps of fuzzy inference system design. Functions are provided for many common fuzzy logic methods, including fuzzy clustering and adaptive neuro fuzzy learning.

The toolbox lets you model complex system behaviors using simple logic rules and then implements these rules in a fuzzy inference system. You can use the toolbox as a standalone fuzzy inference engine. Alternatively, you can use fuzzy inference blocks in SIMULINK and simulate the fuzzy systems within a comprehensive model of the entire dynamic system.

CHAPTER 8

SIMULATION RESULTS

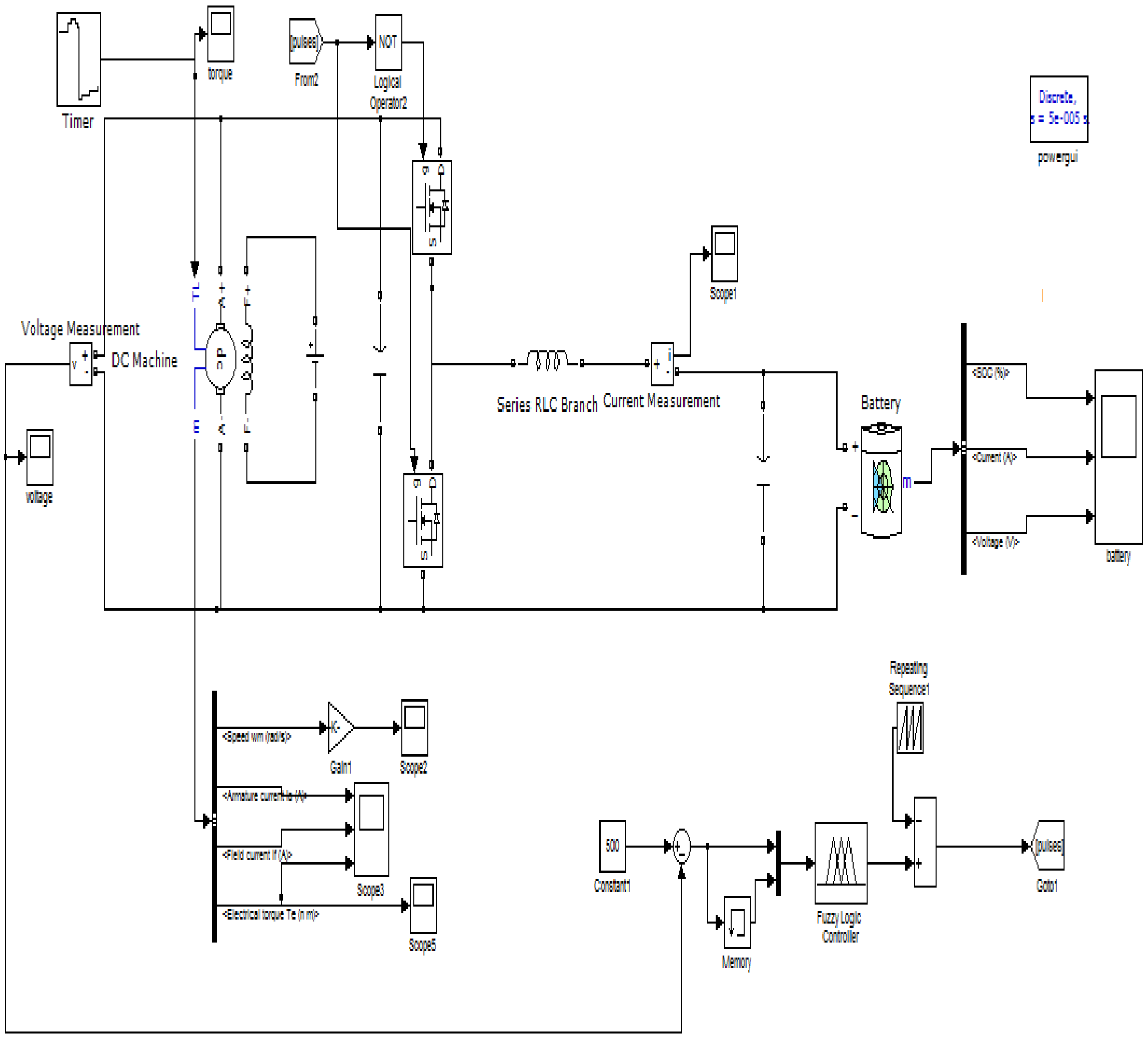


Fig 8.1 Proposed circuit configuration

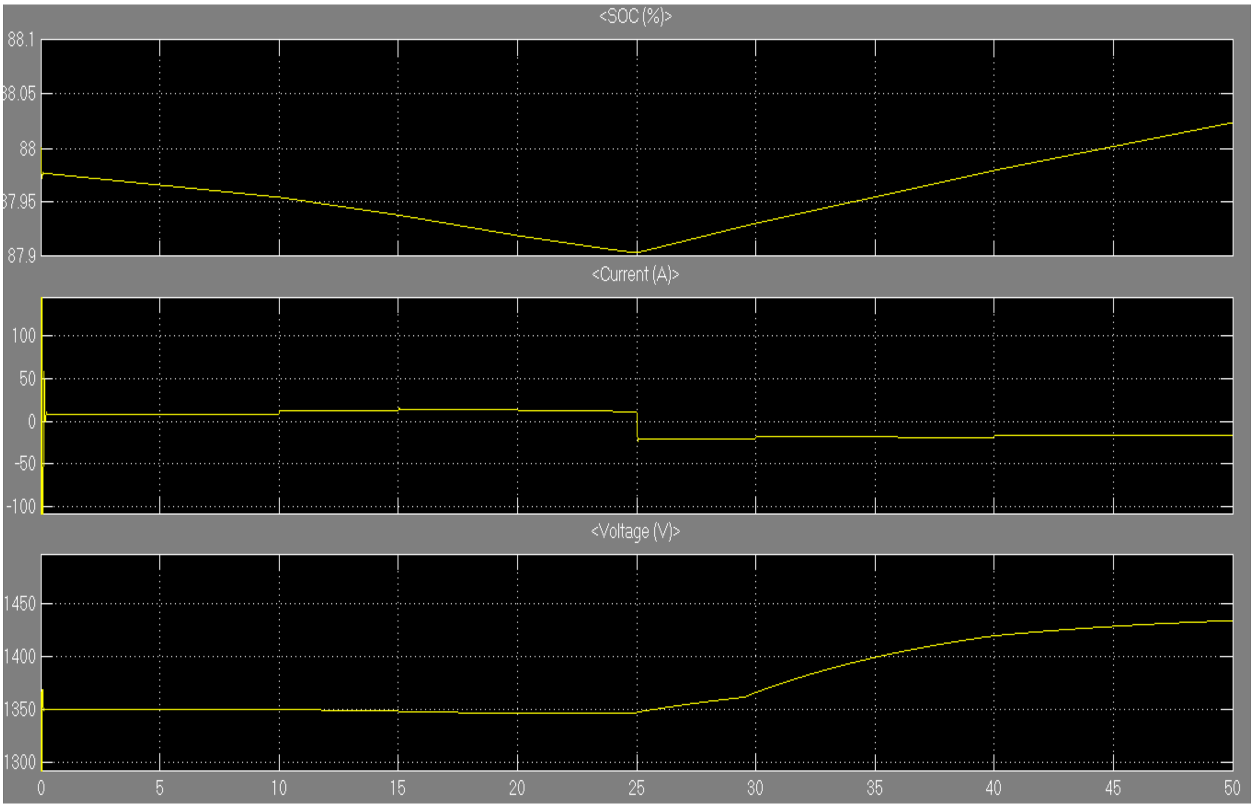


Fig 8.2 Proposed system Battery SOC, current, voltage

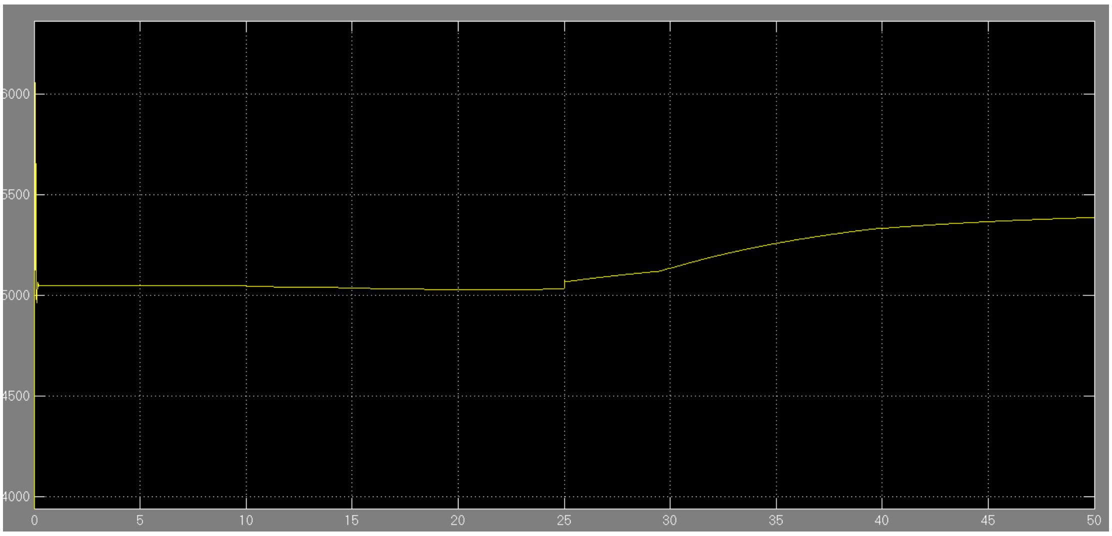


Fig 8.3 Proposed system Speed of the dc machine

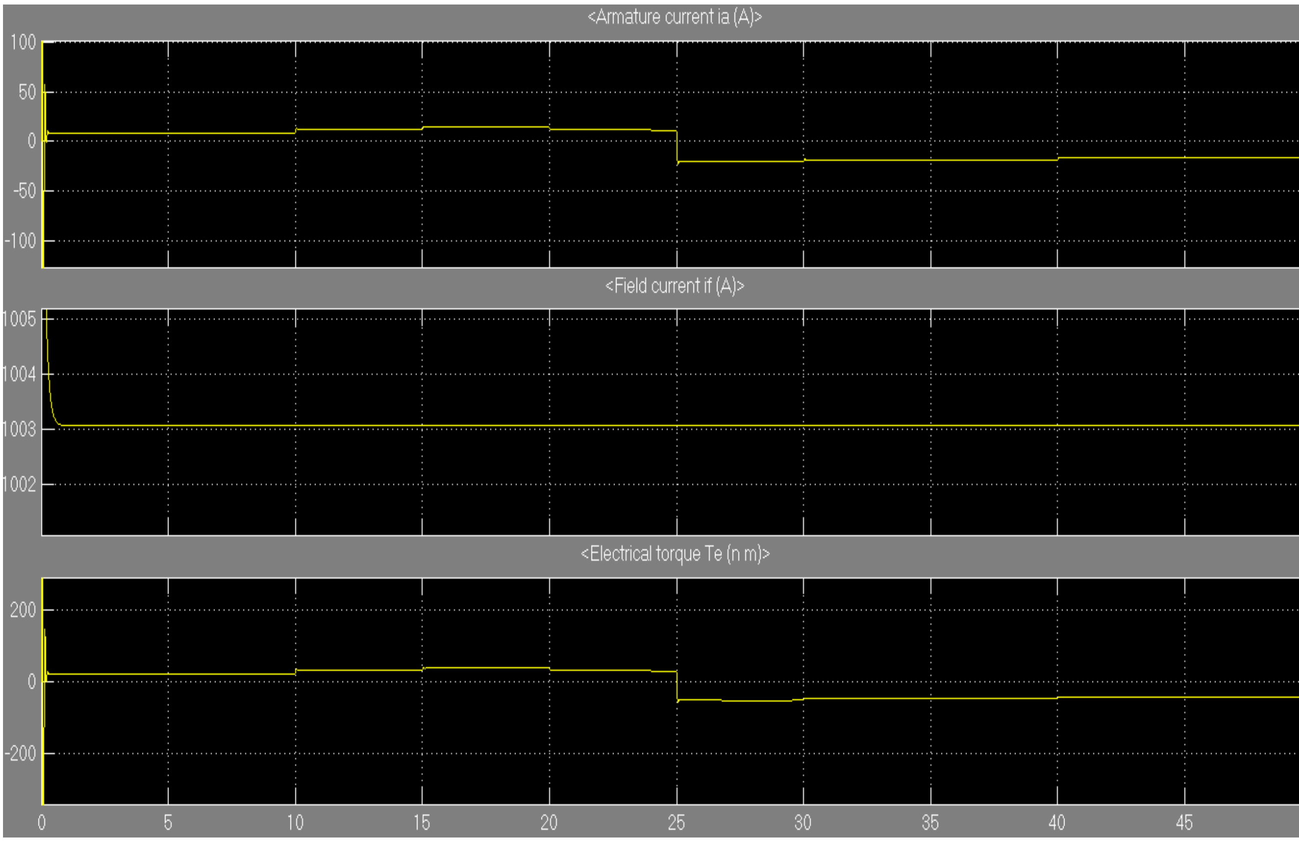


Fig 8.4 Proposed system Armature current, Field current, Electromagnetic torque

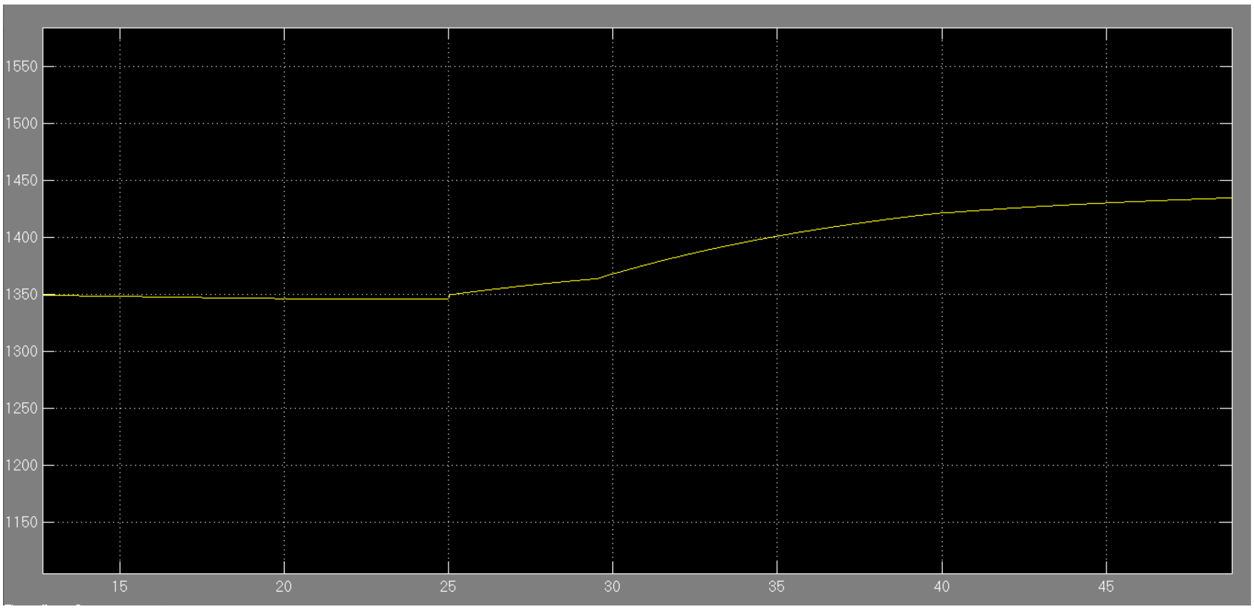


Fig 8.5 Proposed Dc machine across voltage

CHAPTER 9

CONCLUSION

This project presents design and control bi-directional dc-dc converter for all-electric vehicle. The bi-directional dc-dc converter is controlled with FLC according to rules. When the battery is discharged, the dc machine is operated in motor mode and bi-directional dc-dc converter is operated in boost mode. Variable positive torque values are applied to the dc machine and condition of the battery is observed. According to simulation result, the battery SoC is reduced from %88 to %87.337 and voltage of the dc machine is constant at 500 V. When the battery is charged, the dc machine is operated generator mode and bi-directional dc-dc converter is operated in buck mode. Variable negative torque values are applied to the dc machine and effect on the battery is observed. According to simulation result, the battery SoC is increased from %87.337 to %87.445. In all-electric vehicle, regenerative breaking is occurred in this state. Charge and discharge states of the battery are the most essential for distance to determining.

CHAPTER 10

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APPENDIX

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

a) Development Environment

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

b) The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

e) The MATLAB Application Program Interface (API)

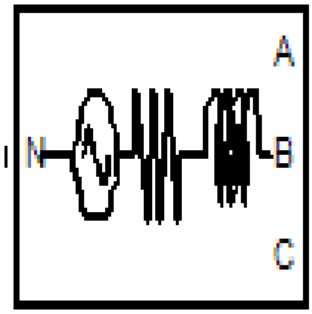
This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

(f) MATLAB Documentation

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

DIFFERENT TYPES OF BLOCKS AND THEIR PURPOSE

(1) Three phase source block

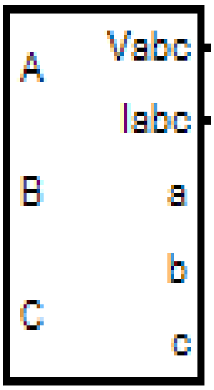


Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

(2) VI measurement block

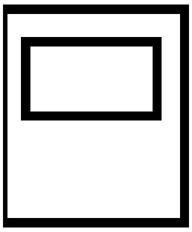
The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents



Three Phase V-I Measurement

(3) Scope

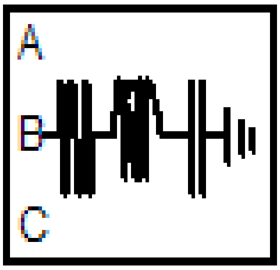
Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes. The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation



Scope

(4) Three-Phase Series RLC Load

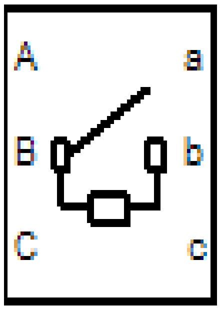
The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.



Three-Phase Series RLC Load

(5) Three-Phase Breaker block

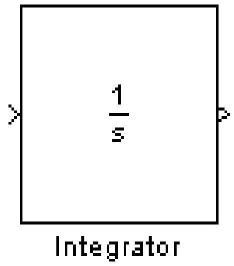
The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.



Three-Phase Breaker Block

(6) Integrator

Library: Continuous



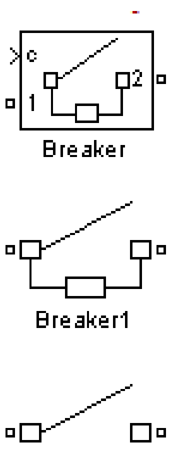
Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

(7) Breaker

Implement circuit breaker opening at current zero crossing.

Library: Elements



Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it).

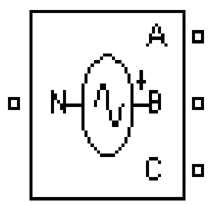
When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

(8) Three-Phase Programmable Voltage Source

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources



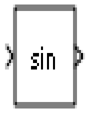
Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

(9) Trigonometric Function

Specified trigonometric function on input

Library: Math Operations



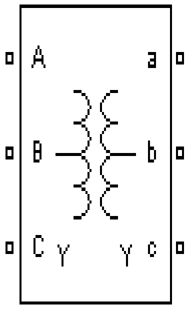
Trigonometric Function

Purpose: The Trigonometric Function block performs common trigonometric functions

(10) Three-Phase Transformer (Two Windings)

Implement three-phase transformer with configurable winding connections

Library: **Elements**



Three Phase Transformer

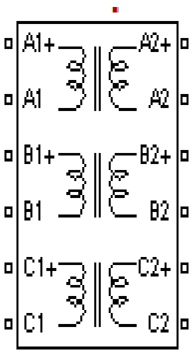
Purpose:

The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

(11) Three-Phase Transformer 12 Terminals

Implement three single-phase, two-winding transformers where all terminals are accessible

Library: *Elements*



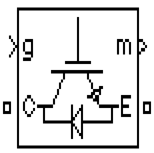
Two winding Transformer

Purpose: The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

(12) IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: **Power Electronics**



IGBT

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

A

PROJECT REPORT

On

STABILITY ANALYSIS OF A DC DISTRIBUTION SYSTEM FOR POWER SYSTEM INTEGRATION OF PLUG-IN ELECTRIC VEHICLES

Submitted by

1) D. Rithvik (17K81A0212) 2) K. Lokeswara Ravindra Rao(17K81A0224)

3) A. Gurcharan (17K81A0203) 4) C. Kapil Kumar Reddy (17K81A0210)

in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

Ms. T.V. SAI KALYANI, M.Tech,(PhD)

Assistant Professor

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ST.MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled **STABILITY ANALYSIS OF A DC DISTRIBUTION SYSTEM FOR POWER SYSTEM INTEGRATION OF PLUG-IN ELECTRTIC VEHICLE** is being submitted by **1.D.Rithvik(17K81A0212), 2.K.Lokeswara Ravindra Rao (17K81A0224), 3.A.GuruCharan(17K81A0203), 4.C.Kapil Kumar Reddy(17K81A0210)** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN ELECTRICAL AND ELECTRONICS ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Ms. T. V. Sai Kalyani
Department of Electrical and Electronics

Head of the Department
Dr. N. Ramchandra
Department of Electrical and Electronics

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of **Electrical And Electronics Engineering**, session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled **STABILITY ANALYSIS OF A DC DISTRIBUTION SYSTEM FOR POWER SYSTEM INTEGRATION OF PLUG-IN ELECTRTIC VEHICLE** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

D. Rithvik	17K81A0212
K. Lokeswara Ravindra Rao	17K81A0224
A. Gurucharan	17K81A0203
C. Kapil Kumar Reddy	17K81A0210

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1. D. Rithvik
2. K. Lokeswara Ravindra Rao
3. A. Gurucharan
4. C. Kapil Kumar Reddy

ABSTRACT

This project proposes a method for enhancing the stability of a dc distribution system that integrates plug-in hybrid electric vehicles (PHEVs) with an ac power grid. The DC distribution system is interfaced with the host AC grid via a voltage-sourced converter and can also embed photovoltaic (PV) modules. Thus, bidirectional DC–DC electronic power converters act as battery chargers and interface the PHEVs with the DC distribution system, while DC Link modules are interfaced with the DC distribution system via unidirectional DC–DC converters. The DC distribution system is expected to be more efficient and economical than a system of AC–DC battery chargers directly interfaced with an AC grid, but it is prone to instabilities due to the constant-power property of the DC–DC converters. Using a nonlinear control strategy, the proposed stability enhancement method mitigates the issue of instability by altering the power set points of the battery chargers, bidirectional DC–DC converters, without a need for changing system. The project presents mathematical models for the original and modified systems and demonstrates that the proposed technique expands the stable operating region of the dc distribution system.

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LIST OF OUTPUT SCREENS

LIST OF ACRONYMS

AC	Alternating Current
DC	Direct Current
BEV	Battery Electric Vehicle
EMS	Energy Management Strategy
EV	Electric Vehicle
GUI	Graphical User Interface
PCC	Point of Common Coupling
PEV	Plug-in Electric Vehicle
PFC	Power-Factor Correction
PHEV	Plug-in Hybrid Electric Vehicle
PI	Proportional-Integral
PWM	Pulse width modulation

INTRODUCTION

1.0 OVERVIEW OF THE PROJECT

These days Electric vehicle charging market is very high. In which we have the most of the companies involved in research and development of this areas and work to reduce the charging time of EV's. Today most of the EV's can be charged at 50KW and 400V following the fast-charging standards and are designed to withstand higher charging power. So, the output power characteristics are key features of EV's charging system by using power electronics building block (PEBB). Connecting EV charger to medium level voltage (MV) AC grid. Bidirectional PEBB is connected to MV grid through 50/60 Hz transformer. Advantage of this is that the battery charger can be fully assembled with half-bridge power modules. It is a two-stage power conversion system. Converts three phase AC to DC pulse DC to DC.

The front-end circuit consists of three phase two level voltage source rectifier which has low complexity, low cost and proper voltage conversion rate. The back-end circuit has three channel pulse width modulators with DC-DC buck type converter. This feature improves the current shared between parallel circuits and results in the improvement in total conduction and switching losses. PWM will cancel out the high frequency harmonics in both voltage and current. The power which we get from the dc link will be given to different loads as per the requirement. Here we will be having a battery which stores the dc power to charge the electric vehicles. At the other output we will be giving it to a dc machine which might bring initial harmonics in the DC bus, where we have to analyze the stability by using three different modes.

In the first part, a systematic method for developing a model for a dc distribution system, based on the configuration of the system is proposed. The developed model is of the matrix form and, therefore, can readily be expanded to represent a dc distribution system of any desired number of dc-dc converters. The model captures both the steadystate and dynamic characteristics of the system, and includes the port capacitors of the converters, as well as the interconnection cables. Thus, it can be used for identifying the condition for the existence of a steady state, as well as for stability analysis.

In the second part, the thesis proposes a method for enhancing the stability of the dc distribution system. Using a nonlinear control strategy, the proposed stability enhancement method mitigates the issue of instability by altering the power setpoints of the battery chargers, bidirectional dc-dc converters, without a need for changing system parameters or hardware. The thesis presents mathematical models for the original and modified systems and demonstrates that the proposed technique expands the stable operating region of the dc distribution system.

The power system integration of Plug-in Electric Vehicles (PEVs) and the possibility of bidirectional power exchange between them and the host grid have attracted attentions recently. In addition to providing traction power, batteries in a PEV can potentially be used for bulk energy storage in such applications as peak shaving, reactive power compensation, and the integration of renewable energy resources

1.1 **OBJECTIVES OF THE STUDY:**

Comparing with AC power distribution systems, DC power distribution systems have the advantages of low external interference, low power loss, large power supply capacity, high power quality, strong power supply reliability, and easy access to distributed power sources. Therefore, the DC power distribution system has become a new development direction of the future urban power distribution system, but the disordered random charge and discharge requirements of the electric vehicle may affect the stability of the DC power distribution system, which may easily cause instability of the DC power distribution system.

Therefore, how to improve the stability of DC power distribution system including electric vehicles has become a hot research topic. In the stability analysis model of DC power distribution system with plug-in electric vehicle is established. The potential random charging demand of electric vehicle can cause the instability of DC power distribution system. A power setting for changing the charging device of electric vehicle is proposed. The fixed-point nonlinear control strategy effectively improves the stability of the system. The influence of electric vehicle charging on the stability of DC power distribution system is analyzed from the aspects of load, grid loss and voltage. The intelligent charging method of electric vehicle is proposed, which effectively enhances system stability and improves voltage quality.

None of the documents gives the stability difference of the DC distribution system including the electric vehicle under the constant current charging (discharging) mode and the constant voltage charging mode (Electric vehicles cannot be discharged by constant voltage discharge mode) . In order to enrich theoretical research, the stability of DC distribution system with electric vehicles under constant current charging (discharging) mode, constant voltage charging mode and constant power charging (discharging) mode will be studied. Firstly, the stability model of DC power distribution system with electric vehicles under different charging (discharging) modes is established. Secondly, the stability of DC power distribution system under different charging (discharging) modes is determined by Nyquist stability criterion. Finally, the example of DC power distribution system with electric vehicle is built in Dig SILENT simulation software and verifies the rationality of the above theoretical analysis.

1.2 SCOPE OF THE STUDY

Stability analysis is a key performance which is used to analyse the stable nature of every DC distribution network. This analysis will provide un-interrupted power supply to the output load with good efficiency. Off-boarding charging can be installed effectively with high power quality. The power system integration of Plug-in Electric Vehicles (PEVs) and the possibility of bidirectional power exchange between them and the host grid have attracted attentions recently [1,2]. In addition to providing traction power, batteries in a PEV can potentially be used for bulk energy storage in such applications as peak shaving, reactive power compensation [3], and the integration of renewable energy resources. Public parking areas within hospitals, department stores, and residential and commercial premises are examples of locations where a large number of PEVs can be integrated with the power system

1.3 MATERIAL REQUIREMENT

- Matlab
- Three phase source blocks
- VI measurement block
- Scope
- Three-Phase Series RLC Load
- Three-Phase Breaker block
- Integrator
- Breaker
- Three-Phase Programmable Voltage Source
- Trigonometric Function
- Three-Phase Transformer (Two Windings)
- PWM converter
- Reactor
- Voltage Source Converter
- Battery
- Dc machine
- Buck Boost Chopper
- PI controller

- IGBT/Diode
- Three-Phase Transformer 12 Terminals
- IGBT/Diode

1.3 PROCUMENT OF EQUIPMENT:

MATLAB Documentation

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

Three phase source block

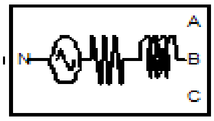


Fig1.1: Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

VI measurement block:

The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents

2

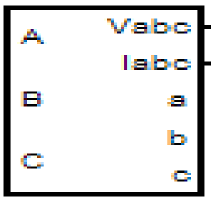


Fig1.2:Three Phase V-I Measurement

Scope:

Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes. The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation

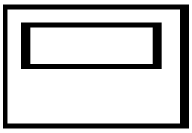


Fig:1.3: Scope

Three-Phase Series RLC Load:

The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

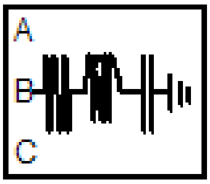


Fig:1.4: Three-Phase Series RLC Load

Three-Phase Breaker block:

The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.

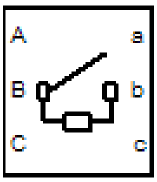


Fig:1.5: Three-Phase Breaker Block

Integrator:

Library: Continuous

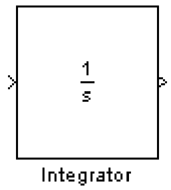


Fig:1.6: Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

Breaker:

Implement circuit breaker opening at current zero crossing.

Library: Elements

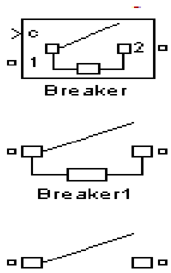


Fig:1.7: Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series R_s-C_s snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it).

When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance R_{on}. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

Three-Phase Programmable Voltage Source:
Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources

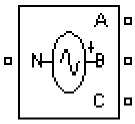


Fig:1.8: Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

Trigonometric Function:
Specified trigonometric function on input

Library: Math Operations

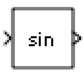


Fig.1.9: Trigonometric Functions

Purpose: The Trigonometric Function block performs common trigonometric functions

Three-Phase Transformer (Two Windings):

Implement three-phase transformer with configurable winding connections

Library: Elements

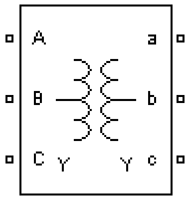


Fig:1.10: Three Phase Transformer

Purpose:

The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

Three-Phase Transformer 12 Terminals:

Implement three single-phase, two-winding transformers where all terminals are accessible

Library: Elements

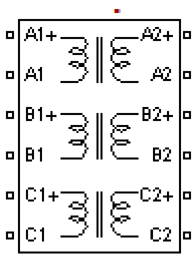


Fig:1.11. Two winding Transformer

Purpose: The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: Power Electronics

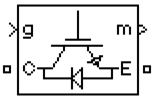


Fig:1.12. IGBT

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

1.5 ORGANIZATION OF CHAPTERS

1.5.0 INTRODUCTION:

The outlook of a large number of electric vehicles, including plug-in hybrid electric vehicles (PHEVs), and their potential impacts on the power system have motivated much research recently. The U.S. Department of Energy projects that more than about one million PHEVs will have been sold in the U.S. by 2015 and the current incentives by the U.S. government will promote and increase the sales of PHEVs.

In public parking areas where a sizable number of PHEVs are interfaced with the power grid, such ancillary services as the provision of back-up power for commercial facilities, voltage support, frequency regulation, peak shaving, reactive-power support, and integration of photovoltaic (PV) panels can be offered by PHEV batteries. To provide such services, bidirectional battery chargers must be employed to enable energy exchange between PHEVs and the host grid. In most proposed integration strategies, ac–dc power electronic converters act as the battery chargers and are directly interfaced with the power grid As a perceived technically and economically superior alternative, dc distribution systems have recently been proposed in which dc–dc converters act as the battery charges, especially for public areas.

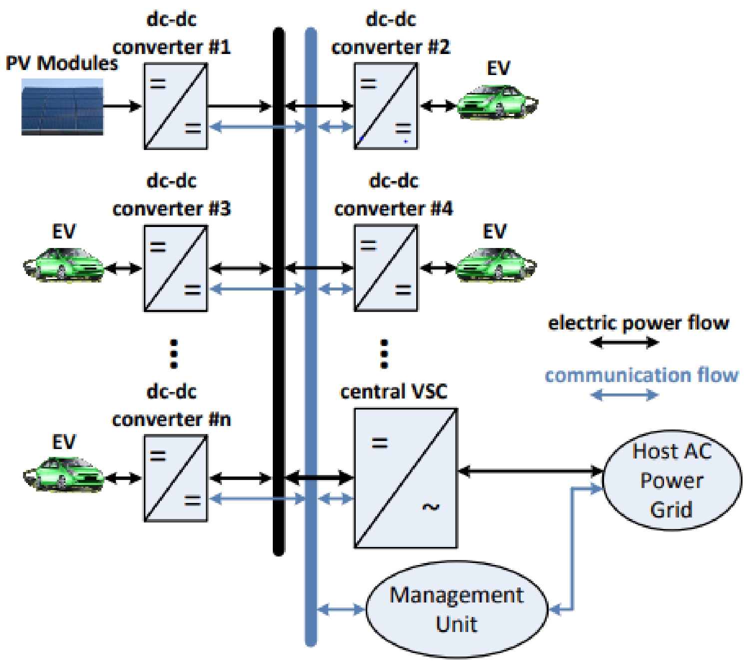


Fig:1.13. Dc bus for distribution of power in a parking lot for PHEV's

A dc distribution system can more efficiently host PV modules and interfaced with the power grid via a central ac–dc power-electronic converter. However, due to the constant-power property of dc–dc converters, it becomes unstable if the powers absorbed by the battery chargers exceed certain values [13].

This phenomenon inflicts a limit on the maximum power that can be imported to charge the batteries and, consequently, precludes full utilization of the installed capacities and prolongs the charging times. Therefore, it is imperative to: 1) systematically characterize the phenomenon and identify the prevailing constraints; 2) devise a stability enhancement technique, in order to push the limits and expand the stable operating region of the dc system. To mitigate the aforementioned issue of instabilities caused by constant-power elements in a dc distribution system, various methods have been proposed in the literature, [17]–[19]. The method proposed in [17] stabilizes a dc-link electric propulsion system where a dc–ac converter drives an induction motor, by altering the torque setpoint of the motor. The proposed technique, therefore, is applied to a dc system with one constant power element; there is no analysis for multiple constant-power elements.

The techniques proposed in [18] and [19] deal with a system in which a dc–dc converter is assumed to be supplying another constant-power element. However, both techniques require information about the internal state variables and access to the pulse width modulation (PWM) signal of the dc–dc converter. Moreover, the studied systems include only one dc–dc converter and one constant-load element. Expanding upon the idea proposed in [17], this paper proposes a control technique for expanding the stable operating region of a dc distribution system integrating PHEVs via bidirectional dc–dc converters (battery chargers), such that the dc system and its PHEVs can import larger powers from the host ac grid. The proposed technique is simple, does not require information internal to the system or its embedded converters, and does not need hardware modifications. Rather, it only employs local measurements and individual power set points and, therefore, can be exercised in a decentralized fashion.

These, in turn, permit the use of commercially available dc–dc converters (battery chargers), expected to further reduce the overall cost of the system. The proposed technique is also applicable to other dc distribution systems, e.g., shipboard power systems, that have multiple power-electronic converters 1 illustrates a dc distribution system, for example, in a parking lot, that hosts PHEVs and PV modules. In this system, dc–dc converters are utilized as battery chargers for the PHEVs and also for interfacing the PV modules. Moreover, a central voltage-sourced converter (VSC) interfaces the dc distribution system to the host ac grid. A communication network [20] is used to enable the exchange of metering and control information for a management unit, to and from the dc–dc converters and the central VSC. The management unit calculates the limits of the power exchange set points and sends them to the dc–dc converters, to ensure that the dc system operates in its stable operation region. The PHEV owners, on the other hand, can set state-of-charge (SoC) limits for their vehicles, to permit power exchanges only if the SoC resides within a certain range. For example, if the SoC is above 70%, then energy can be sold to the rest of the system, whereas if the SoC is below 40%, then the vehicle should buy energy from the rest of the system.

The aforementioned limits (determined based on the trip plans, electricity price, and other factors) translate into power setpoints for the corresponding dc–dc converters. For example, for a PHEV with 20 kWh of battery capacity, if the SoC limit for energy export is 70% and the present SoC is 85%, then 3 kWh (that is, 15% of the battery capacity) can be sold by the PHEV to the rest of the system, meaning that the power setpoint of this particular PHEV can be set to export 9 kW of power in 20 min, or 3 kW of power in 1 h, and so on.

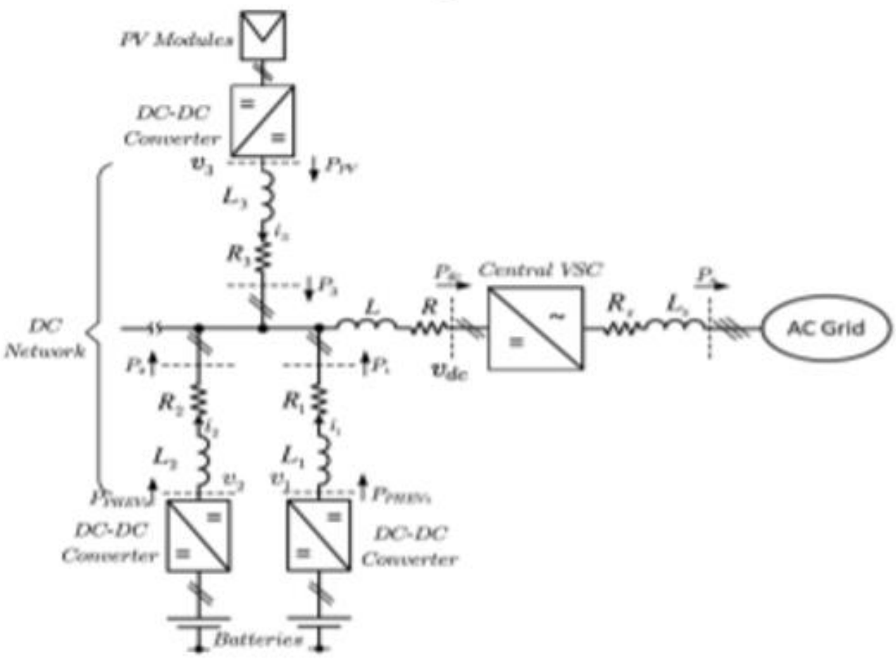


Fig:1.14. Schematic diagram of the dc system.

1.5.1 LITERATURE SURVEY

This focuses on the mathematical model for the dc distribution system. A dc distribution system is expected to offer a higher efficiency and to enable an easier integration of renewable energy sources such as photovoltaic (PV) and fuel-cell systems [26,27], as compared with a system of ac-dc battery chargers. However, it is prone to instabilities due to constant-power property of the hosted dc-dc converters, if powers drawn by the dc-dc converters (to charge the batteries) exceed certain limits [20,28,29]. Thus, one needs a model of the system to characterize the steady-state and dynamic behaviors of the system. Such a model should be tractable, while adequately accurate, and it should also represent both the steady-state and dynamic characteristics of the system.

1.5.2 PROJECT DESIGN:

In this overall design ac grid will be converted into dc bus by a voltage source converter which in fact provides to charge the plug in electric vehicles. The particulars of the overall design are concentrated more on the controllers which are PI controllers which provide analyzing the stability of the DC distribution system when it is connected to the load

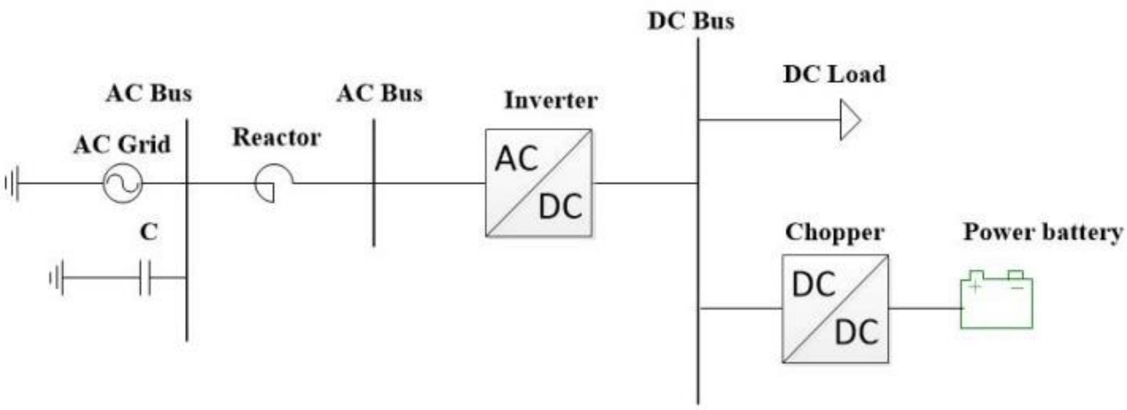


Fig:1.15: Block diagram of a DC distribution system

1.5.3 PROJECT IMPLEMENTATION;

The stability analysis of a Dc distribution system can be done on the MATLAB software which provides the analyzation of the harmonics which are present in the DC distribution system when it is integrated with the plug-in electric vehicles. Which in fact provides us in analyzing the best way to find out to reduce the initial harmonics which are present in the DC distribution system.

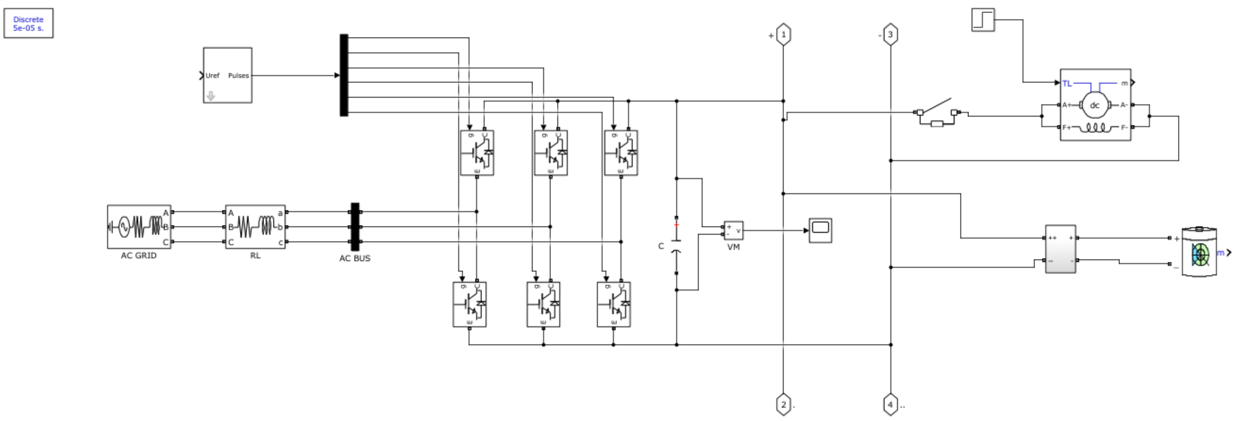


Fig:1.16.Connection the circuit in MATLAB software

1.5.4 CONCLUSION AND FUTURE ENHANCEMENT:

This project is advance development in power systems where we are eliminating Transformers and other costly equipment needed for High voltage conversion. Future scope of this project is to connect Renewable Sources like Solar PV panels to the system. By connecting PV panels we can also supply energy towards the Grid as it is a bidirectional system.

2. LITERATURE SURVEY

2.0 LITERATURE REVIEW ON RESEARCH AREA:

A dc distribution system is expected to offer a higher efficiency and to enable an easier integration of renewable energy sources such as photovoltaic (PV) and fuel-cell systems [26, 27], as compared with a system of ac-dc battery chargers. However, it is prone to instabilities due to constant-power property of the hosted dc-dc converters, if powers drawn by the dc-dc converters (to charge the batteries) exceed certain limits [20, 28, 29]. Thus, one needs a model of the system to characterize the steady-state and dynamic behaviors of the system. Such a model should be tractable, while adequately accurate, and it should also represent both the steady-state and dynamic characteristics of the system.

One should also be able to systematically expand it to represent a system of any desired, and most likely large, number of dc-dc converters. To the author's best of knowledge, the published technical literature does not present a model with the aforementioned features.

Several prior studies have reported system-level models for dc distribution systems [30–33]. The main issue associated with the aforementioned studies is that they consider a limited number of dc-dc converters on the dc distribution system and develop the model for the system based on that assumption. Reference [30], proposes a model for a dc distribution system, but the model only describes the steady-state behavior of the system. Reference [31] develops a model, and proposes a method for stabilizing a dc distribution system.

However, the presented model is limited to three converters and, consequently, cannot be adopted for a dc distribution system with a large number of converters. In [27] a model is proposed for a dc distribution system with multiple loads and sources, but it does not consider the interconnection cables of the system. Reference [34] proposes a reduced-order model for a generic dc micro grid.

The presented model, however, does not account for the terminal capacitors of the dc-dc converters; the interconnection cables and the terminal capacitors both play important roles in the steady-state and dynamic behaviors of a dc distribution system and, therefore, cannot be ignored. To address the foregoing shortcomings, this thesis proposes a systematic approach to develop a mathematical model for a dc distribution system. The proposed mathematical model is of the matrix form and can be used to analyze small-signal dynamic behavior of the dc distribution system with an arbitrarily large number of dc-dc converters. The thesis also derives a set of computationally efficient equations for calculating the dc distribution system eigenvalues to facilitate online stability assessment of the system on an embedded signal-processing platform.

Due to the constant-power property of dc-dc converters [28,35], the dc distribution systems, that include dc-dc converters, become unstable if the powers absorbed by the converters exceed certain values [20]. This phenomenon inflicts a limit on the maximum power that can be imported to charge the batteries and, consequently, precludes full utilization of the installed capacities and prolongs the charging times. Therefore, it is imperative to systematically characterize the phenomenon and identify the prevailing constraints, and devise a stability enhancement technique, in order to push the limits and expand the stable operating region of the dc system. To mitigate the aforementioned issue of instabilities caused by constant-power elements in a dc distribution system, various methods have been proposed in the literature, [31, 36–41]. The method proposed in [36] stabilizes a dc-link electric propulsion system where a dc-ac converter drives an induction motor, by altering the torque setpoint of the motor.

2.1 REVIEW ON RELATED LITERATURE:

Several recent reported studies have proposed charging strategies for PEVs [7,24,43– 49]. Reference [24] proposes algorithms for optimizing the PEV charging schedule from the owner's perspective. A real-time smart load management control strategy is proposed in [7] to coordinate the charging of PEV, to minimize the power loss and the charging cost, and to mitigate the voltage fluctuations at the host ac grid. A strategy is proposed in [43] to mitigate the adverse impacts that uncontrolled charging of the PEVs impose on the host power system. Using empirical driving profiles, reference [44] shows the economic benefits of a smart charging strategy against a uncontrolled charging strategy for charging the PEVs. In [45], it is assumed that there is a limited future knowledge of the mobility of the PEVs and it is shown that by using this information, the negative impacts of the PEV charging can be reduced. Reference [46] proposes charging control strategies for a battery swapping station, where the PEV owners can quickly swap their depleted batteries with previously charged batteries. In [47], optimal scheduling has been proposed for both charging and discharging of the PEVs. The references cited above do not necessarily concern dc systems. However, they all assume an integral entity, an aggregator, that negotiates with the PEVs, in one hand, and with the host power system in the other hand. Hence, the host ac grid deals with only one entity, the aggregator, rather than a large number of PEVs.

In the majority of the reported studies, the proposed strategies aim to only optimize the charging costs for the PEV owners, or minimize the power loss within the system, but do not offer to the owners an option for fast battery charging (by which the charging time is minimized rather than the charging cost). Further, the reported studies commonly assume that the PEV owners fully comply with the (proposed) charging strategies, i.e., they connect their vehicles to the chargers, for the entire specified period, and do not depart early. In practice, however, an owner may decide to leave before the planned period has elapsed.

Most of the reported studies also assume a unidirectional power flow, that is, into the PEVs, whereas there is a possibility for bidirectional power exchange among the PEVs and the host ac grid. To address the foregoing shortcomings, this thesis proposes an energy management strategy that offers both fast and optimized energy exchange options to the PEV owners. The proposed strategy limits the power consumption and power generation of the dc distribution system to prevent the negative impacts of simultaneous charging or discharging of a large number of electric vehicles on the ac power grid. The proposed strategy seamlessly handles requests for charging or discharging of the electric vehicles and also takes into account the likelihood of early departure of the PEV owners.

2.2 CONCLUSIONS ON REVIEWS:

This review concentrates on mitigating the instability issue of the dc distribution system. Due to the constant-power property of dc-dc converters, the dc distribution systems, that include dc-dc converters, become unstable if the powers absorbed by the converters exceed certain values. This phenomenon inflicts a limit on the maximum power that can be imported to charge the batteries and, consequently, precludes full utilization of the installed capacities and prolongs the charging times. Therefore, it is imperative to systematically characterize the phenomenon and identify the prevailing constraints, and devise a stability enhancement technique, in order to push the limits and expand the stable operating region of the dc system.

3. PROJECT DESIGN

3.0 OVERVIEW OF THE DESIGN

In this system, dc–dc converters are utilized as battery chargers for the PHEVs and also for interfacing the PV modules. Moreover, a central voltage-sourced converter (VSC) interfaces the dc distribution system to the host ac grid. for a PHEV with 20 kWh of battery capacity, if the SoC limit for energy export is 70% and the present SoC is 85%, then 3 kWh (that is, 15% of the battery capacity) can be sold by the PHEV to the rest of the system, meaning that the power setpoint of this particular PHEV can be set to export 9 kW of power in 20 min, or 3 kW of power in 1 h, and so on.

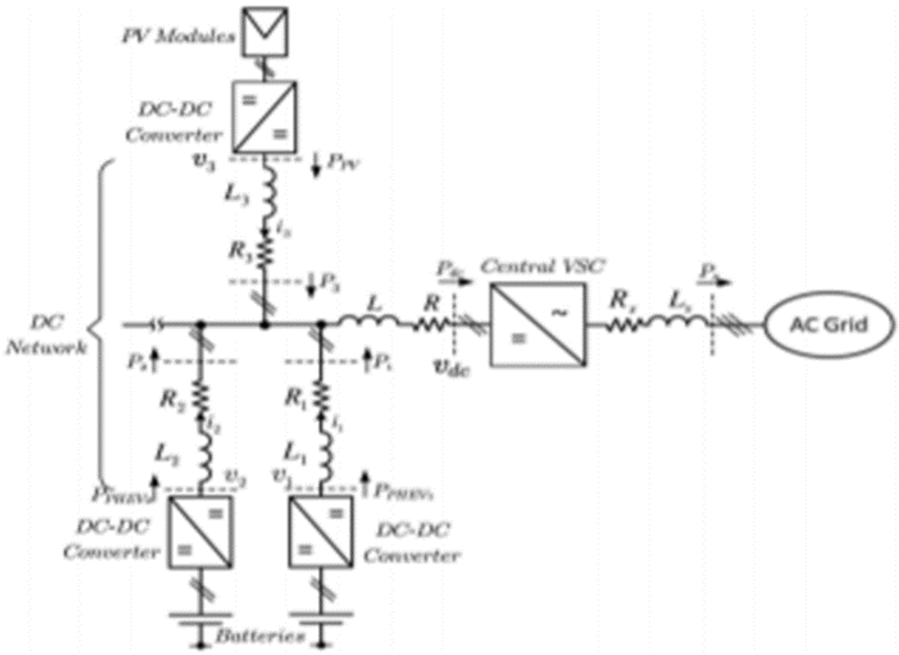


Fig:3.1. Schematic Diagram of the dc system

The central VSC and its control scheme act as a controlled dc-voltage power port [21] and regulate the dc voltage of the network (Fig. 3 illustrates the concept). The VSC is current controlled, such that its output real power, Ps, rapidly tracks the real-power setpoint, P∗ s ,issued by a dc-voltage regulation loop (variables with superscript * signifies the setpoints). Pdc denotes the power that the rest of the dc system delivers to the VSC. A measure of Pdc is incorporated in the control loop, as a feed-forward signal, to mitigate the dynamic coupling between the dc-voltage regulation loop and the rest of the dc system.

The PHEV batteries exchange energy with the dc system through corresponding bidirectional dc–dc power-electronic converters which are referred, hereafter, to as the battery chargers. shows a simplified schematic diagram of a full-bridge dc–dc converter which, with no loss of generality, is assumed to represent a battery charger (e.g., for the ith PHEV of the dc system). The battery current, iBi, is regulated at its setpoint, i ∗ Bi, by a feedback control loop in which a compensator, Ki(s), processes the error (i ∗ Bi−iBi) and generates the control signal ui. A measure of the battery voltage, Vbati, is then added to ui, and the resulting signal is divided by a measure of the network-side terminal voltage of the converter, vi, to generate the pulse-width modulating (PWM) signal of the converter.

In turn, i ∗ Bi is calculated by dividing the battery power setpoint, P∗ Bi, by Vbati. Assuming a fast and accurate current-control loop, the battery power PBi equals P∗ Bi. On the other hand, PBi is almost equal to the power that leaves the network-side port of the converter, Pti; the approximation is plausible in view of the typically small battery-side filter resistance RBi and inductance LBi (due to the typically large switching frequency of the converter), as well as negligible power losses of the converter.

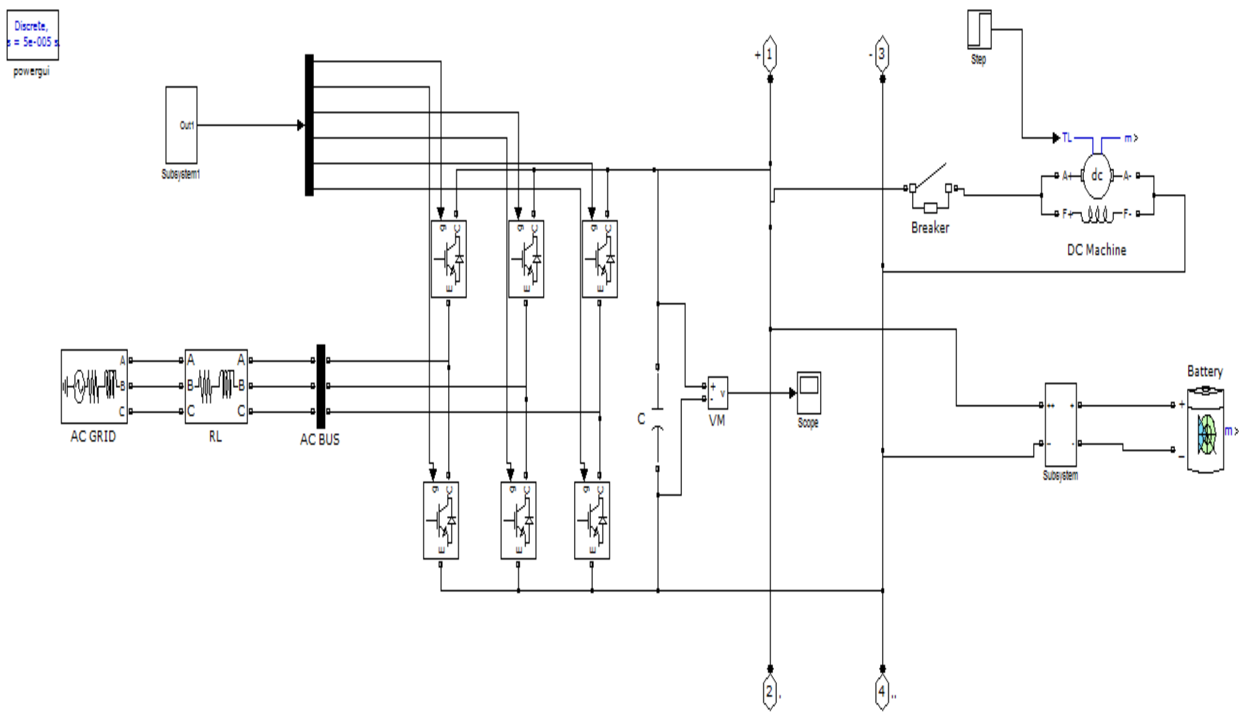


Fig:3.2.PROPOSED CIRCUIT CONFIGURATION WITHOUT COMPENSATION

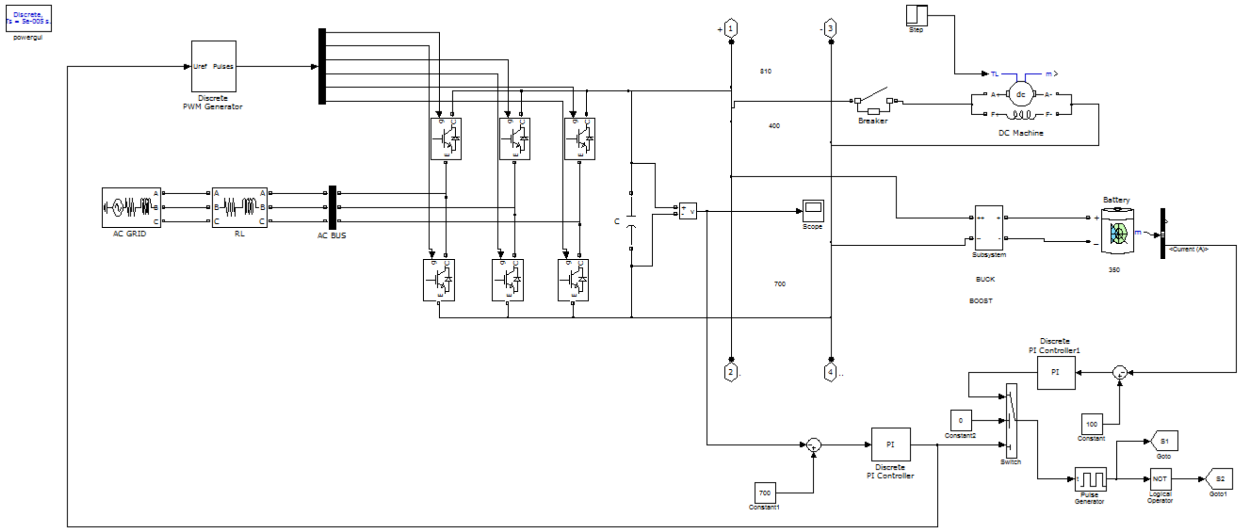


Fig:3.3. PROPOSED CIRCUIT CONFIGURATION WITH CURRENT CHARGING METHOD

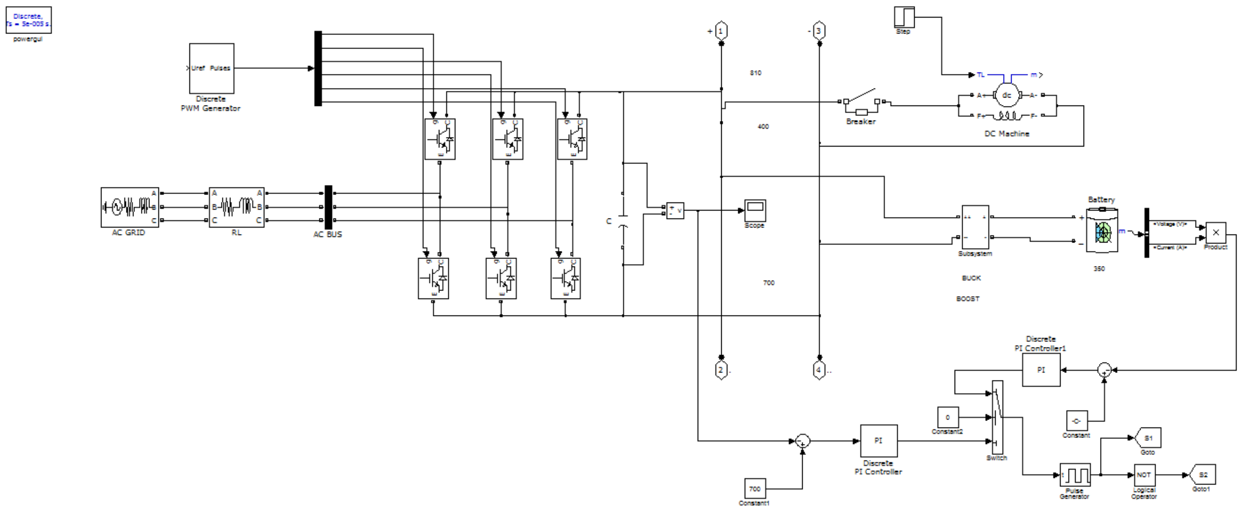


Fig:3.4. PROPOSED CIRCUIT CONFIGURATION WITH POWER CHARGING METHOD

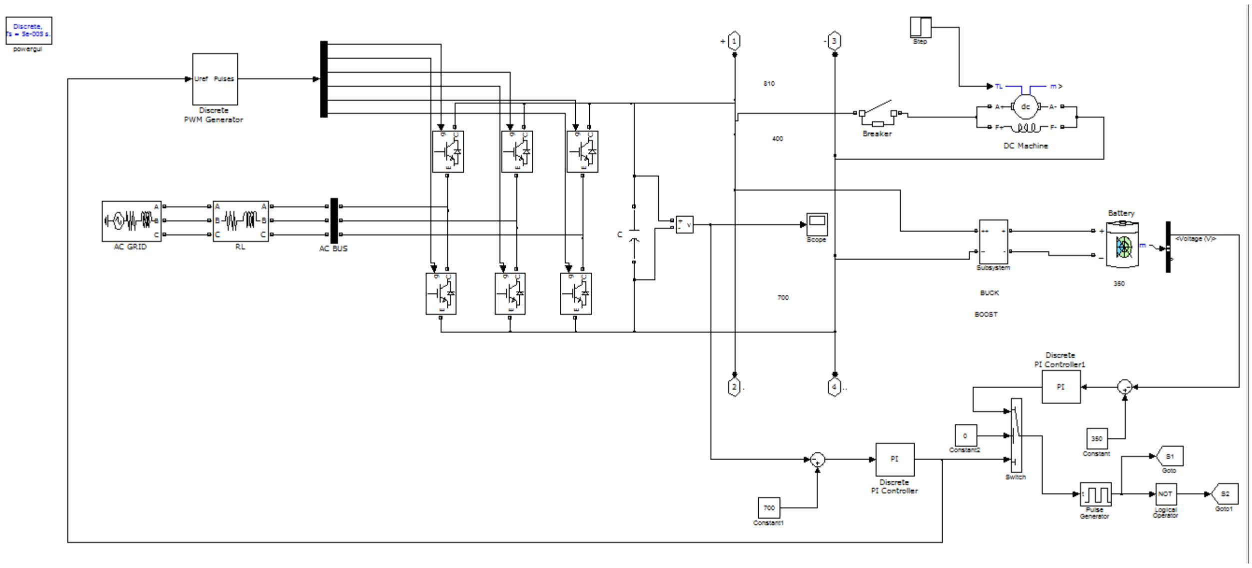


Fig:3.5.PROPOSED CIRCUIT CONFIGURATION WITH VOLTAGE CHARGING METHOD

3.1 EQUIPMENT ANALYSIS

3.1.1 INTRODUCTION

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and many other electrical, mechanical, and thermodynamic systems.

Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor. The model depicts the time-dependent mathematical relationships among the system's inputs, states, and outputs. Then, we use Simulink to simulate the behavior of the system over a specified time span. Simulink uses information that you entered into the model to perform the simulation.

3.1.2 BATTERY STORAGE SYSTEM:

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode.[2] The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to include devices composed of a single cell.

Primary (single-use or "disposable") batteries are used once and discarded, as the electrode materials are irreversibly changed during discharge; a common example is the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechargeable) batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and mobile phones.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smartphones, to large lead acid batteries or lithium-ion batteries in vehicles, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centers.

Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. In automobiles, this is somewhat offset by the higher efficiency of electric motors in converting chemical energy to mechanical work, compared to combustion engines.

Batteries that are stored for a long period or that are discharged at a small fraction of the capacity lose capacity due to the presence of generally irreversible side reactions that consume charge carriers without producing current. This phenomenon is known as internal self-discharge. Further, when batteries are recharged, additional side reactions can occur, reducing capacity for subsequent discharges. After enough recharges, in essence all capacity is lost and the battery stops producing power.

Internal energy losses and limitations on the rate that ions pass through the electrolyte cause battery efficiency to vary. Above a minimum threshold, discharging at a low rate delivers more of the battery's capacity than at a higher rate. Installing batteries with varying A·h ratings does not affect device operation (although it may affect the operation interval) rated for a specific voltage unless load limits are exceeded. High-drain loads such as digital cameras can reduce total capacity, as happens with alkaline batteries. For example, a battery rated at 2 A·h for a 10- or 20-hour discharge would not sustain a current of 1 A for a full two hours as its stated capacity implies.

3.1.3 PROPOSED DC DC CONVERTER:

Buck–Boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, ranging from much larger (in absolute magnitude) than the input voltage, down to almost zero.

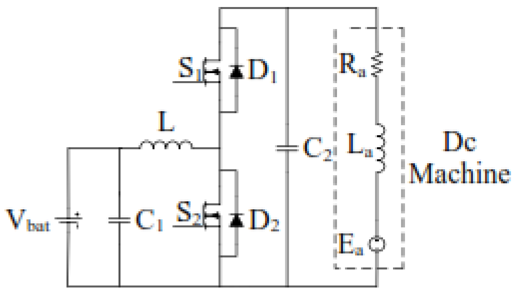


Fig:3.6.Proposed converter

The output voltage is of the opposite polarity than the input. This is a switched-mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. However, this drawback is of no consequence if the power supply is isolated from the load circuit (if, for example, the supply is a battery) because the supply and diode polarity can simply be reversed. When they can be reversed, the switch can be on either the ground side or the supply side.

A buck (step-down) converter combined with a boost (step-up) converter

The output voltage is typically of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor mode and the boost inductor mode, using switches instead of diodes,[2][3] sometimes called a "four-switch buck-boost converter",[4] it may use multiple inductors but only a single switch as in the SEPIC topologies.

Buck Boost converter-principle of operation-applications

3.1.4 Introduction to Buck Boost converter

A Buck converter is a switch mode DC to DC converter in which the output voltage can be transformed to a level less than or greater than the input voltage. The magnitude of output voltage depends on the duty cycle of the switch. It is also called as step up/step down converter. The name step up/step down converter comes from the fact that analogous to step up/step down transformer the input voltage can be stepped up/down to a level greater than/less than the input voltage. By law of conservation of energy, the input power has to be equal to output power (assuming no losses in the circuit).

Modes of operation of Buck Boost converter

The Buck Boost converter can be operated in two modes

a) Continuous conduction mode in which the current through inductor never goes to zero i.e. inductor partially discharges before the start of the switching cycle.

b) Discontinuous conduction mode in which the current through inductor goes to zero i.e. inductor is completely discharged at the end of switching cycle.

Circuit analysis of Buck converter

Assume in the entire analysis that the current swing (maximum to minimum value) through inductor and voltage swing through capacitor is very less so that they vary in a linear fashion. This is to ease the analysis and the results we will get through this analysis are quite accurate compared to real values.

Continuous conduction mode

case-1: When switch S is ON

When switch in ON for a time t_{on}, the diode will be open circuited since it does not allow currents in reverse direction from input to output. Hence the Buck Boost converter can be redrawn as follows

During this state the inductor charges and the inductor current increases. The current through the inductor is given as

$$I_L = (1/L) * \int V * dt$$

Assume that prior to the opening of switch the inductor current is $I'_{L, off}$. Since the input voltage is constant

$$I_{L,on} = (1/L) * \int V_{in} * dt + I'_{L,on}$$

Assume the switch is open for ton seconds which is given by $D*T_s$ where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch on state is given as

$$I_{L, on} = (1/L) *V_{in}*D*T_s + I'_{L, on} \text{ (equation 1)}$$

$$\text{Hence } \Delta I_{L,on} = (1/L)*V_{in}*D*T_s.$$

case 2: When switch is off

When switch in OFF the diode will be forward biased as it allows current from output to input (p to n terminal) and the Buck Boost converter circuit can be redrawn as follows

The inductor now discharges through the diode and RC combination. Assume that prior to the closing of switch the inductor current is $I''_{L, off}$. The current through the inductor is given as

$$I'''_{L,off} = -(1/L) * \int V_{out} * dt + I''_{L,off}$$

Note the negative sign at the front end of equation signifies that the inductor is discharging. Assume the switch is open for t_{off} seconds which is given by $(1-D)*T_s$ where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch off state is given as

$$I'''_{L, off} = -(1/L) *V_{out}*(1-D)*T_s + I''_{L, off} \text{ (equation 2)}$$

In steady state condition as the current through the inductor does not change abruptly, the current at the end of switch on state and the current at the end of switch off state should be equal. Also the currents at the start of switch off state should be equal to current at the end of switch on state. Hence

$$I'''_{L,\,off} = I_{L,\,on} \text{ also } I'_{L,\,off} = I''_{L,\,off}$$

Using the equations 1 and 2 we get

$$(1/L) * V_{in} * D * T_s = (1/L) * V_{out} * (1-D) * T_s$$

$$V_{in} * D = V_{out} * (1-D)$$

$$V_{out}/V_{in} = D/(1-D)$$

Since D < 1, Vout can be greater than or less than Vin.For D>0.5 the Buck boost converter acts as boost converter with Vout >Vin.For D<0.5 the Buck boost converter acts as buck converter with Vout >Vin. Assuming no losses in the circuit and applying the law of conservation of energy

$$Vout*Iout = Vin*Iin$$

This implies $I_{out}/I_{in} = (1-D)/D$, Thus $I_{out} > I_{in}$ for D<0.5 and $I_{out} < I_{in}$ for D<0.5 . As the duty cycle increases the output voltage increases and output current decreases.

Discontinuous conduction mode

As mentioned before the converter when operated in discontinuous mode the inductor drains its stored energy completely before completion of switching cycle. The current and voltage wave forms of Buck Boost converter in discontinuous mode is shown in the figure below

The inductor in discontinuous mode drains all the current which it piled up in charging interval of same switching cycle. The current through the inductor is given as

$$I_L = (1/L) \int V_L * dt$$

and the ratio of output to input current from law of conservation of energy is $I_{out}/I_{in} = \delta/D$.

Applications of Buck boost converter

- It is used in the self-regulating power supplies.
- It has consumer electronics.
- It is used in the Battery power systems.
- Adaptive control applications.
- Power amplifier applications

3.1.5 PULSE WIDTH MODULATION:

A modulation technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photovoltaic solar battery chargers,[1] the other being MPPT.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. Typically switching has to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

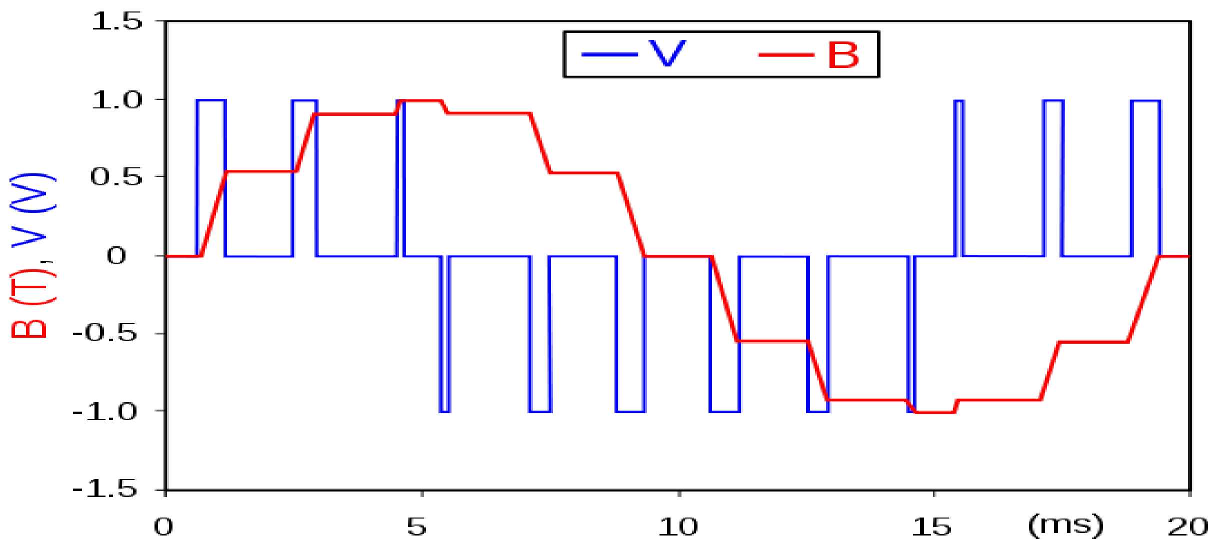


Fig 3.7 wave for combined positive and negative pulse

An example of PWM in an idealized inductor driven by a voltage source: the voltage source (blue) is modulated as a series of pulses that results in a sine-like current/flux (red) in the inductor. The blue rectangular pulses nonetheless result in a smoother and smoother red sine wave as the switching frequency increases. Note that the red waveform is the (definite) integral of the blue waveform.

Principle

Pulse-width modulation uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform. If we consider a pulse waveform $f(t)$, with period T, low value y_{min}, a high value y_{max} and a duty cycle D (see figure 1), the average value of the waveform is given by:

$$\bar{y} = \frac{1}{T}\int_0^T f(t)\,dt.$$

As $f(t)$ is a pulse wave, its value is y_{max} for $0 < t < D \cdot T$ and y_{min} for $D \cdot T < t < T$. The above expression then becomes:

$$\begin{aligned}\bar{y} &= \frac{1}{T}\left(\int_0^{DT} y_{max}\,dt + \int_{DT}^{T} y_{min}\,dt\right)\\ &= \frac{D \cdot T \cdot y_{max} + T\,(1-D)\,y_{min}}{T}\\ &= D \cdot y_{max} + (1-D)\,y_{min}.\end{aligned}$$

This latter expression can be fairly simplified in many cases where $y_{min} = 0$ as $\bar{y} = D \cdot y_{max}$. From this, it is obvious that the average value of the signal ($\bar{y}$) is directly dependent on the duty cycle D.

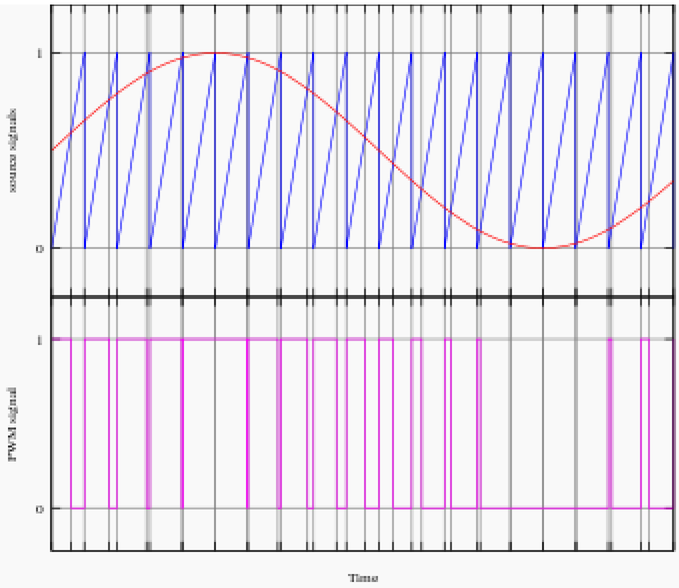


Fig. 4.2: A simple method to generate the PWM pulse train corresponding to a given signal is the intersective PWM: the signal (here the red sinewave) is compared with a sawtooth waveform (blue). When the latter is less than the former, the PWM signal (magenta) is in high state (1). Otherwise it is in the low state (0).

The simplest way to generate a PWM signal is the intersective method, which requires only a sawtooth or a triangle waveform (easily generated using a simple oscillator) and a comparator. When the value of the reference signal (the red sine wave in figure 2) is more than the modulation waveform (blue), the PWM signal (magenta) is in the high state, otherwise it is in the low state.

The **PWM** is a technique which is used to drive the inertial loads since a very long time.The simple example of an inertial load is a motor. Apply the power to a motor for a very short period of time and then turn off the power: it can be observed that the motor is still running even after the power has been cut off from it. This is due to the inertia of the motor and the significance of this factor is that the continuous power is not required for that kind of devices to operate. A burst power can save the total power supplied to the load while achieving the same performance from the device as it runs on continuous power.

The **PWM technique** is use in devices like DC motors, Loudspeakers, Class -D Amplifiers, SMPS etc. They are also used in communication field as-well. The modulation techniques like AM, FM are widely used RF communication whereas the PWM is modulation technique is mostly used in Optical Fiber Communication (OFC).

As in the case of the inertial loads mentioned previously, the PWM in a communication link greatly saves the transmitter power. The immunity of the PWM transmission against the inter-symbol interference is another advantage. This article discusses the technique of generating a PWM wave corresponding to a modulating sine wave.

DESCRIPTION:

The **Pulse Width Modulation** is a technique in which the ON time or OFF time of a pulse is varied according to the amplitude of the modulating signal, keeping time

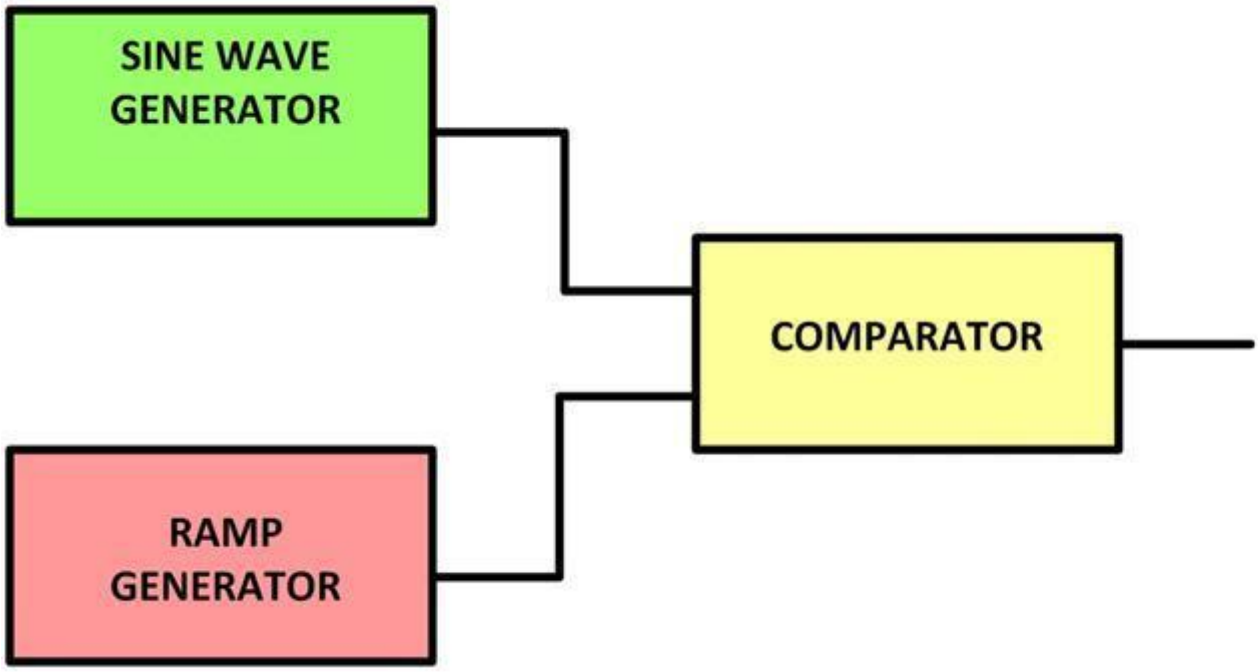


Fig:3.8. SPWM block diagram

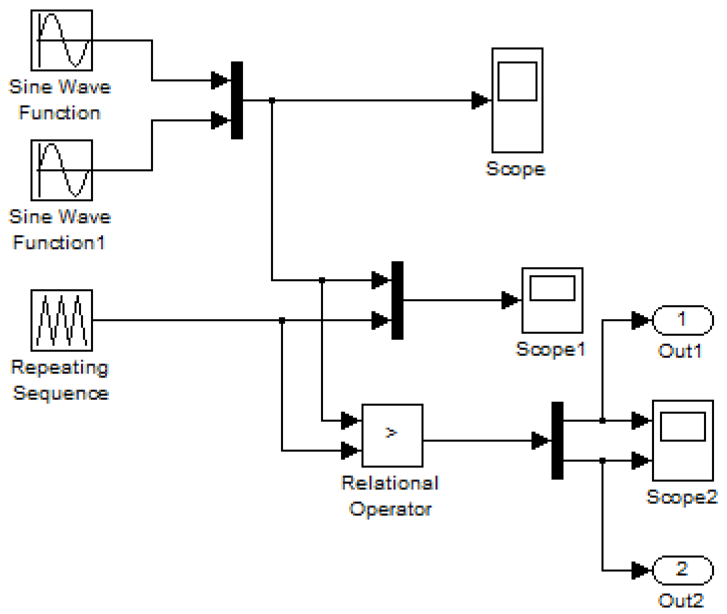


Fig:3.9 SPWM SIMULATION DIAGRAM

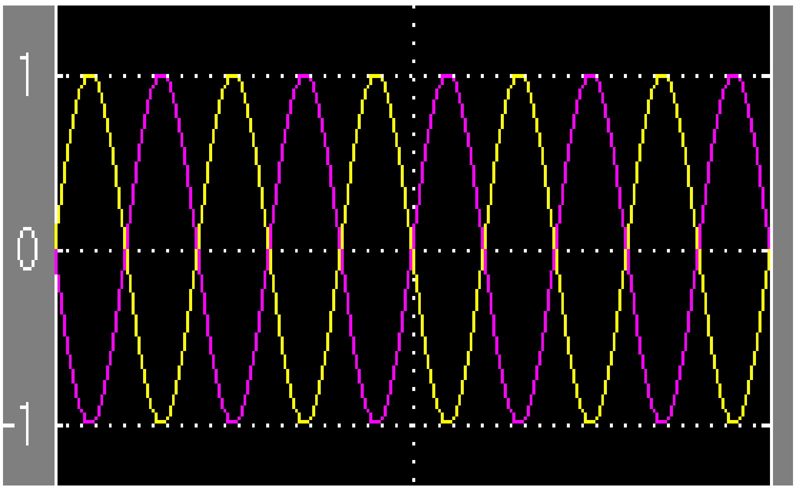


Fig:3.10. SCOPE VIEW

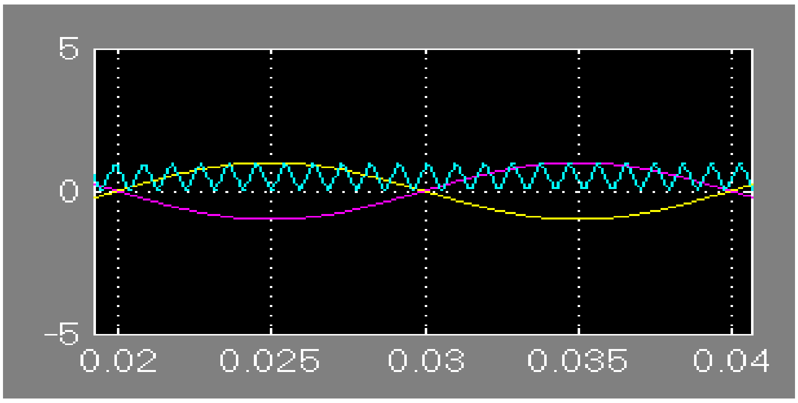


Fig:3.11 SCOPE 1 VIEW

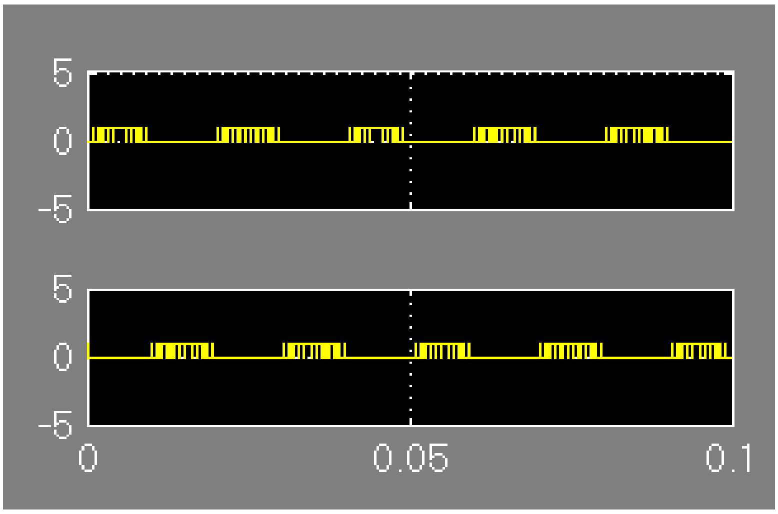


Fig:3.12 SCOPE 2 view

the (ON time + OFF time) time of the pulse as constant. The (ON time + OFF time) of a pulse is called ‘Period’ of the pulse, and the ratio of the ON time or OFF time with the Period is called the ‘Duty Cycle’. Hence the PWM is a kind of modulation which keeps the Period of pulses constant but varying their duty cycle according to the amplitude of the modulating signal.

The conventional method of generating a PWM modulated wave is to compare the message signal with a ramp waveform using a comparator. The block diagram required for the generation of a simple PWM is shown

WHY PULSE WIDTH MODULATION

1.Cheap to make.

2. Little heat whilst working.

3. Low power consumption.

4. Can utilize very high frequencies (40-100 Khz is not uncommon.)

5. Very energy-efficient when used to convert voltages or to dim light bulbs.

6. High power handling capability

7. Efficiency up to 90%

3.1.6 PROPOSED AC DC CONVERTER:

Because thyristors can only be turned on (not off) by control action, and rely on the external AC system to effect the turn-off process, the control system only has one degree of freedom – when to turn on the thyristor. This limits the usefulness of HVDC in some circumstances because it means that the AC system to which the HVDC converter is connected must always contain synchronous machines in order to provide the commutating voltage – the HVDC converter cannot feed power into a passive system. With some other types of semiconductor device such as the insulated-gate bipolar transistor (IGBT), both turn-on and turn-off can be controlled, giving a second degree of freedom. As a result, IGBTs can be used to make self-commutated converters.

In such converters, the polarity of DC voltage is usually fixed and the DC voltage, being smoothed by a large capacitance, can be considered constant. For this reason, an HVDC converter using IGBTs is usually referred to as a voltage-source converter (or voltage-sourced converter). The additional controllability gives many advantages, notably the ability to switch the IGBTs on and off many times per cycle in order to improve the harmonic performance, and the fact that (being self-commutated) the converter no longer relies on synchronous machines in the AC system for its operation. A voltage-sourced converter can therefore feed power to an AC network consisting only of passive loads, something which is impossible with LCC HVDC. Voltage-source converters are also considerably more compact than line-commutated converters (mainly because much less harmonic filtering is needed) and are preferable to line-commutated converters in locations where space is at a premium, for example on offshore platforms.

In contrast to line-commutated HVDC converters, voltage-source converters maintain a constant polarity of DC voltage and power reversal is achieved instead by reversing the direction of current. This makes voltage-source converters much easier to connect into a Multi-terminal HVDC system or “DC Grid”. HVDC systems based on voltage-source converters normally use the six-pulse connection because the converter produces much less harmonic distortion than a comparable LCC and the twelve-pulse connection is unnecessary. This simplifies the construction of the converter transformer. However, there are several different configurations of voltage-source converter and research is continuing to take place into new alternatives.

Two-level converter

From the very first VSC-HVDC scheme installed (the Hellsjön experimental link commissioned in Sweden in 1997[7]) until 2012, most of the VSC HVDC systems built were based on the two level converter. The two-level converter is the simplest type of three-phase voltage-source converter and can be thought of as a six pulse bridge in which the thyristors have been replaced by IGBTs with inverse-parallel diodes, and the DC smoothing reactors have been replaced by DC smoothing capacitors. Such converters derive their name from the fact that the voltage at the AC output of each phase is switched between two discrete voltage levels, corresponding to the electrical potentials of the positive and negative DC terminals. When the upper of the two valves in a phase is turned on, the AC output terminal is connected to the positive DC terminal, resulting in an output voltage of +½ U_d with respect to the midpoint potential of the converter. Conversely when the lower valve in a phase is turned on, the AC output terminal is connected to the negative DC terminal, resulting in an output voltage of -½ U_d. The two valves corresponding to one phase must never be turned on simultaneously, as this would result in an uncontrolled discharge of the DC capacitor, risking severe damage to the converter equipment.

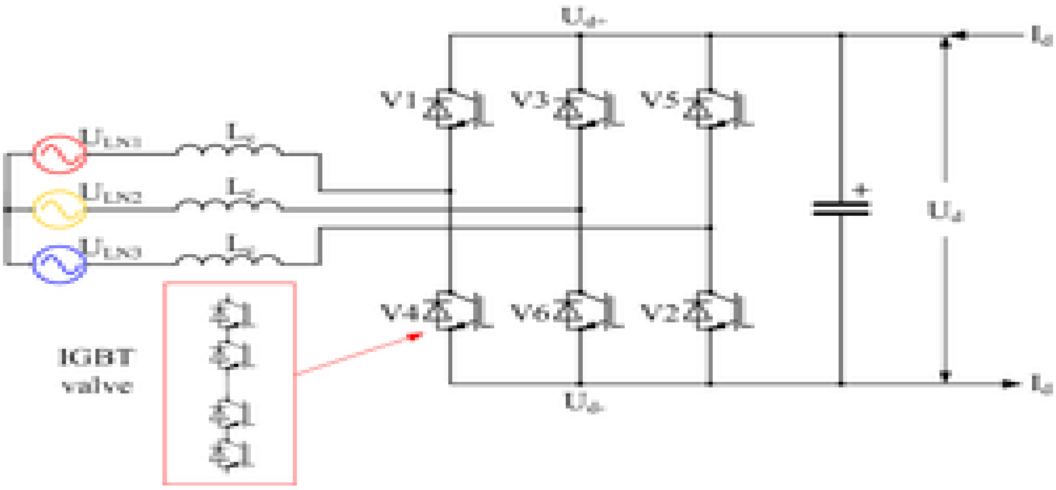


Fig:3.13. Three-phase, two-level voltage-source converter

The simplest (and also, the highest-amplitude) waveform that can be produced by a two-level converter is a square wave; however this would produce unacceptable levels of harmonic distortion, so some form of Pulse-width modulation (PWM) is always used to improve the harmonic distortion of the converter. As a result of the PWM, the IGBTs are switched on and off many times (typically 20) in each mains cycle.[30]

This results in high switching losses in the IGBTs and reduces the overall transmission efficiency. Several different PWM strategies are possible for HVDC[31] but in all cases the efficiency of the two-level converter is significantly poorer than that of a LCC because of the higher switching losses. A typical LCC HVDC converter station has power losses of around 0.7% at full load (per end, excluding the HVDC line or cable) while with 2-

level voltage-source converters the equivalent figure is 2-3% per end.

Another disadvantage of the two-level converter is that, in order to achieve the very high operating voltages required for an HVDC scheme, several hundred IGBTs have to be connected in series and switched simultaneously in each valve.[32] This requires specialized types of IGBT with sophisticated gate drive circuits, and can lead to very high levels of electromagnetic interference. In an attempt to improve on the poor harmonic performance of the two-level converter, some HVDC systems have been built with three level converters. Three-level converters can synthesize three (instead of only two) discrete voltage levels at the AC terminal of each phase: +½ U_d, 0 and -½ U_d. A common type of three-level converter is the diode-clamped (or neutral-point-clamped) converter, where each phase contains four IGBT valves, each rated at half of the DC line to line voltage, along with two clamping diode valves.[32] The DC capacitor is split into two series-connected branches, with the clamping diode valves connected between the capacitor midpoint and the one-quarter and three-quarter points on each phase. To obtain a positive output voltage (+½ U_d) the top two IGBT valves are turned on, to obtain a negative output voltage (-½ U_d) the bottom two IGBT valves are turned on and to obtain zero output voltage the middle two IGBT valves are turned on. In this latter state, the two clamping diode valves complete the current path through the phase.

In a refinement of the diode-clamped converter, the so-called active neutral-point clamped converter, the clamping diode valves are replaced by IGBT valves, giving additional controllability. Such converters were used on the Murray link project in Australia and the Cross Sound Cable link in the United States.[34] However, the modest improvement in harmonic performance came at a considerable price in terms of increased complexity, and the design proved to be difficult to scale up to DC voltages higher than the ±150 kV used on those two projects.

Another type of three-level converter, used in some adjustable-speed drives but never in HVDC, replaces the clamping diode valves by a separate, isolated, flying capacitor connected between the one-quarter and three-quarter points.[32] The operating principle is similar to that of the diode-clamped converter. Both the diode-clamped and flying capacitor variants of three-level converter can be extended to higher numbers of output levels (for example, five), but the complexity of the circuit increases disproportionately and such circuits have not been considered practical for HVDC applications.

First proposed for HVDC applications in 2003 by Marquardt and first used commercially in the Trans Bay Cable project in San Francisco, the Modular Multi-Level

Converter (MMC) is now becoming the most common type of voltage-source converter for HVDC.

Like the two-level converter and the six-pulse line-commutated converter, a MMC consists of six valves, each connecting one AC terminal to one DC terminal. However, where each valve of the two-level converter is effectively a high-voltage controlled switch consisting of a large number of IGBTs connected in series, each valve of a MMC is a separate controllable voltage source in its own right. Each MMC valve consists of a number of independent converter submodules, each containing its own storage capacitor. In the most common form of the circuit, the half-bridge variant, each submodule contains two IGBTs connected in series across the capacitor, with the midpoint connection and one of the two capacitor terminals brought out as external connections.[35]

Depending on which of the two IGBTs in each submodule is turned on, the capacitor is either bypassed or connected into the circuit. Each submodule therefore acts as an independent two-level converter generating a voltage of either 0 or U_{sm} (where U_{sm} is the submodule capacitor voltage). With a suitable number of submodules connected in series, the valve can synthesize a stepped voltage waveform that approximates very closely to a sine-wave and contains very low levels of harmonic distortion.

3.1.7 BLOCK DIAGRAM

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block). The lines represent connections of block inputs to block outputs. Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time. A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate. A block comprises one or more of the following:

1) A set of inputs,

2) A set of states, and

3) A set of outputs.

A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance. Continuous Versus discrete Blocks Simulink's standard block set includes continuous blocksand discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only atintegral multiples of a fixed interval called the block's sample time. Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, dependingon whether they are driven by continuous or discrete blocks.

A block that can beeither discrete or continuous is said to have an implicit sample rate. The implicitsample time is continuous if any of the block's inputs are continuous. The implicit sample time is equal to the shortest input sample time if all the input sample timesare integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times.

Simulink can optionally color code a block diagram to indicate the sampletimes of the blocks it contains, e.g., black (continuous), magenta (constant),yellow (hybrid), red (fastest discrete), and so on. The block contains block name,icon, and block library that contain the block, the purpose of the block SIMULINK BLOCK LIBRARIES

Simulink organizes its blocks into block libraries according to their behavior.

1) The Sources library contains blocks that generate signals.
2) The Sinks library contains blocks that display or write block output.
3) The Discrete library contains blocks that describe discrete-time components.
4) The Continuous library contains blocks that describe linear functions.
5) The Math library contains blocks that describe general mathematics functions.
6) The Functions & Tables library contains blocks that describe general functions and table look-up operations.
7) The Nonlinear library contains blocks that describe nonlinear functions.
8) The Signal & Systems library contains blocks that allow multiplexing and demultiplexing, implement external input/output, pass data to other parts of the model, and perform other functions.
9) The Subsystems library contains blocks for creating various types of subsystems.
10) The Block sets and Toolboxes library contains the Extras block library of specialized blocks.

3.1.8 SUB SYSTEMS

Simulink allows to model a complex system as a set of interconnected subsystems each of which is represented by a block diagram. We create a subsystem using Simulink's Subsystem block and the Simulink model editor. We can embed subsystems with subsystems to any depth to create hierarchical models. We can create conditionally executed subsystems that are executed onlywhen a transition occurs on a triggering or enabling input.

3.1.9 SOLVERS

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model. The process of computing the successive states of a system from its model is known as solving the model. No single method of solving a model suffices for allsystems. Accordingly, Simulink provides a set of programs, known as solvers, that each embody a particular approach to solving a model. The Simulation Parameters dialog box allows us to choose the solver most suitable for our model. Fixed-Step and Variable-Step Solvers

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size. Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly and increasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time, required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step size. You can specify the step size or let the solver choose the step size. Generally, decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation. They reduce the step size to increase accuracy when a model's states are changing rapidly and increase the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence the simulation time required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

Fixed-step and variable-step solvers compute the next simulation time as the sum of the current simulation time and the step size. The Type control on the Solver configuration pane allows you to select the type of solver. With a fixed-step solver, the step size remains constant throughout the simulation. With a variable-step solver, the step size can vary from step to step, depending on the model dynamics. In particular, a variable-step solver increases or reduces the step size to meet the error tolerances that you specify.

The choice between these types depends on how you plan to deploy your model and the model dynamics. If you plan to generate code from your model and run the code on a real-time computer system, choose a fixed-step solver to simulate the model. You cannot map the variable-step size to the real-time clock.

If you do not plan to deploy your model as generated code, the choice between a variable-step and a fixed-step solver depends on the dynamics of your model. A variable-step solver might shorten the simulation time of your model significantly. A variable-step solver allows this saving because, for a given level of accuracy, the solver can dynamically adjust the step size as necessary. This approach reduces the number of steps required. The fixed-step solver must use a single step size throughout the simulation, based on the accuracy requirements. To satisfy these requirements throughout the simulation, the fixed-step solver typically requires a small step.

3.1.10 Continuous and Discrete Solvers

Continuous solvers use numerical integration to compute a model's continuous states at the current time step from the states at previous time steps and the state derivatives. Continuous solvers rely on the model's blocks to compute the values of the model's discrete states at each time step. Mathematicians have developed a wide variety of numerical integration techniques for solving the ordinary differential equations (ODEs) that represent the continuous states of dynamic systems. Simulink provides an extensive set offixed-step and variable-step continuous solvers, each implementing a specific ODE solution method. Some continuous solvers subdivide the simulation time span into major and minor steps, where a minor time step represents a subdivisionof the major time step. The solver produces a result at each major time step. It use results at the minor time steps to improve the accuracy of the result at the major time step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time-step for a model and nothing else. They do notcompute continuous states and they rely on the model's blocks to update the model's discrete states. We can use a continuous solver, but not a discrete solver,to solve a model that contains both continuous and discrete states. This is becausea discrete solver does not handle continuous states. If you select a discrete solverfor a continuous model, Simulink disregards your selection and uses a continuous solver instead when solving the model.

Simulink provides two discrete solvers, a fixed-step discrete solver and a variable-step discrete solver. The fixed-step solver by default chooses a step size and hence simulation rate fast enough to track state changes in the fastest block in our model. The variable-step solver adjusts the simulation step size to keep pace with the actual rate of discrete state changes in our model. This can avoid unnecessary steps and hence shorten simulation time for multirate models.

Simulink provides both continuous and discrete solvers. When you select a solver type, you can also select a specific solver. Both sets of solvers include discrete and continuous solvers. Discrete and continuous solvers rely on the model blocks to compute the values of any discrete states. Blocks that define discrete states are responsible for computing the values of those states at each time step. However, unlike discrete solvers, continuous solvers use numerical integration to compute the continuous states that the blocks define. When choosing a solver, determine first whether to use a discrete solver or a continuous solver.

If your model has no continuous states, then Simulink switches to either the fixed-step discrete solver or the variable-step discrete solver. If your model has only continuous states or a mix of continuous and discrete states, choose a continuous solver from the remaining solver choices based on the dynamics of your model. Otherwise, an error occurs.

Continuous solvers use numerical integration to compute a model's continuous states at the current time step based on the states at previous time steps and the state derivatives. Continuous solvers rely on the individual blocks to compute the values of the model's discrete states at each time step.

Discrete solvers exist primarily to solve purely discrete models. They compute the next simulation time step for a model and nothing else. In performing these computations, they rely on each block in the model to update its individual discrete states. They do not compute continuous states.

The solver library contains two discrete solvers: a fixed-step discrete solver and a variable-step discrete solver. The fixed-step solver by default chooses the step size and simulation rate fast enough to track state changes in the fastest block in your model. The variable-step solver adjusts the simulation step size to keep pace with the actual rate of discrete state changes in your model. This adjustment can avoid unnecessary steps and shorten simulation time for multirate models. See Sample Times in Systems for more information.

3.1.11 MODEL EXECUTION PHASE

In the simulation model execution phase, Simulink successively computesthe states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps. The length of time between steps is called the step size. The step size depends on thetype of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states have discontinuities (Zero Crossing Detection). At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated. At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

1) Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and statesto the output function as it may require these arguments to compute the block's output. Simulink updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.
2) Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's continuous states by numerically integratingthe time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.
3) Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.
4) Computes the time for the next time step.

Simulink repeats steps 1 through 4 until the simulation stop time is reached.

Block Sorting Rules

Simulink uses the following basic update rules to sort the blocks:

1) Each block must be updated before any of the direct-feed through blocks that it drives. This rule ensures that the inputs to direct-feed through blocks will be valid when they are updated.

2) Non direct-feed through blocks can be updated in any order as long as theyare updated before any direct-feed through blocks that they drive. This rule can be met by putting all non direct-feed through blocks at the head of the update list in any order. It thus allows Simulink to ignore non direct-feed through blocks during the sorting process.

The result of applying these rules is an update list in which non direct- feed through blocks appear at the head of the list in no particular order followed by direct-feed through blocks in the order required to supply valid inputs to the blocks they drive. During the sorting process, Simulink checks for and flags the occurrence of algebraic loops, that is, signal loops in which an output of a direct-feed through block is connected directly or indirectly to one of the block's inputs.Such loops seemingly create a deadlock condition since Simulink needs the input of a direct-feed through block in order to compute its output. However, an algebraic loop can represent a set of simultaneous algebraic equations (hence thename) where the block's input and output are the unknowns. Further, these equations can have valid solutions at each time step. Accordingly, Simulink assumes that loops involving direct-feed through blocks do, in fact, represent a solvable set of algebraic equations and attempts to solve them each time the block is updated during a simulation.

3.1.12 DETERMINING BLOCK UPDATE ORDER

During a simulation, Simulink updates the states and outputs of a model's blocks once per time step. The order in which the blocks are updated is thereforecritical to the validity of the results. In particular, if a block's outputs are a function of its inputs at the current time step, the block must be updated after theblocks that drive its inputs. Otherwise, the block's outputs will be invalid. The order in which blocks are stored in a model file is not necessarily the order in which they need to be updated during a simulation. Consequently, Simulink sortsthe blocks into the correct order during the model initialization phase.

In order to create a valid update ordering, Simulink categorizes blocks according to the relationship of outputs to inputs. Blocks whose current outputs depend on their current inputs are called direct feed through blocks. All other blocks are called non direct-feed through blocks. Examples of direct-feed through blocks include the Gain, Product, and Sum blocks. Examples of non direct-feed through blocks include the Integrator block (its output is a function

purely of its state), the Constant block (it does not have an input), and the Memory block (its output is dependent on its input in the previous time step). Simulink allows you to assign update priorities to blocks. Simulink updates higher priority blocks before lower priority blocks. Simulink honors the priorities only if they are consistent with its block sorting rules.
Some of SIMULINK blocks, which are used in this thesis, are given

below.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

3.2 MODULE DEFINITION

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactivelanguage such as C or FORTRAN.

3.3 MODULE FUNTIONALITIES*:*

Three phase source block

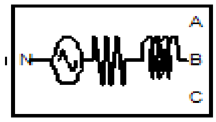


Fig:3.14. Three Phase Source Block

The Three-Phase Source block implements a balanced three-phase voltage source with internal R-L impedance. The three voltage sources are connected in Y with a neutral connection that can be internally ground.

VI measurement block:

The Three-Phase V-I Measurement block is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents

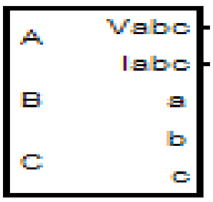
3 

Fig:3.15.Three Phase V-I Measurement

Scope:

Display signals generated during a simulation. The Scope block displays its input with respect to simulation time. The Scope block can have multiple axes (one per port); all axes have a common time range with independent y-axes. The Scope allows you to adjust the amount of time and the range of input values displayed. You can move and resize the Scope window and you can modify the Scope's parameter values during the simulation

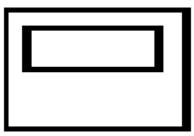


Fig:3.16. Scope

Three-Phase Series RLC Load:

The Three-Phase Series RLC Load block implements a three-phase balanced load as a series combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

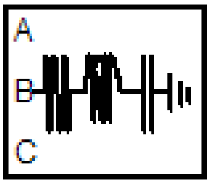


Fig:3.17Three-Phase Series RLC Load

Three-Phase Breaker block:

The Three-Phase Breaker block implements a three-phase circuit breaker where the opening and closing times can be controlled either from an external Simulink signal or from an internal control signal.

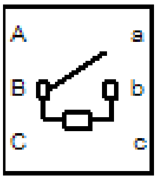


Fig:3.18. Three-Phase Breaker Block

Integrator:

Library: Continuous

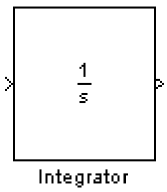


Fig:3.19. Integrator

The integrator block outputs the integral of its input at the current time step. The following equation represents the output of the block y as a function of its input u and an initial condition y_0, where y and u are vector functions of the current simulation time t.

Breaker:

Implement circuit breaker opening at current zero crossing.

Library: Elements

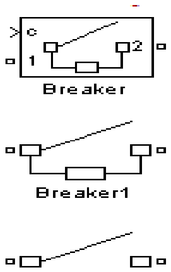


Fig:3.20. Circuit Breaker

Purpose: The Breaker block implements a circuit breaker where the opening and closing times can be controlled either from an external SIMULINK signal (external control mode), or from an internal control timer (internal control mode).

A series Rs-Cs snubber circuit is included in the model. It can be connected to the circuit breaker. If the Breaker block happens to be in series with an inductive circuit, an open circuit or a current source, you must use a snubber.

When the breaker block is set in external control mode, a SIMULINK input appears on the block icon. The control signal connected to the SIMULINK input must be either 0 or 1 (0 to open the breaker, 1 to close it).

When the Breaker block is set in internal control mode, the switching times are specified in the dialog box of the block.

When the breaker is closed, it is represented by a resistance Ron. The Ron value can be set as small as necessary in order to be negligible compared with external components (a typical value is 10 m ohms). When the breaker is open, it has an infinite resistance.

Three-Phase Programmable Voltage Source:

Implement three-phase voltage source with programmable time variation of amplitude, phase, frequency, and harmonics

Library: Electrical Sources

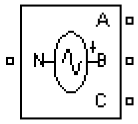


Fig:3.21. Three Phase Voltage Sources

Purpose: This block is used to generate a three-phase sinusoidal voltage with time-varying parameters. It can be programmed with the time variation for the amplitude, phase or frequency of the fundamental component of the source. In addition, two harmonics can be programmed and superimposed on the fundamental signal.

Trigonometric Function:

Specified trigonometric function on input

Library: Math Operations

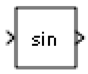


Fig:3.22. Trigonometric Functions

Purpose: The Trigonometric Function block performs common trigonometric functions

Three-Phase Transformer (Two Windings):

Implement three-phase transformer with configurable winding connections

Library: Elements

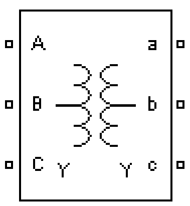


Fig:3.23. Three Phase Transformer

Purpose:

The Three-Phase Transformer (Two Windings) block implements a three-phase transformer using three single-phase transformers. The saturation characteristic, when activated, is the same as the one described for the saturable Transformer block, and the icon of the block is automatically updated. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

Three-Phase Transformer 12 Terminals:

Implement three single-phase, two-winding transformers where all terminals are accessible

Library: Elements

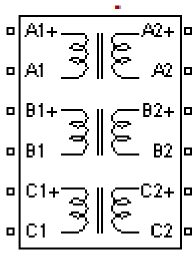


Fig:3.24. Two winding Transformer

Purpose: The Three-Phase Transformer 12 Terminals block implements three single-phase, two-winding linear transformers where all the twelve winding connectors are accessible. The block can be used in place of the Three-Phase Transformer (Two Windings) block to implement a three-phase transformer when primary and secondary are not necessarily connected in Star or Delta.

IGBT/Diode

Implements ideal IGBT, GTO, or MOSFET and antiparallel diode

Library: Power Electronics

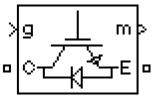


Fig:3.25.IGBT

Purpose: The IGBT/Diode block is a simplified mode of an IGBT (or GTO or MOSFET)/Diode pair where the forward voltages of the forced-commutated device and diode are ignored.

3.4 RELATED GRAPHS

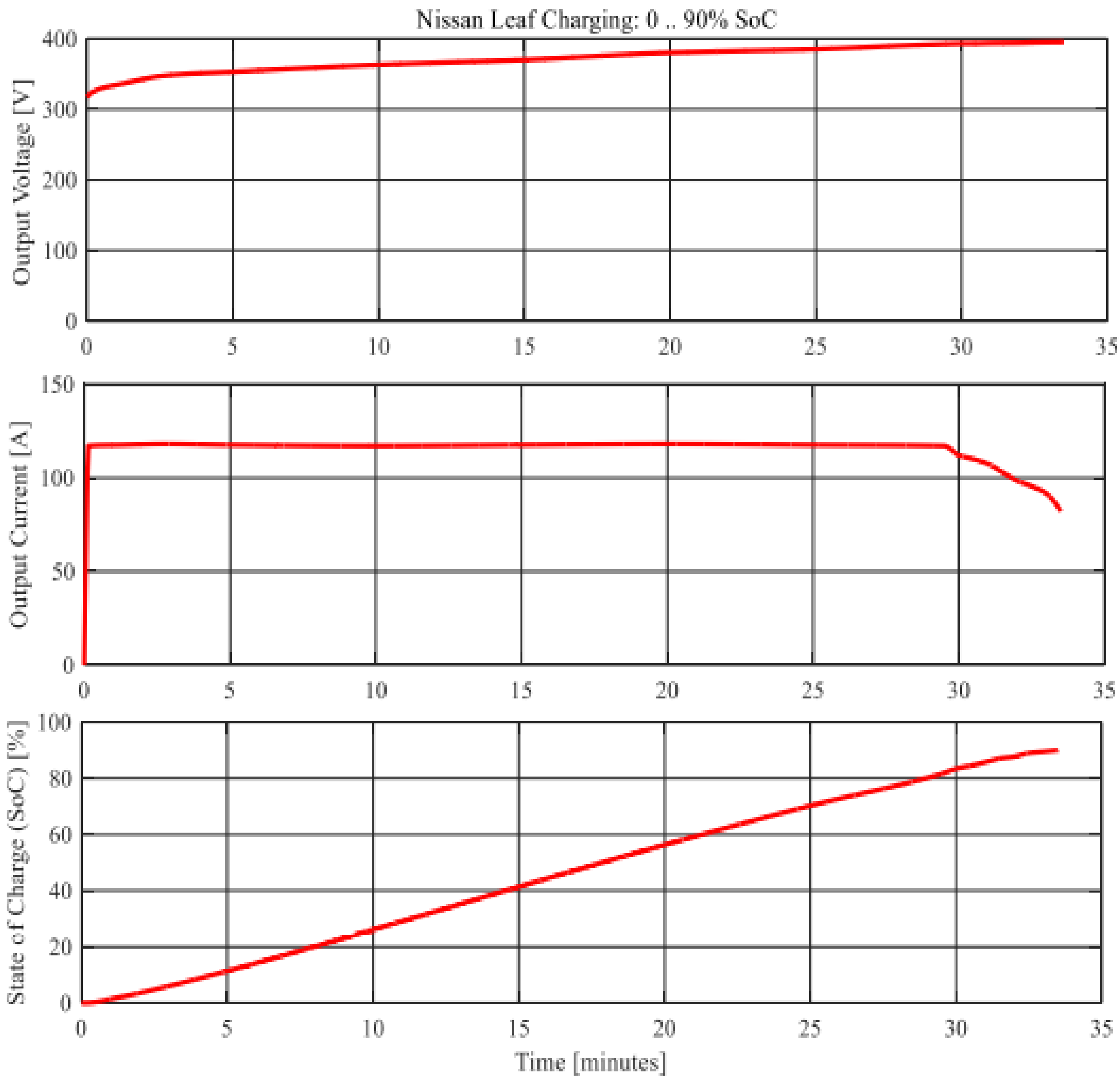


Fig. 3.26. charging profile of a 30 kWh Nissan Leaf EV from 0% to 90% of state of-charging

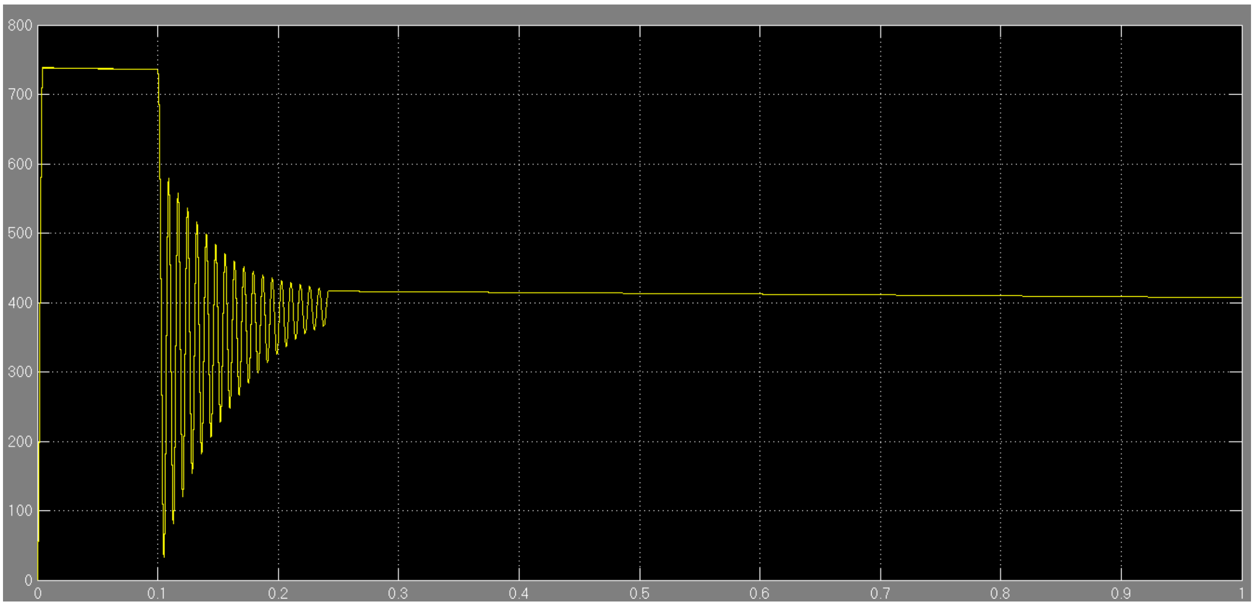


Fig. 3.27. DC LINK VOLTAGE WITHOUT ANY COMPENSATION

4. Project Implementation:

4.0. Implementation Stages:

4.1. Mode of Implementation:

Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. The simulation results can be put in the MATLAB workspace for post processing and visualization .Here we will be simulating three scenarios and by them we can obtain the stability criterion.

Simulink simulates a dynamic system by computing its states at successive time step solver a specified time span, using information provided by the model. The process of computing the successive states of a system from its model is known as solving the model. No single method of solving a model suffices for all systems Fixed-step solvers solve the model at regular time intervals from the beginning to the end of the simulation. The size of the interval is known as the step-size. We can specify the step size or let the solver choose the step size. Generally decreasing the step size increases the accuracy of the results while increasing the time required to simulate the system.

Variable-step solvers vary the step size during the simulation, reducing the step size to increase accuracy when a model's states are changing rapidly and increasing the step size to avoid taking unnecessary steps when the model's states are changing slowly. Computing the step size adds to the computational overhead at each step but can reduce the total number of steps, and hence simulation time, required to maintain a specified level of accuracy for models with rapidly changing or piecewise continuous states.

PROPOSED CIRCUIT CONFIGURATION WITHOUT COMPENSATION:

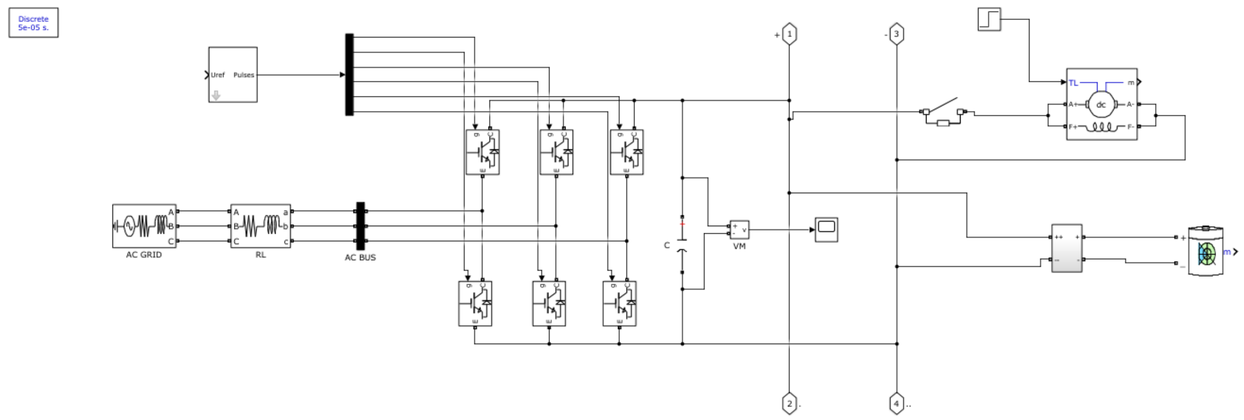


Fig:4.1.PROPOSED CIRCUIT CONFIGURATION WITHOUT COMPENSATION

This is the basic Simulink model of the DC power integration system without compensation. This basic module has the instability of the dc power in the output. To identify the best stability module we will introduce three charging modes by which the output scope waves can be occurred in the nyquist plots. So by them we will be comparing all the output nyquist waveforms and can obtain a conclusion about the best stability method.

PROPOSED CIRCUIT CONFIGURATION WITH CURRENT CHARGING METHOD

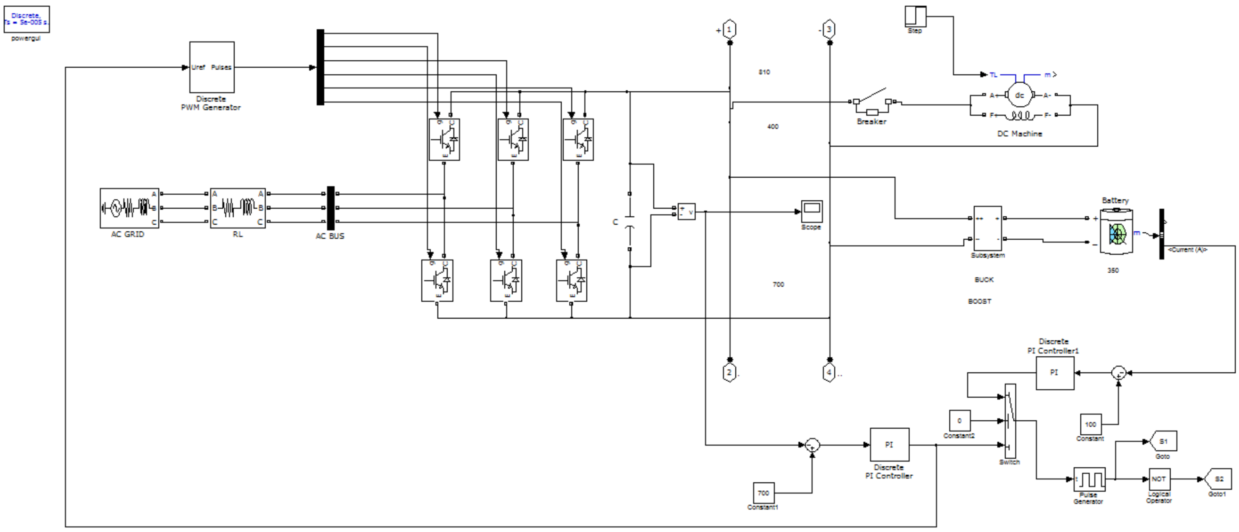


Fig:4.2.PROPOSED CIRCUIT CONFIGURATION WITH CURRENT CHARGING METHOD

In current charging method, the current is kept as constant by using PI controller which is given as a feedback to the dc side bus. When the constant current is set to the circuit model then the output voltage waveform will be obtained in the scope. As power is drawn from the AC grid through the AC bus it will be passed through converter. In the converter PWM module plays a key role in reducing the harmonics. Through the DC bus the dc power is passed towards the DC-DC converter and to the battery. Here PI controller is installed taking power from the battery and feedback is set to the dc bus so as to reduce the stability error signals. Here in the PI controller current is made constant and the plot is drawn in nyquist plot.

PROPOSED CIRCUIT CONFIGURATION WITH POWER CHARGING METHOD

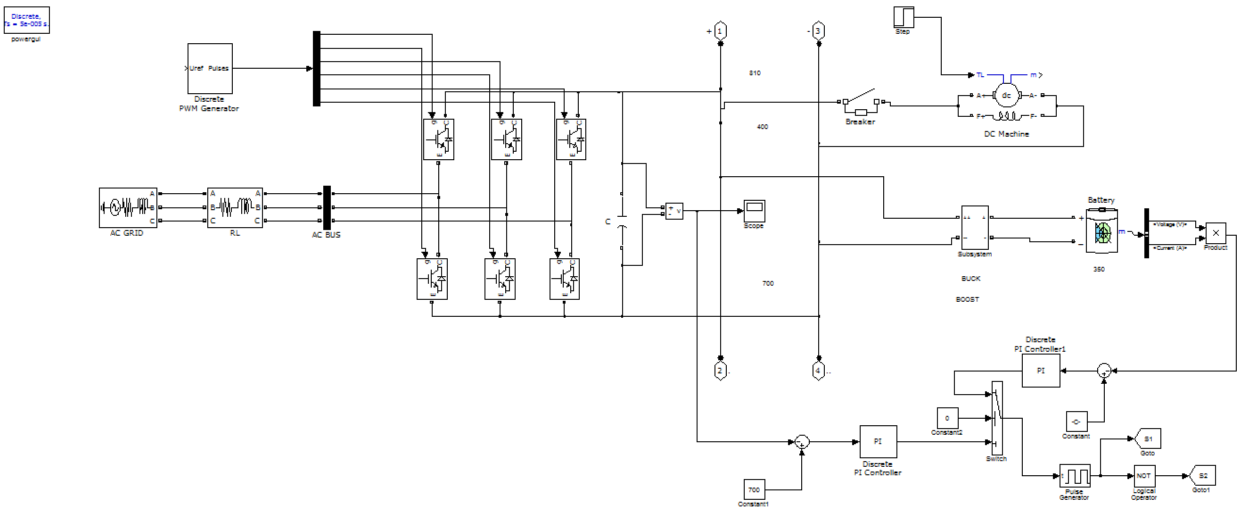


Fig:4.3.PROPOSED CIRCUIT CONFIGURATION WITH POWER CHARGING METHOD

In power charging method, the power is kept as constant by using PI controller which is given as a feedback to the dc side bus. Here voltage and current are to considered so as to set the power as constant by using PI controller. When the constant power is set to the circuit model then the output voltage waveform will be obtained in the scope. As power is drawn from the AC grid through the AC bus it will be passed through converter. In the converter PWM module plays a key role in reducing the harmonics. Through the DC bus the dc power is passed towards the DC-DC converter and to the battery. Here PI controller is installed taking power from the battery and feedback is set to the dc bus so as to reduce the stability error signals. Here in the PI controller power is made constant and observed in scope.

PROPOSED CIRCUIT CONFIGURATION WITH VOLTAGE CHARGING METHOD

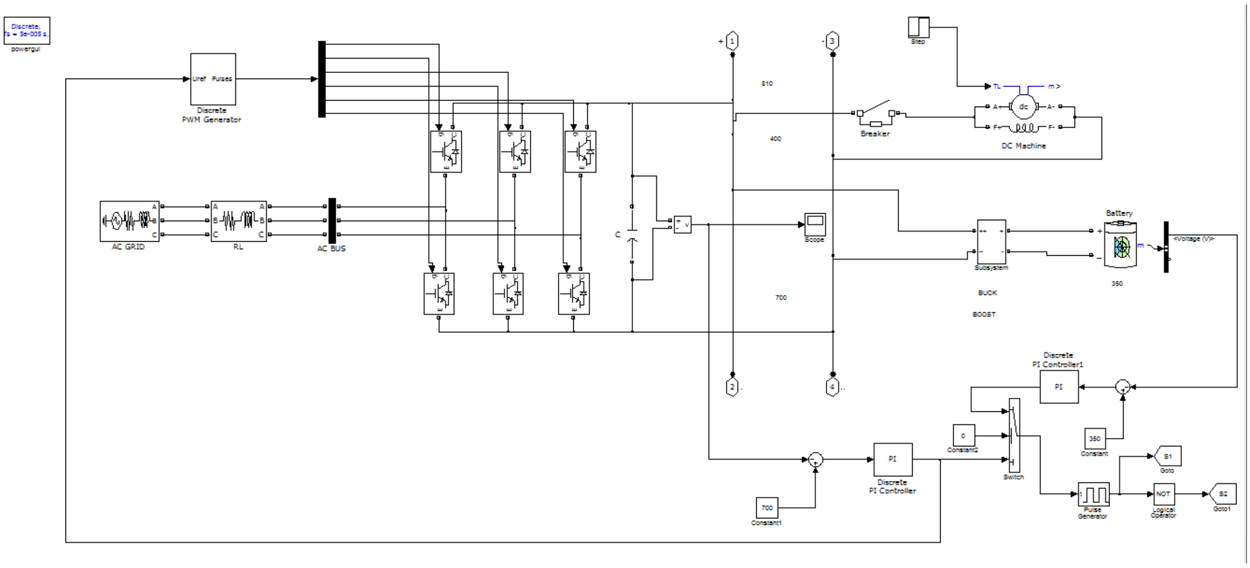
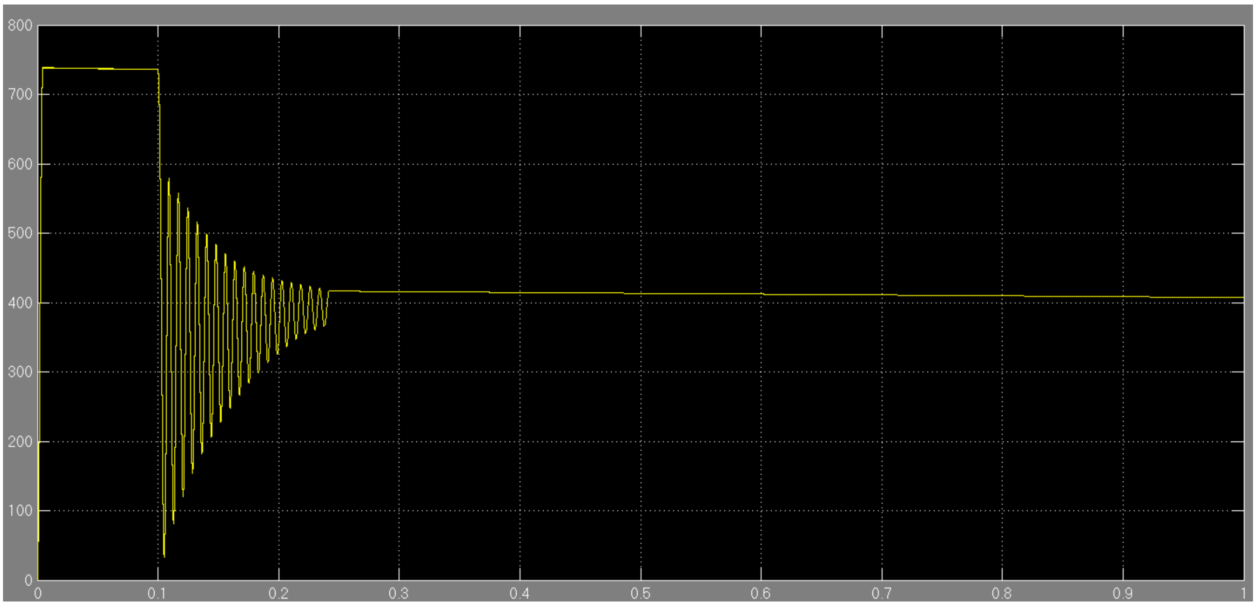


Fig:4.4.PROPOSED CIRCUIT CONFIGURATION WITH VOLTAGE CHARGING METHOD

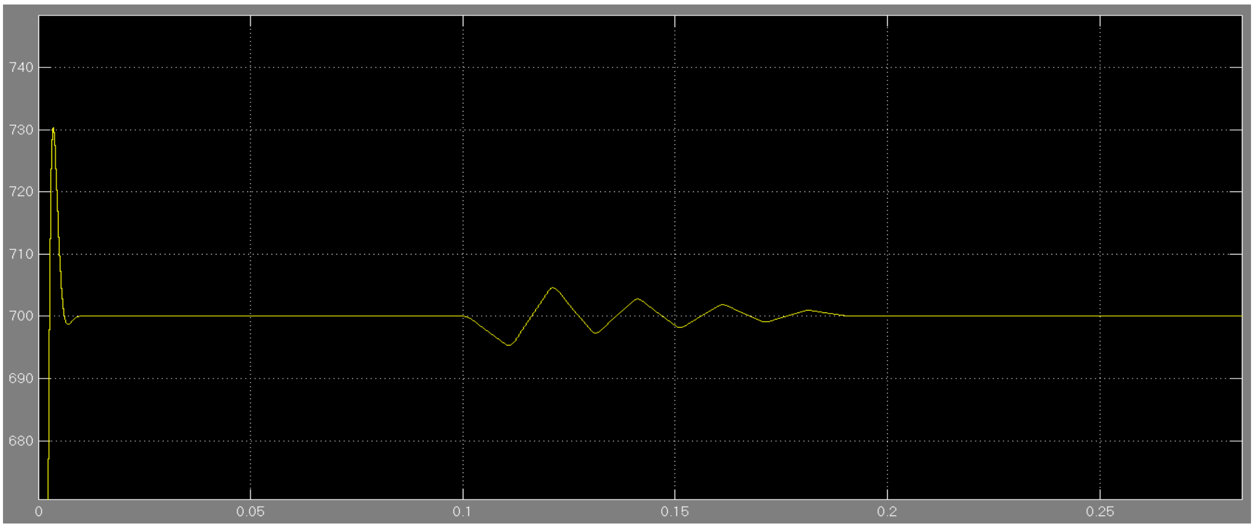
In voltage charging method, the voltage is kept as constant by using PI controller which is given as a feedback to the dc side bus. When the constant voltage is set to the circuit model then the output voltage waveform will be obtained in the scope. As power is drawn from the AC grid through the AC bus it will be passed through converter. In the converter PWM module plays a key role in reducing the harmonics. Through the DC bus the dc power is passed towards the DC-DC converter and to the battery. Here PI controller is installed taking power from the battery and feedback is set to the dc bus so as to reduce the stability error signals. Here in the PI controller voltage is made constant and the plot is drawn in Nyquist plot

4.2. Result:



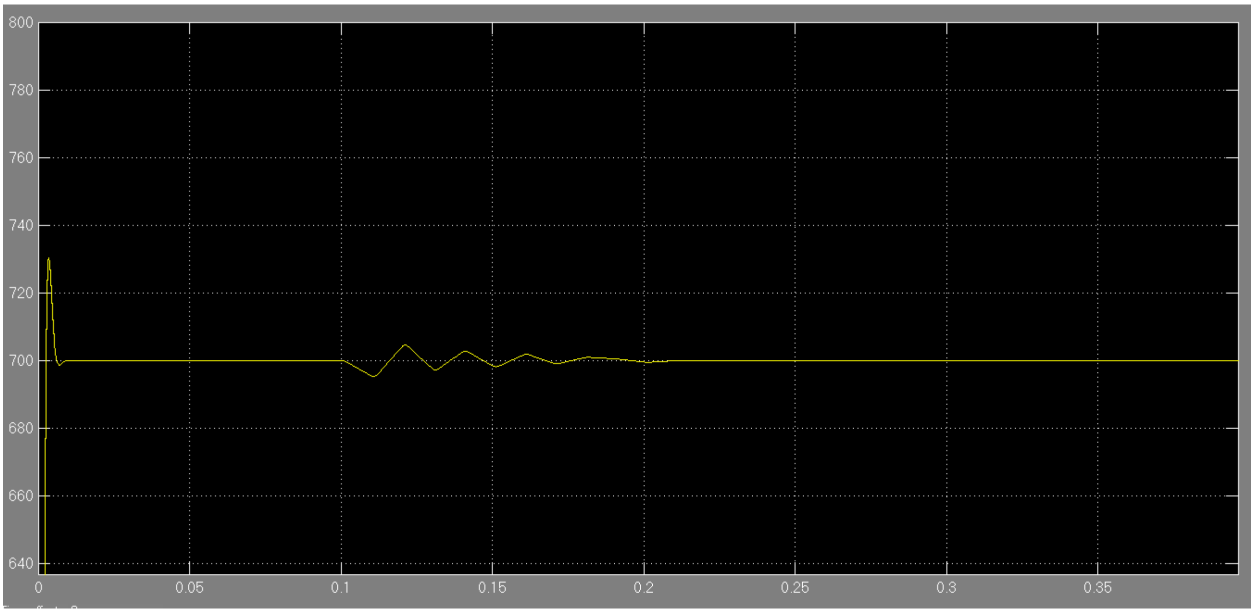
OS:4.5. DC LINK VOLTAGE WITHOUT ANY COMPENSATION

Here in this nyquist plot of circuit without any compensation the harmonic distortions have been occurred in wide range. These distortions are being observed through scope. So to reduce these distortions the following three methods have been installed to get the stabililty of the system.



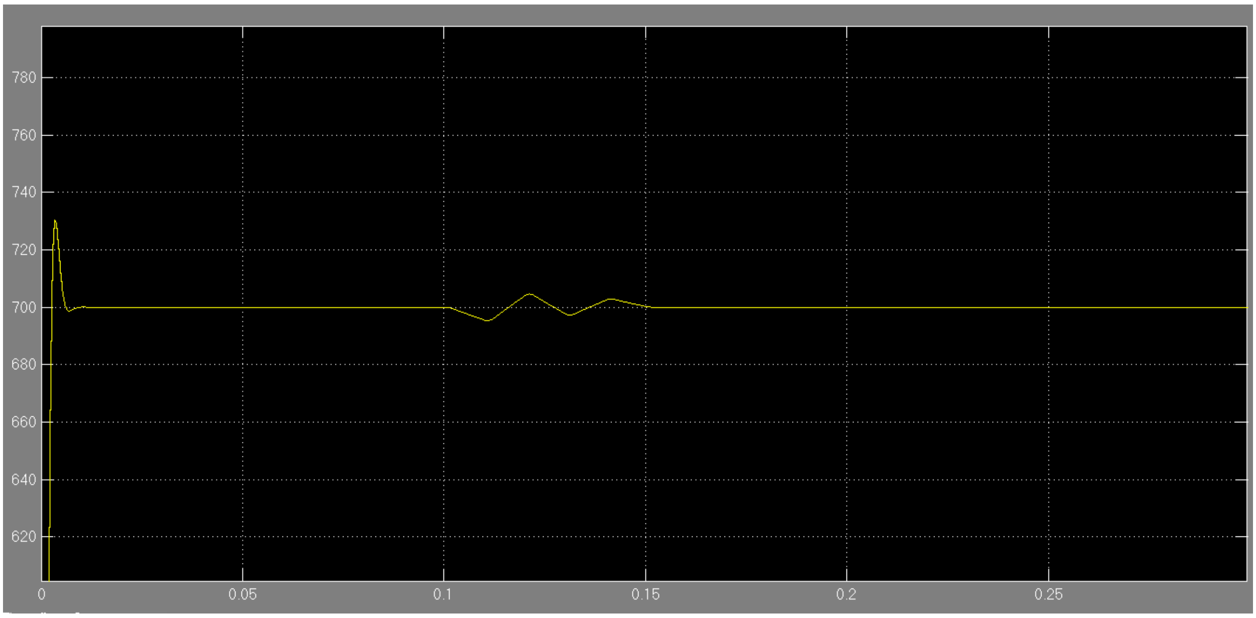
OS:4.6.DC LINK VOLTAGE WITH CURRENT CHARGING METHOD

In the circuit with constant current as a motive the nyquist plot has been acquired with few harmonic distortions. These distortions are being recorded so that it can be compared with other modes of nyquist plots.



OS:4.7.DC LINK VOLTAGE WITH POWER CHARGING METHOD

In the circuit with constant power as a motive the nyquist plot has been acquired with few harmonic distortions. These distortions are being recorded so that it can be compared with other modes of nyquist plots. In this the harmonics are the combination of constant voltage and current which can be set by the help of PI controller. As compared with the current charging method, the power charging method has higher distortions which is comparatively tough to obtain the stability



OS:4.8.DC LINK VOLTAGE WITH VOLTAGE CHARGING METHOD

In the circuit with constant voltage as a motive the Nyquist plot has been acquired with few harmonic distortions. These distortions are being recorded so that it can be compared with other modes of Nyquist plots. As compared with other Nyquist plots, we can observe that the voltage charging method has the least distortions so that the stability can be enabled by using the voltage charging method. These minute distortions occurred due to constant voltage.

5. CONCLUSION AND FUTURE ENHANCEMENT

This project is advance development in power systems where we are eliminating Transformers and other costly equipment needed for High voltage conversion. Future scope of this project is to connect Renewable Sources like Solar PV panels to the system. By connecting PV panels, we can also supply energy towards the Grid as it is a bidirectional system. A method was proposed for enhancing the stability of a dc distribution system intended to integrate EVs with an ac power grid. The dc distribution system is interfaced with the host ac grid via a VSC and can also embed DC modules.

Thus, bidirectional dc–dc power-electronic converters act as battery chargers and interface the EVs with the dc distribution system, while DC modules are interfaced with the dc distribution system via unidirectional dc–dc converters. It was demonstrated the proposed stability enhancement method mitigates the issue of instability by altering the power set points of the battery chargers, without a need for changing system parameters or hardware. DC power distribution system is an important development direction of future urban power distribution system.

The project presented mathematical models for the original and modified systems and demonstrated that the proposed technique expands the stable operating region of the dc distribution system. Simulation studies were conducted to demonstrate the effectiveness of the proposed method. This proposes a dc distribution system for power system integration of plugin electric vehicles. The proposed system is expected to be more efficient an economical than an equivalent aggregate of ac-dc battery charges connected to the ac grid, since it relieves the battery chargers from the need for a bidirectional, front-end, power-factor correction (PFC) stage. Further, due to its DC nature, the proposed system is amenable to integration of Photovoltaic (PV) modules.

PUBLICATION

PROPOSED TITLE : Stability Analysis Of A Dc Distribution System For Power System Integration Of Plug-In Electric Vehicles.

CONFERENCE NAME: International conference on "Recent Developments in Power Engineering (ICRDPE21)", organized by Department of Electrical And Electronics **ST.MARTIN'S ENGINEERING COLLEGE, HYDERABAD**

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APPENDICES

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

The MATLAB system consists of six main parts:

(a) Development Environment

This is the set of tools and facilities that help to use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

(b) The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

(c) The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

(d) Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

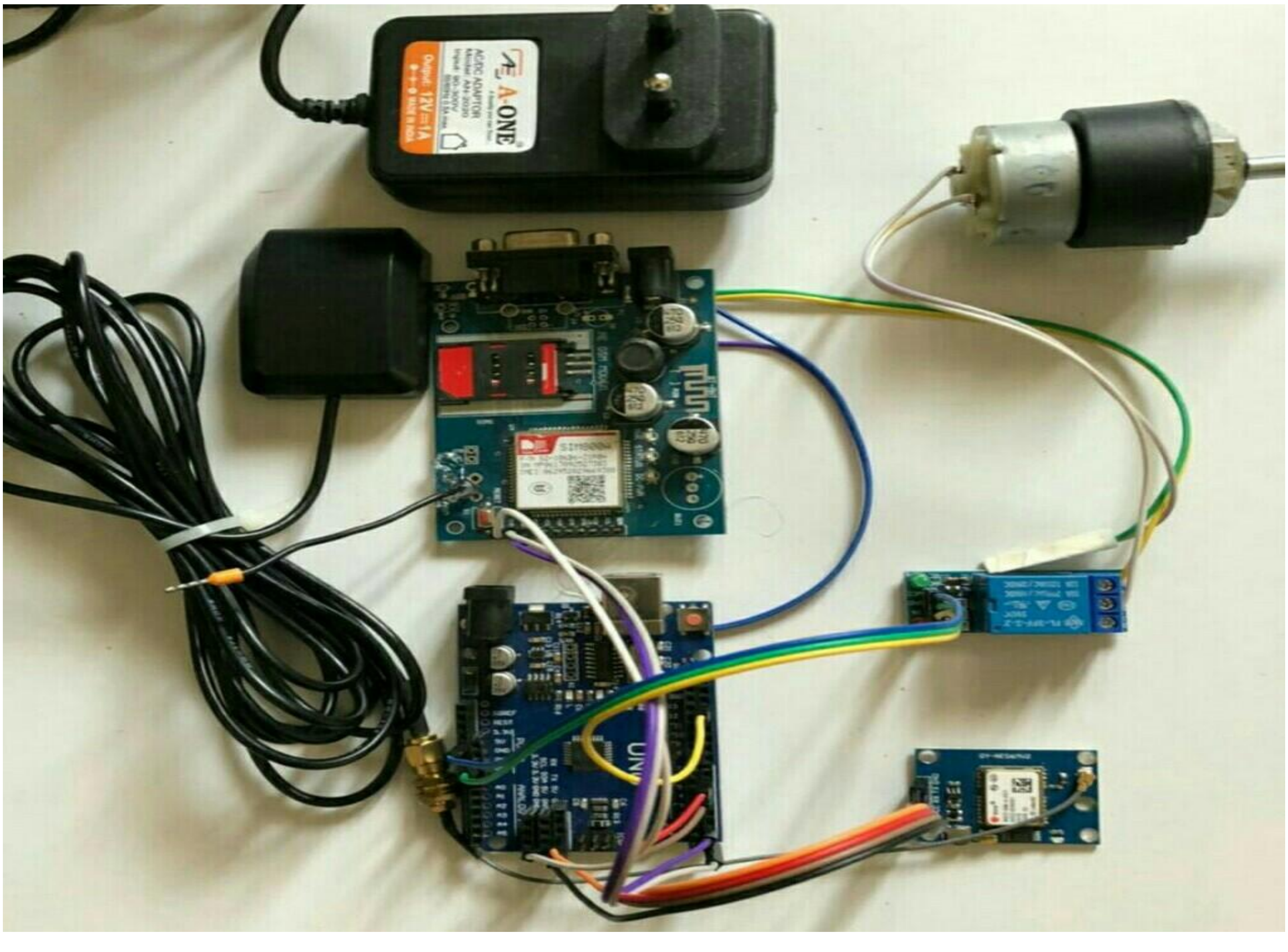
(e) The MATLAB Application Program Interface (API)

This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

(f) MATLAB Documentation

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

VEHICLE TRACKING SYSTEM



A

PROJECT REPORT

On

VEHICLE TRACKING SYSTEM

Submitted by

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in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

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ST. MARTIN'S ENGINEERING COLLEGE

(An Autonomous Institute)

Dhulapally, Secunderabad – 500 100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled **VEHICLE TRACKING SYSTEM**, is being submitted by **1. Mr.KOMMINENI VAMSHI Regd.No:17K81A0225, 2. Mr.GALALA SAIKIRAN Regd.No:17K81A0213, 3. Mr.ATHELLI PRUDHVIRAJ GOUD Regd.No:17K81A0204 4. Mr.CHILUKA ANVESH KUMAR Regd.No:18K85A0212** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN ELECTRICAL AND ELECTRONICS ENGINEERING** is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

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Assistant Professor
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Dr.N.Ramchandra
Professor & HOD
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Internal Examiner

External Examiner

Place: Dhulapally

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of **ELECTRICAL AND ELECTRONICS ENGINEERING**, session: 2017 - 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled **VEHICLE TRACKING SYSTEM** is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

This project presents a vehicle tracking system that can be remotely monitored by a GSM phone. It is designed to track the position of a vehicle at any period of time. It comprises of a GPS receiver, a microcontroller and a GSM module. The combination of these technologies produces a tracking system. The GPS continuously takes input data from the satellite and stores the latitude and longitude values in a ATmega328P microcontroller. This basically means that if a person has to track a vehicle, a message has to be sent to a GSM device, by which it gets activated. The location of the vehicle is identified using global positioning system (GPS) and global system for mobile communication (GSM). These systems constantly watch a moving vehicle and report the status on demand. When theft is identified, the owner sends an SMS to the microcontroller and the microcontroller sends back a message containing the location of the vehicle in terms of latitude, longitude and time.

Key Words: Vehicle tracking security, GSM, GPS, SMS, microcontroller.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

The rising cases of vehicle theft, vehicle hijack, kidnapping, diversion of crude oil and petrol, change of route by drivers of transport companies and theft of valuable containers and items in sea ports have necessitated the use of a more reliable security system in vehicles and storage facilities for valuable items. A security system that can track, monitor and give feedback of the location of the vehicle or container.

Several technologies have been developed to provide reliable security for vehicles and valuable goods. Some of the technologies are locking systems such as the steering wheel lock, central locking systems, theft detection systems, fuel and ignition disabling system, etc. all these can reduce the possibility of vehicle been stolen but can easily be manipulated by the thief and does not give a trace or location of the vehicle or goods if the vehicle is eventually stolen. Several researchers and companies have designed and constructed vehicle monitoring and tracking device. Many of them are microcontroller-based system.

The Atmel 8-bit AVR RISC-based microcontroller combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte oriented 2 wire serial interface, SPI serial port 6 channel 10-bit A/D converter programmable watch dog timer with internal oscillator and five software selectable power saving modes. The device operates between 1.8-5.5 volts. The device achieves approaching put 1MIPS per MHz.

The vehicle tracking system presented here is a vehicle theft or location change monitoring and tracking system that gives information on demand of the new location of vehicle. This system is suitable for vehicle owners, school buses, transport business companies, fleet management, crude oil and petrol tankers owners etc. It consists of small electronic unit which is fixed in a hidden place in the vehicle to monitor the location of the vehicle. It is fixed in the vehicle in such a manner that it is not visible to anyone who is inside or outside the vehicle except the owner of the vehicle or the company that installed it. After installation, the system will locate target by the use of a web application (HTML based application) in Google map. When the vehicle changes location or is stolen, the GPS module (receiver) in the device receives information about the location (coordinates) from the GPS satellites and transmits data to the microcontroller. The GSM modem provided with a registered SIM card receives the GPS parameters of latitude, longitude and time from the microcontroller. The Exact location of the vehicle is indicated in the form of latitude and longitude along with the exact navigated track on Google map. The arrived data, in the form of latitude and longitude is used to locate the vehicle on Google maps, the output is then displayed on the LCD and transmits to the vehicle owner mobile phone in the form of SMS when request is made. This system is user friendly, easily installable, easily accessible and can be used for various other purposes. The system is not limited to find the location of the target but also calculates the distance travelled between two stations.

1.1 OVERVIEW OF THE PROJECT

A vehicle tracking system is a unique system based on advanced technology that is used to track vehicles under authorization. Vehicle monitoring System allows a party to track, trace and monitor its vehicles in real time. Vehicle Tracking System allows a party to track, trace and monitor its vehicles in real time using GSM/GPRS technology.

Vehicle Tracking System:

A vehicle tracking system is a unique system based on advanced technology that is used to track vehicles under authorization. It is a system based on electronics that uses highly sophisticated technology to ensure that the results are not only accurate, but also proper authorised. It is essentially a software installed at every operational base to enable the owner or a third party to track the vehicle's location. Vehicle monitoring System allows a party to track, trace and monitor its vehicles in real time. Vehicle Tracking System allows a party to track, trace and monitor its vehicles in real time using GSM/GPRS technology.

Fig 1: Overview of VTS

Vehicle Security using VTS:

Vehicle Security is a primary concern for all vehicle owners. Owners as well as researchers are always on the lookout for new and improved security systems for their vehicles. One has to be thankful for the upcoming technologies, like GPS systems, which enables the owner to closely monitor and track his vehicle in real-time and also check the history of vehicles movements. This new technology, popularly called Vehicle Tracking Systems has done wonders in maintaining the security of the vehicle tracking system is one of the biggest technological advancements to track the activities of the vehicle. The security system uses Global Positioning System GPS, to find the location of the monitored or tracked vehicle and then uses satellite or radio systems to send to send the coordinates and the location data to the monitoring center. Due to real-time tracking facility, vehicle tracking systems are becoming increasingly popular among owners of expensive vehicles.

1.2 OBJECTIVES OF THE STUDY

A GPS tracking vehicle tracking devices gadget isn't the same as an auto GPS. Equally GPS products operate by employing details by using satellite coordinates. The fundamental function of the GPS tracker is usually to monitor a particular concentrate on auto or motor vehicles. The tracking machine will be able to relay info relating to where by the motor vehicle has travelled, just how long the automobile stopped, and so on. GPS monitoring equipment are generally set up in autos. Having said that, GPS tracking units may be useful for motor cycles, scooters and bicycles. Some GPS trackers are created to monitor and keep track of movements of laptop computer pcs if computer is lost or stolen.

All GPS trackers use worldwide positioning satellites which may identify properly a vehicle's locale and speed. The GPS monitoring process sends info to orbiting GPS satellites which route the info by way of a mobile or cellular phone network back to an linked obtaining machine. GPS trackers may also send details by means of the internet and warn the receiver by using SMS text messaging.

Like a popular auto GPS procedure, GPS trackers may deliver thorough mapping information showing in which a concentrate on vehicle has traveled. The mapping particulars obtained is often archived for later on reference.

Fig 2: Objective of VTS

GPS trackers are utilized by law enforcement, private investigators, fraud or coverage investigators, corporate and personal folks to safe details needed for investigative applications. Some firms, like limousine firms, cab providers and supply providers, use GPS trackers keep an eye on and preserve precise facts records on how company car or truck fleets or homes are being utilized. In addition, GPS monitoring equipment is usually accustomed to keep track of company autos if stolen.

Some providers applied GPS monitoring systems to enhance productiveness by monitoring mileage and pace of organization motor vehicles to control gas use, therefore preserving fuel charge. GPS tracking units may be accustomed to log how staff use organization autos for consumer linked shipping and delivery of solutions by detailing just each time a merchandise was shipped and acquired.

Also, GPS tracking devices can be utilised legally to monitor relatives' pursuits, i.e., children or spouses. Having said that, the usage of GPS trackers is controversial in these regions. Although GPS monitoring equipment is often utilized for most States, lawfully with no special permit or license, a single must test relevant State or Federal laws regarding the usage of GPS tracking gadgets.

1.3 SCOPE OF THE STUDY

Global Positioning System (GPS) is much more than just the means of finding a way while commuting. It fulfils a much higher purpose than finding the fastest route. They help you to monitor crucial parameters like speed, trip distance, geo-fencing, real-time tracking among others. GPS trackers have paved the way for both automobiles like cars, trucks, buses as well as personal safety devices like GPS tracking smartwatches. They are easily trackable via smartphone or laptop keeping you tension-free. Trackers are small with technological advancement, tend to grow and improve. The future of GPS tracking looks extremely promising and we can expect some interesting advancement in this area. Let's look at what the

future holds for GPS monitoring systems.

Fig 3: Scope of VTS

Compact Size and Longer Life Span: Compact GPS devices are smaller than a cell phone butthe experts predict that continuous development may shrink the sizes of these devices further.

The size of the tracker depends on the battery, while a thumbnail-sized receiver can be improved, it needs to be big enough to accommodate the battery. As the battery technology unfolds, in the future, we may be able to see GPS trackers getting smaller in size.

These days, the best trackers can go up to 30 days without a recharge but to go longer, extended battery packs may be needed which provide up to 6 months of uninterrupted usage.

Affordability: GPS trackers are no longer a luxury reserved for big organizations and governmentagencies. The low-price points have brought it within the reach of small companies andeven individuals. GPS vehicle tracking is a must for every business and the raised productivity andefficiency make it a value for money.

They are immensely useful for both the professional and personal front. As per their requirements, different sections of people can be catered through the affordable price range. The devices are getting compact yet powerful. Hence, this is the best time to invest in GPS tracking solutions.

Extensive Usage: Past few years have seen a considerable rise in businesses turning to GPS technology, as an effective way to manage their transports, employees, and assets. GPS fleet management systems allow enterprises to access driver's performance, vehicle maintenance to providing other necessary inputs like live vehicle tracking. As the crime rate increases with each passing day, GPS trackers give a sigh of relief for parents. Trackers ensure the safety of your loved ones- be it children or elderly family members. Parents rely on these trackers to keep a watch and control their inexperienced young teenagers' reckless driving.

1.4 MATERIAL REQUIREMENT

HARDWARE REQUIREMENT:

1. Ardunio UNO
2. GSM Module
3. GPS Module
4. Power supply
5. Max232
6. RS232
7. LCD display
8. LED
9. Infrared sensor
10. Jumper Wires
11. Resistors
12. Capacitors
13. Transformers
14. IC LM7805
15. Bridge rectifier
16. Microcontroller Atmega328
17. Relay
18. DC Motor
19. Adapter

SOFTWARE REQUIREMENT :

1. Aruduino IDE

HARDWARE REQUIREMENT:

1. ARDUINO UNO:

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits.The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. It is similar to the Arduino Nano and Leonardo. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available.

1.1 Technical specifications:

Operating Voltage: 5 Volts

Input Voltage: 7 to 20 Volts

Digital I/O Pins: 14 (of which 6 can provide PWM output)

UART: 1

I2C: 1

SPPI: 1

Analog Input Pins: 6

DC Current per I/O Pin: 20 Ma

DC Current for 3.3V Pin: 50 mA

Flash Memory: 32 KB of which 0.5 KB used by bootloader

SRAM: 2 KB

EEPROM: 1 KB

Clock Speed: 16 MHz

Length: 68.6 mm

Width: 53.4 mm

Weight: 25 g

Headers

1.2 General Pin functions:

LED: There is a built-in LED driven by digital pin 13. When the pin is high value, the LED is on, when the pin is low, it is off.

VIN: The input voltage to the Arduino/Genuino board when it is using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can Arduino UNO … supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 20V), the USB connector (5V), or the VIN pin of the board (7-20V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage the board.

3V3: A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.

GND: Ground pins. IOREF: This pin on the Arduino/Genuino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the

IOREF pin voltage and select the appropriate power source, or enable voltage translators on the outputs to work with the 5V or 3.3V.

Reset: Typically used to add a reset button to shields that block the one on the board.

Special pin functions Each of the 14 digital pins and 6 analog pins on the Uno can be used as an input or output, under software control (using … pinMode(), digitalWrite(), and digitalRead() functions).

They operate at 5 volts. Each pin can provide or receive 20 mA as the recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50K ohm. A maximum of 40mA must not be exceeded on any I/O pin to avoid permanent damage to the microcontroller.

The Uno has 6 analog inputs, labeled A0 through A5; each provides 10 bits of resolution (i.e. 1024 different values). By default, they measure from ground to 5 volts, though it is possible to change the upper end of the range using the AREF pin and the analogReference() function]

Fig 4: Arduino UNO

In addition, some pins have specialized functions:

Serial / UART: pins 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL serial chip.

External interrupts: pins 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.

PWM (pulse-width modulation): pins 3, 5, 6, 9, 10, and 11. Can provide 8-bit PWM output with the analogWrite() function.

SPI (Serial Peripheral Interface): pins 10 (SS), 11 (MOSI), 12 (MISO), and 13 (SCK). These pins support SPI communication using the SPI library.

TWI (two-wire interface) / I²C: pin SDA (A4) and pin SCL (A5). Support TWI communication using the Wire library.

AREF (analog reference): Reference voltage for the analog inputs.

2. GSM MODULE (GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS):

A **GSM modem** or **GSM module** is a hardware device that uses GSM mobile telephone technology to provide a data link to a remote network. From the view of the mobile phone network, they are essentially identical to an ordinary mobile phone, including the need for a SIM to identify themselves to the network. GSM modems typically provide TTL-level serial interfaces to their host. They are usually used as part of an embedded system**.**

GSM Module (SIM800A):

SIM800 is a complete Quad-band GSM/GPRS solution in a SMT type which can be embedded in the customer applications. **SIM800** support Quad-band 850/900/1800/1900MHz, it can transmit Voice, SMS and data information with low power consumption.

Fig 5: GSM Module

3. GPS MODULE (GLOBAL POSITIONING SYSTEM):

The **Global Positioning** System (**GPS**) is a navigation system using satellites, a receiver and algorithms to synchronize location, velocity and time data for air, sea and land travel.

GPS Module (SKG13BL):

The **SKG13BL** is a complete **GPS module** that features with super sensitivity, ultra low power and small form factor. The **GPS** signal is applied to the antenna input of **module**, the serial interface output NMEA protocol data or customer protocol data with position, velocity and time information.

Fig 6: GPS Module

4. POWER SUPPLY:

It consists of step down transformer, bridge rectifier, capacitors and voltage regulatorICs. 230V AC is converted to 12V DC using transformer and bridge rectifier. This 12VDC is further reduced to 5V DC using voltage regulator IC.

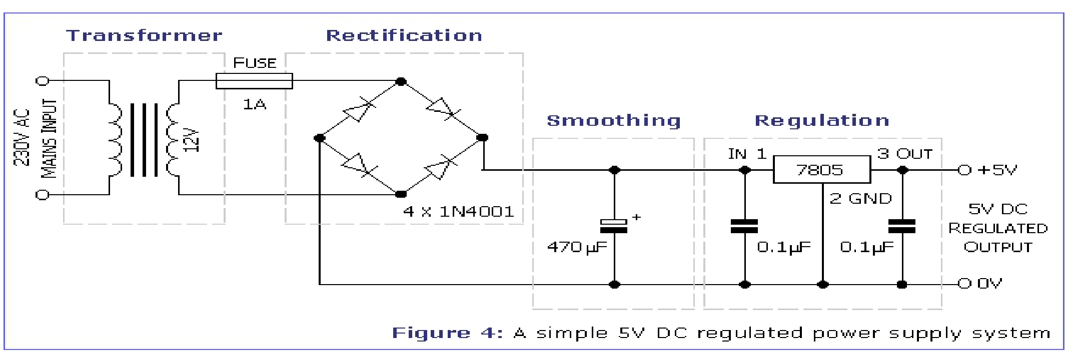

Fig 7: Power Supply

5. Max232:

The **MAX232** is an IC, first created in 1987 by Maxim Integrated Products, that converts signals from an RS-232 serial port to signals suitable for use in TTL compatible digital logic circuits. The MAX232 is a dual driver/receiver and typically converts the RX, TX, CTS and RTS signals.

The drivers provide RS-232 voltage level outputs (approx. ± 7.5 V) from a single + 5 V supply via on-chip charge pumps and external capacitors. This makes it useful for implementing RS-232 in devices that otherwise do not need any voltages outside the 0 V to + 5 V range, as power supply design does not need to be made more complicated just for driving the RS-232 in this case.

The receivers reduce RS-232 inputs (which may be as high as ± 25 V), to standard 5 V TTL levels. These receivers have a typical threshold of 1.3 V, and a typical hysteresis of 0.5 V.

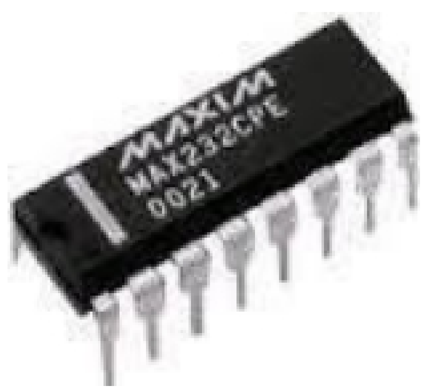

Fig 8: MAX232 IC

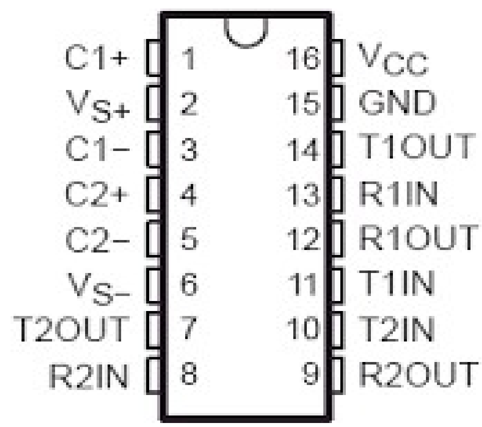

Fig 8: PIN DIAGRAM OF MAX232 IC

6.RS232:

In telecommunications systems used today **RS-232** is a standard for serial communication transmission of data. It formally defines the signals connecting between a DTE (data terminal equipment) such as a computer terminal, and a DCE (data circuit-terminating equipment, originally defined as data communication equipment), such as a modem.

The RS-232 standard is commonly used in computer serial ports. The standard defines theelectrical characteristics and timing of signals, the meaning of signals, and the physical size and pinout of connectors. The current version of the standard is TIA-232-F Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange, issued in 1997.

An RS-232 serial port was once a standard feature of a personal computer, used for connections to modems, printers, mice, data storage, uninterruptible power and other peripheral devices. RS-232 is hampered by low transmission speed, large voltage swing, and large standard connectors.

In modern personal computers, USB has displaced RS-232 from most of its peripheral interface roles. Many computers do not come equipped with RS- 232 ports and must use either an external USB-to-RS-232 converter or an internal expansion card with one or more serial ports to connect to RS-232 peripherals. Nevertheless, RS-232 devices are still used, especially in industrial machines, networking equipment and scientific instruments.

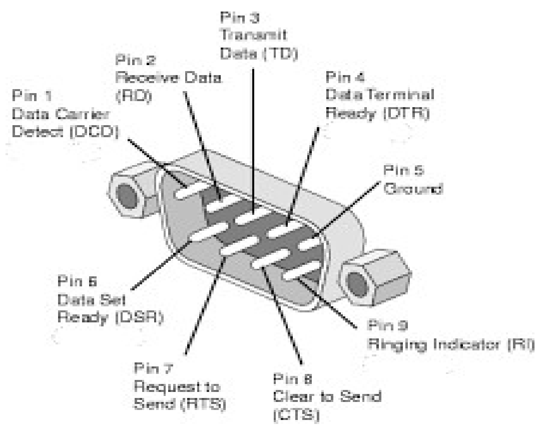

Fig 9: RS232

7. LCD DISPLAY:

A liquid-crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly.

LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images which can be displayed or hidden, such aspreset words, digits, and 7-segment displays as ina digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements.

LCDs are used in a wide range of applications including computer monitors, televisions, instrument panels, aircraft cockpit displays, and signage. They are common in consumer devices such as DVD players, gaming devices, clocks, watches, calculators, and telephones, and have replaced cathode ray tube (CRT) displays in most applications.The LCD screen is more energy efficient and can be disposed of more safely than a CRT. Its low electrical power consumption enables it to be used in battery-powered electronic equipment.

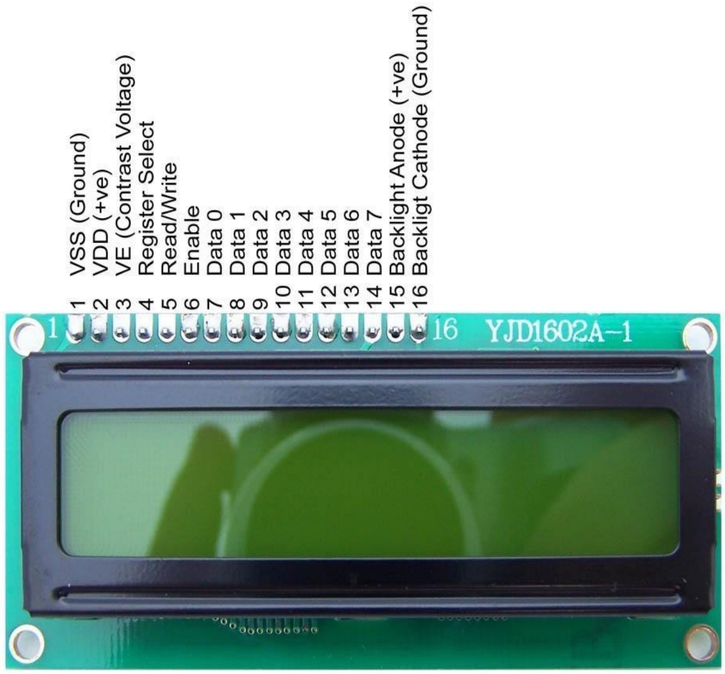

Fig 10: 16*2 lcd and its pin description

8. LED:

A light-emitting diode (LED) is a two-lead semiconductor light source. It is a pn-junction diode, which emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect

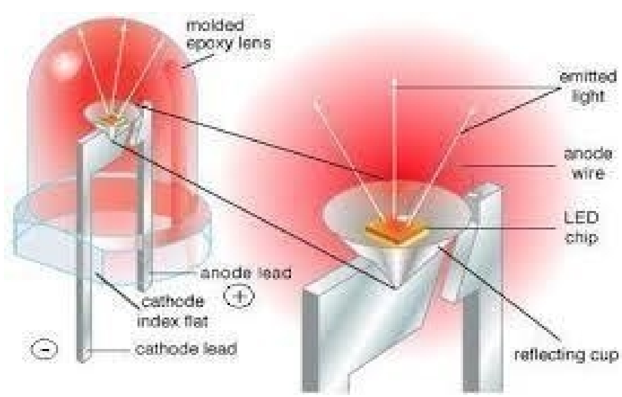

Fig 11: ILLUSTRATION OF LIGHT EMITTED BYLED

is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.

9. INFRARED SENSOR:

An infrared sensor is an electronic instrument which is used to sense certain characteristics of its surroundings by either emitting and/or detecting infrared radiation. Infrared sensors are also capable of measuring the heat being emitted by an object and detecting motion.

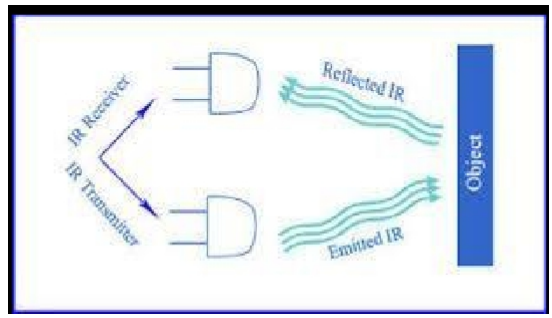

Fig 12: INFRARED SENSOR & HOW IT WORKS

10. JUMPER WIRES:

A jump wire (also known as jumper, jumper wire, jumper cable, DuPont wire or cable) is an electrical wire, or group of them in a cable, with a connector or pin at each end (or sometimes without them – simply "tinned"), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering

Individual jump wires are fitted by inserting their "end connectors" into the slots provided in a breadboard, the header connector of a circuit board, or a piece of test equipment. Stranded 22AWG jump wires with solid tips

Types Jumper wires with crocodile clips Jump wires at the end of a multi-coloured ribbon cable are used to connect the pin header at the left side of a blue USB2Serial board to a white breadboard below. Another jumper cable ending in a USB micro male connector mates to the right side of the USB2Serial board. Red and black tinned jump wires can be seen on the breadboard.

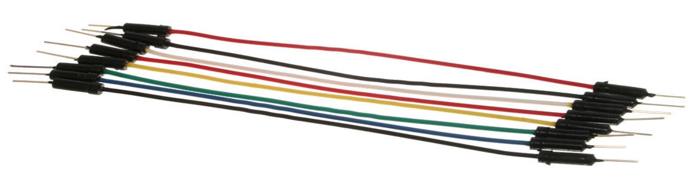

Fig 13: Jumper Wires

TYPES OF JUMPER WIRES:

There are different types of jumper wires. Some have the same type of electrical connector at both ends, while others have different connectors. Some common connectors are:

Solid tips – are used to connect on/with a breadboard or female header connector. The arrangement of the elements and ease of insertion on a breadboard allows increasing the mounting density of both components and jump wires without fear of shortcircuits. The jump wires vary in size and colour to distinguish the different working signals.

Crocodile clips – are used, among other applications, to temporarily bridge sensors, buttons and other elements of prototypes with components or equipment that have arbitrary connectors, wires, screw terminals, etc.

Banana connectors – are commonly used on test equipment for DC and lowfrequency AC signals.

Registered jack (RJnn) – are commonly used in telephone (RJ11) and computer networking (RJ45).

RCA connectors – are often used for audio, low-resolution composite video signals, or other low-frequency applications requiring a shielded cable.

RF connectors – are used to carry radio frequency signals between circuits, test equipment, and antennas.

RF jumper cables - Jumper cables is a smaller and more bendable corrugated cable which is used to connect antennas and other components to network cabling.

11. RESISTORS:

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits.

In electronic circuits resistors are used to limit current flow, to adjust signal levels, bias active elements, terminate transmission lines among other uses. High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators.

Fixed resistors have resistances that only change slightly with temperature, time or operating voltage.

Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors as discrete components can be composed of various compounds and forms.

Fig 14 : Resistor

The electrical function of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine orders of magnitude. The nominal value of the resistance will fall with in a manufacturing tolerance.

Resistor is a circuit element having the function of introducing electrical resistance in to the circuit. There are three basic types of resistors.

a) Fixed resistor

b) Rheostat

c)Potentiometer

A fix resistor is a two terminal device which electrical resistance is constant. A rheostat is a resistor that can be changed in resistance value without opening the circuit to make adjustment.

A potentiometer is an adjustable resistor with three terminals, on a teach end of the resistor element and thin movable along its length.

There are three basic types of resistors:

1.Carbon composite resistors

2.Wire wound resistors

3.Carbon-Film resistors.

12. CAPACITORS:

A capacitor (originally known as a condenser) is a passive two- terminal electrical component used to store energy electrostatically in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors (plates) separated by a dielectric (i.e. insulator). The conductors can be thin films, foils or sintered beads of metal or conductive electrolyte, etc. The nonconducting dielectric acts to increase the capacitor's charge capacity. A dielectric can be glass, ceramic, plastic film, air, vacuum, paper, mica, oxide layer etc. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, an ideal capacitor does not dissipate energy. Instead, a capacitor stores energy in the form of an electrostatic field between its plates.

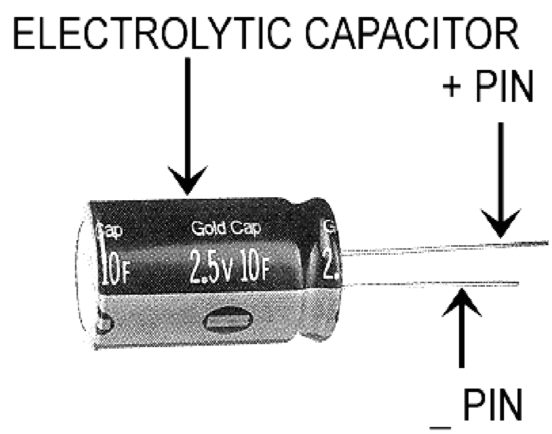

Fig 15 : Capacitor

13. TRANSFORMERS:

A transformer is an electrical device that transfers energy between two or more circuits through electromagnetic induction. A varying current in the transformer's primary winding creates a varying magnetic flux in the core and a varying magnetic field impinging on the secondary winding. This varying magnetic field at the secondary induces a varying electromotive force (EMF) or voltage in the secondary winding. Making use of Faraday’s Law in conjunction with high magnetic permeability core properties, transformers can thus be designed to efficiently change AC voltages from one voltage level to another within power networks.

Transformers range in size from RF transformers less than a cubic centimetre in volume to units interconnecting the power grid weighing hundreds of tons. A wide range of transformer designs is encountered in electronic and electric power applications. Since the invention in 1885 of the first constant potential transformer, transformers have become essential for the AC transmission, distribution , and utilization of electrical energy.

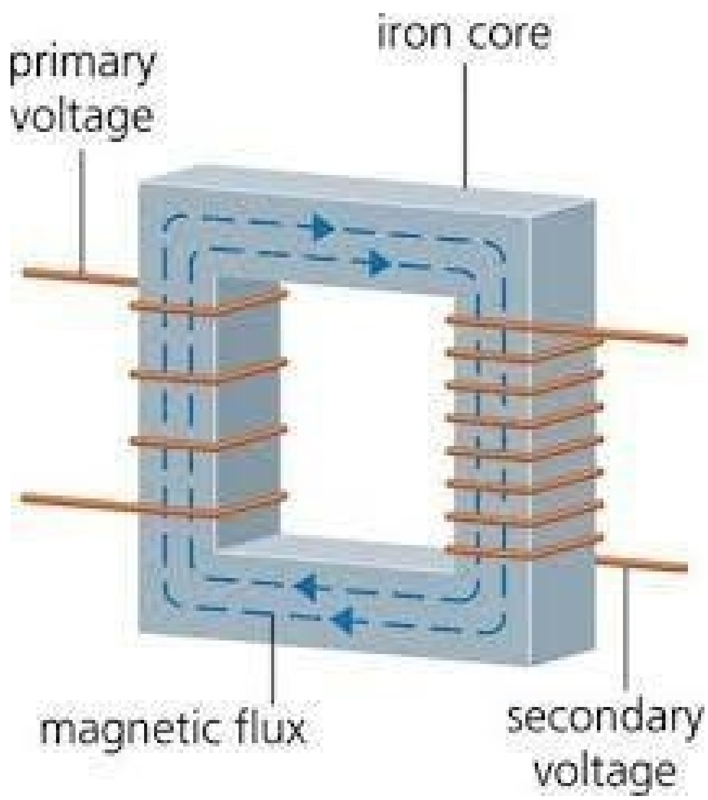

Fig 16 : Transformer

14. IC LM7805:

7805 is a voltage regulator integrated circuit. It is a member of 78xx series of fixed linear voltage regulator ICs. The voltage source in a circuit may have fluctuations and would not give the fixed voltage output. The voltage regulator IC maintains the output voltage at a constant value. The xx in 78xx indicates the fixed output voltage it is designed to provide. 7805provides +5V regulated power supply. Capacitors of suitable values can be connected at input and output pins depending upon the respective voltage levels.

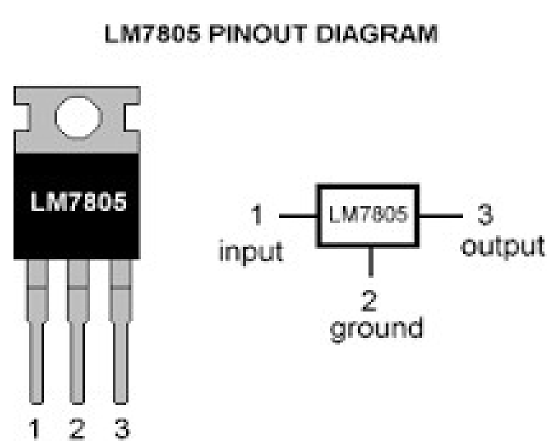

Fig 17 : IC LM7805

15. BRIDGE RECTIFIER:

A bridge rectifier is an arrangement of four or more diodes in a bridge circuit configuration which provides the same output polarity for either input polarity. It is used for converting an alternating current (AC) input into a direct current (DC) output.

DB 107:

Now -a -days Bridge rectifier is available in IC with a number of DB107. In our project we are using an IC in place of bridge rectifier. The picture of DB 107 is shown below

Features:

- Good for automation insertion.
- Surge overload rating - 30 amperes peak.
- Ideal for printed circuit board.
- Reliable low cost construction utilizing molded.
- Glass passivated device.
- Polarity symbols molded on body.
- Mounting position: Any.
- Weight: 1.0 gram.

Fig 18: DB107

16. MICROCONTROLLER ATMEGA328:

The Atmel AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

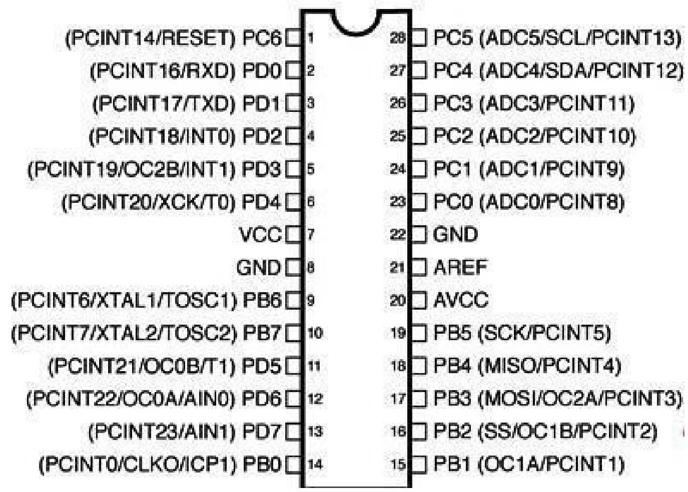

Fig 19: Pin Configuration of Microcontroller Atmega328

The Atmega168 provides the following features: 16 Kbytes of In-System Programmable Flash with Read-While-Write capabilities, 512 bytes of EEPROM, 1 Kbyte of SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte oriented Two wire Serial Interface, a 6-channel ADC (eight channels in TQFP and QFN/MLF packages)with 10-bit accuracy, a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and five software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM; Timer/Counters, SPI port, and interrupt system to continue Function.

The Power down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next Interrupt or Hardware Reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low-power consumption.

17. RELAY:

Relay is an electromagnetic switch operated by a relatively small electric current that can turn on or off a much larger electric current. The heart of a relay is an electromagnet (a coil of wire that becomes a temporary magnet when electricity flows through it). You can think of a relay as a kind of electric lever: switch it on with a tiny current and it switches on ("leverages") another appliance using a much bigger current. Why is that useful? As the name suggests, many sensors are incredibly sensitive pieces of electronic equipment and produce only small electric currents. But often we need them to drive bigger pieces of apparatus that use bigger currents. Relays bridge the gap, making it possible for small currents to activate larger ones. That means relays can work either as switches (turning things on and off) or as amplifiers (converting small currents into larger ones).

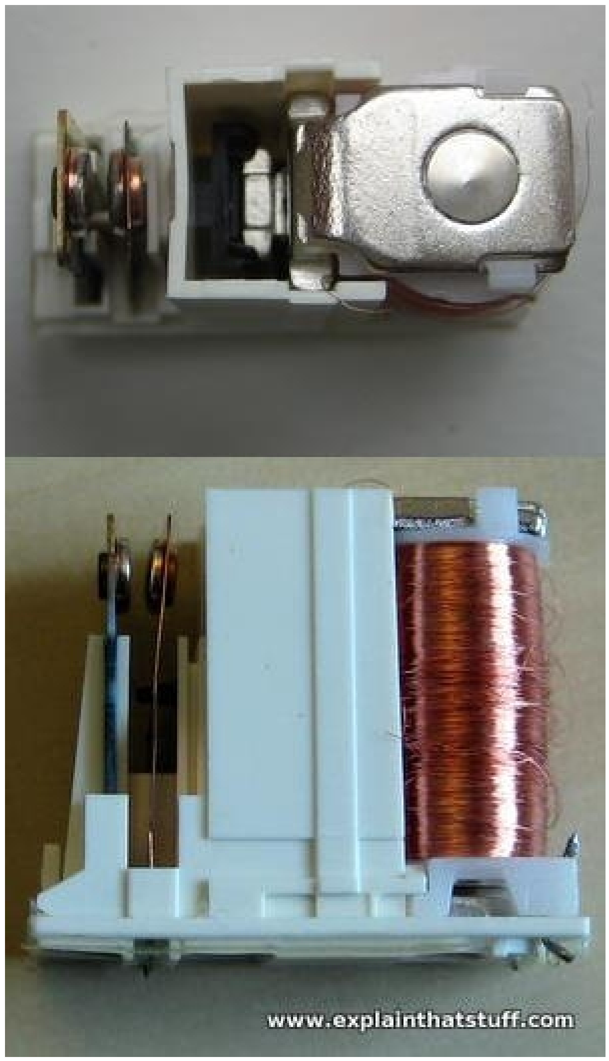

Fig:20-Relay

When power flows through the first circuit (1), it activates the electromagnet (brown), generating a magnetic field (blue) that attracts a contact (red) and activates the second circuit (2). When the power is switched off, a spring pulls the contact back up to its original position, switching the second circuit off again.

This is an example of a "normally open" (NO) relay: the contacts in the second circuit are not connected by default, and switch on only when a current flows through the magnet. Other relays are "normally closed" (NC; the contacts are connected so a current flows through them by default) and switch off only when the magnet is activated, pulling or pushing the contacts apart. Normally open relays are the most common.

Here's another animation showing how a relay links two circuits together. It's essentially the same thing drawn in a slightly different way. On the left side, there's an input circuit powered by a switch or a sensor of some kind. When this circuit is activated, it feeds current to an electromagnet that pulls a metal switch closed and activates the second, output circuit (on the right side). The relatively small current in the input circuit thus activates the larger current in the output circuit

1. The input circuit (black loop) is switched off and no current flows through it until something (either a sensor or a switch closing) turns it on. The output circuit (blue loop) is also switched off.
2. When a small current flow in the input circuit, it activates the electromagnet (shown here as a red coil), which produces a magnetic field all around it.
3. The energized electromagnet pulls the metal bar in the output circuit toward it, closing the switch and allowing a much bigger current to flow through the output circuit.
4. The output circuit operates a high-current appliance such as a lamp or an electric motor.

18. DC MOTOR:

Fig:21- DC Motor

DC motors are configured in many types and sizes, including brush less, servo, and gear motor types. A motor consists of a rotor and a permanent magnetic field stator. The magnetic field is maintained using either permanent magnets or electromagnetic windings. DC motors are most commonly used in variable speed and torque.

Motion and controls cover a wide range of components that in some ways are used to generate and/or control motion. Areas within this category include bearings and bushings, clutches and brakes, controls and drives, drive components, encoders and resolves, Integrated motion control, limit switches, linear actuators, linear and rotary motion components, linear position sensing, motors (both AC and DC motors), orientation position sensing, pneumatics and pneumatic components, positioning stages, slides and guides, power transmission ,seals.

Motors are the devices that provide the actual speed and torque in a drive system. This family includes AC motor types (single and multiphase motors, universal, servo motors, induction, synchronous, and gear motor) and DC motors (brush less, servo motor, and gear motor) as well as linear, stepper and air motors, and motor contactors and starters.

In any electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is then placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field. As you are well aware of from playing with magnets as a kid, opposite (North and South) polarities attract, while like polarities (North and North, South and South) repel. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion.

Let's start by looking at a simple 2-pole DC electric motor (here red represents a magnet or winding with a "North" polarization, while green represents a magnet or winding with a "South" polarization).

Every DC motor has six basic parts -- axle, rotor (a.k.a., armature), stator, commutator, field magnet(s), and brushes. In most common DC motors (and all that Beamers will see), the external magnetic field is produced by high-strength permanent magnets1. The stator is the stationary part of the motor -- this includes the motor casing, as well as two or more permanent magnet pole pieces. The rotor (together with the axle and attached commutator) rotates with respect to the stator. The rotor consists of windings (generally on a core), the windings being electrically connected to the commutator. The above diagram shows a common motor layout -- with the rotor inside the stator (field) magnets.

The geometry of the brushes, commutator contacts, and rotor windings are such that when power is applied, the polarities of the energized winding and the stator magnet(s) are misaligned, and the rotor will rotate until it is almost aligned with the stator's field magnets. As the rotor reaches alignment, the brushes move to the next commutator contacts, and energize the next winding. Given our example two-pole motor, the rotation reverses the direction of current through the rotor winding, leading to a "flip" of the rotor's magnetic field, and driving it to continue rotating.

In real life, though, DC motors will always have more than two poles (three is a very common number). In particular, this avoids "dead spots" in the commutator. You can imagine how with our example two-pole motor, if the rotor is exactly at the middle of its rotation (perfectly aligned with the field magnets), it will get "stuck" there. Meanwhile, with a two-pole motor, there is a moment where the commutator shorts out the power supply (i.e., both brushes touch both commutator contacts simultaneously). This would be bad for the power supply, waste energy, and damage motor components as well. Yet another disadvantage of such a simple motor is that it would exhibit a high amount of torque” ripple" (the amount of torque it could produce is cyclic with the position of the rotor).

You'll notice a few things from this -- namely, one pole is fully energized at a time (but two others are "partially" energized). As each brush transitions from one commutator contact to the next, one coil's field will rapidly collapse, as the next coil's field will rapidly charge up (this occurs within a few microsecond). We'll see more about the effects of this later, but in the meantime, you can see that this is a direct result of the coil windings' series wiring:

There's probably no better way to see how an average dc motor is put together, than by just opening one up. Unfortunately this is tedious work, as well as requiring the destruction of a perfectly good motor.

19. ADAPTER (12V):

An AC adapter, AC/DC adapter, or AC/DC converter is a type of external power supply, often enclosed in a case similar to an AC plug. Other common names include plug pack, plug-in adapter, adapter block, domestic mains adapter, line power adapter, wall wart, power brick, and power adapter. Adapters for battery-powered equipment may be described as chargers or rechargers (see also battery charger). AC adapters are used with electrical devices that require power but do not contain internal components to derive the required voltage and power from mains power. The internal circuitry of an external power supply is very similar to the design that would be used for a built-in or internal supply.

External power supplies are used both with equipment with no other source of power and with battery-powered equipment, where the supply, when plugged in, can sometimes charge the battery in addition to powering the equipment.

Fig:22- Adapter

Use of an external power supply allows portability of equipment powered either by mains or battery without the added bulk of internal power components, and makes it unnecessary to produce equipment for use only with a specified power source; the same device can be powered from 120 VAC or 230 VAC mains, vehicle or aircraft battery by using a different adapter. Another advantage of these designs can be increased safety; since the hazardous 120- or 240-volt mains power is transformed to a lower, safer voltage at the wall outlet and the appliance that is handled by the user is powered by this lower voltage.

Modes of operation:

Fig:23- Modes of Operation

An AC adapter disassembled to reveal a simple, unregulated linear DC supply circuit: a transformer, four diodes in a bridge rectifier, and an electrolytic capacitor to smooth the waveform

Originally, most AC/DC adapters were linear power supplies, containing a transformer to convert the mains electricity voltage to a lower voltage, a rectifier to convert it to pulsating DC, and a filter to smooth the pulsating waveform to DC, with residual ripple variations small enough to leave the powered device unaffected. Size and weight of the device was largely determined by the transformer, which in turn was determined by the power output and mains frequency. Ratings over a few watts made the devices too large and heavy to be physically supported by a wall outlet. The output voltage of these adapters varied with load; for equipment requiring a more stable voltage, linear voltage regulator circuitry was added. Losses in the transformer and the linear regulator were considerable; efficiency was relatively low, and significant power dissipated as heat even when not driving a load.

Early in the twenty-first century, switched-mode power supplies (SMPSs) became almost ubiquitous for this purpose. Main's voltage is rectified to a high direct voltage driving a switching circuit, which contains a transformer operating at a high frequency and outputs direct current at the desired voltage. The high-frequency ripple is more easily filtered out than mains-frequency. The high frequency allows the transformer to be small, which reduces its losses; and the switching regulator can be much more efficient than a linear regulator. The result is a much more efficient, smaller, and lighter device. Safety is ensured, as in the older linear circuit, because a transformer still provides galvanic isolation.

A linear circuit must be designed for a specific, narrow range of input voltages (e.g., 220–240 VAC) and must use a transformer appropriate for the frequency (usually 50 or 60 Hz), but a switched-mode supply can work efficiently over a very wide range of voltages and frequencies; a single 100–240 VAC unit will handle almost any mains supply in the world.

However, unless very carefully designed and using suitable components, switching adapters are more likely to fail than the older type, due in part to complex circuitry and the use of semiconductors. Unless designed well, these adapters may be easily damaged by overloads, even transient ones, which can come from lightning, brief mains overvoltage (sometimes caused by an incandescent light on the same power circuit failing), component degradation, etc. A very common mode of failure is due to the use of electrolytic capacitors whose equivalent series resistance (ESR) increases with age; switching regulators are very sensitive to high ESR (the older linear circuit also used electrolytic capacitors, but the effect of degradation is much less dramatic). Well-designed circuits pay attention to the ESR, ripple current rating, pulse operation, and temperature rating of capacitors.

Many inexpensive switched-mode AC adapters do not implement adequate filtering and/or shielding for electromagnetic interference that they generate. The nature of these high speed, high-energy switching designs is such that when these preventative measures are not implemented, relatively high energy harmonics can be generated, and radiated, well into the radio portion of the spectrum. The amount of RF energy typically decreases with frequency; so, for instance, interference in the medium wave (US AM) broadcast band in the one-megahertz region may be strong, while interference with the FM broadcast band around 100 megahertz may be considerably less. Distance is a factor; the closer the interference is to a radio receiver, the more intense it will be. Even WiFi reception in the gigahertz range can be degraded if the receiving antennae are very close to a radiating AC adapter. A determination of if interference is coming from a specific AC adaptor can be made simply by unplugging the suspect adapter while observing the amount of interference received in the problem radio band. In a modern household or business environment, there may be multiple AC adapters in use; in such a case, unplug them all, then plug them back in one by one until the culprit or culprits is found.

SOFTWARE REQUIREMENT:

1. ARDUINO IDE:

Arduino Compiler:

The Arduino IDE is a cross-platform application written in Java, and is derived from the IDE for the Processing programming language and the Wiring project. It is designed to introduce programming to artists and other newcomers unfamiliar with software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the board with a single click. There is typically no need to edit make files or run programs on a command-line interface. Although building on command-line is possible if required with some third-party tools such a Ino.

The Arduino IDE comes with a C/C++ library called "Wiring" (from the project of the same name), which makes many common input/output operations much easier. Arduino programs are written in C/C++.

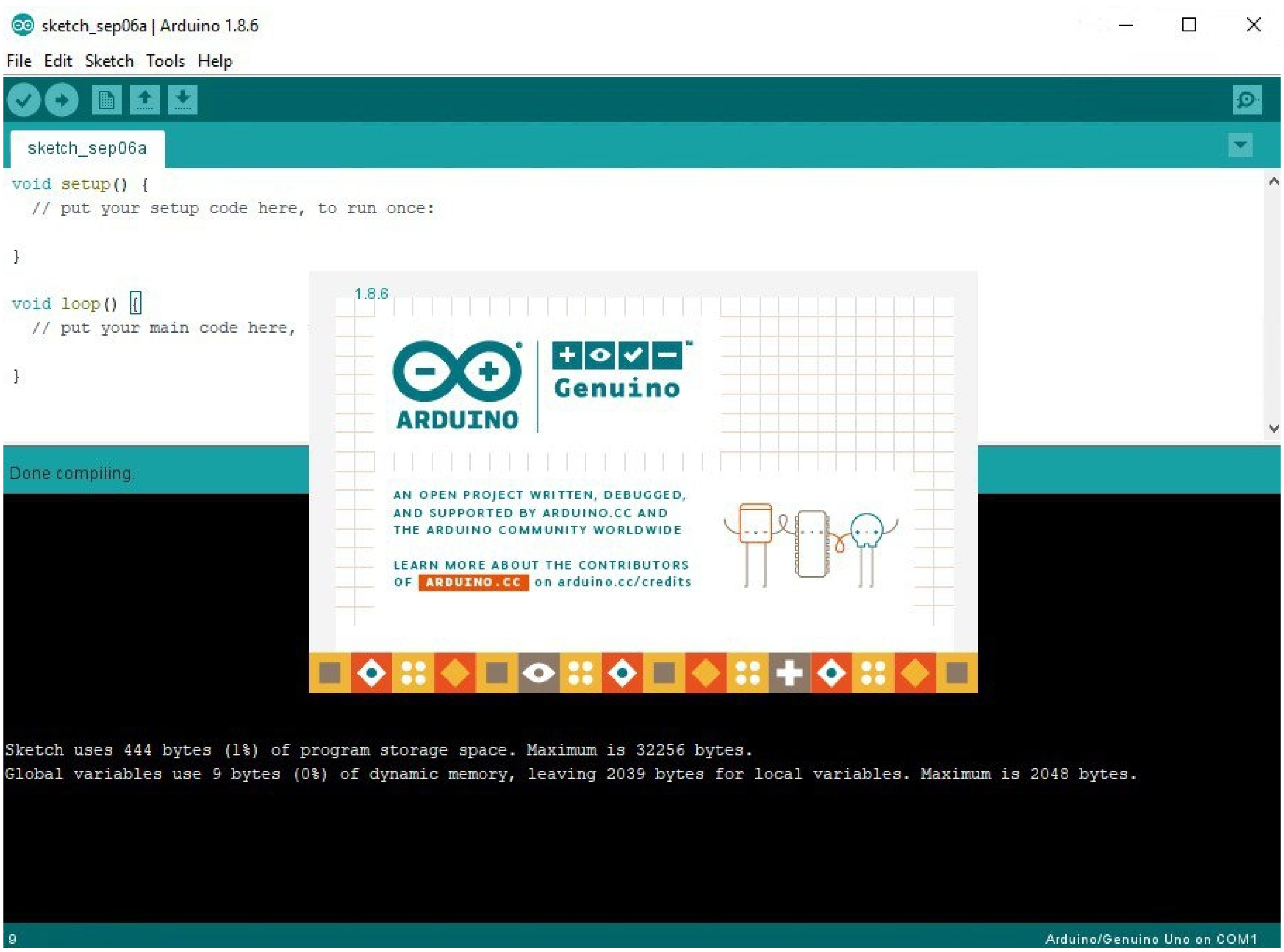

Fig:24-Arduino IDE

Eagle version 5.6.0:

EAGLE (for: **E**asily **A**pplicable **G**raphical **L**ayout **E**ditor, German: Einfach anzuwendender grafischer Layout-Editor) by CAD Soft Computer is a flexible, expandable and scriptable EDA application with schematic capture editor, PCB layout editor, auto-router and CAM and BOM tools developed by CAD Soft Computer GmbH,Germany, since 1988.

EAGLE is popular among smaller design houses and in academia for its favourable licensing termsand rich availability of component libraries on the web.

Google maps:

Google Maps is a desktop and mobile web mapping service application and technology provided by Google, offering satellite imagery, street maps, and Street View perspectives, as well as functions such as a route planner for traveling by foot, car, bicycle (beta test), or with public transportation. Also supported are maps embedded on third-party websites via the Google Maps API, and a locator for urban businesses and other organizations in numerous countries around the world. Google Maps satellite images are not updated in real time; however, Google adds data to their Primary Database on a regular basis. Google Earth support states that most of the images areno more than 3 years old.

CHAPTER 2

LITERATURE SURVEY

2.0 LITERATURE REVIEW ON RESEARCH AREA

GPS based vehicle tracking and monitoring system:

A solution for public transportation. The author of the paper provides a solution for tracking and monitoring the public transportation vehicles using devices such as Raspberry Pi and GPS Antenna. Raspberry Pi processing board can be used to receiving values and gives the result. This method can find a way to monitor the transportation vehicle from the location source to destination. In this paper, there is a use of GPS receiver module for receiving the latitude and longitude values of the present locationof the vehicle continuously. A passenger of the vehicle will give different locations to the system between the source and destination locations. These values will be stored in the Raspberry Pi database and Raspberry Pi processor will compare the passenger specified values with the current vehicle location values and if the result is not the same then the passenger will be informed with warning message via display system that driver is driving in the wrong direction.

Real-time GPS vehicle tracking system:

In this paper implementation and designing of a real-time GPS tracker system via Arduino was applied. This method was applicable for salesman tracking, private driver and for vehicle safety. The author of the paper also tried to solve the problem of owners who have expensive cars to observe and track the vehicle and find out vehicle movement and its past activities of vehicle. The system has GPS/GSM modules controlled by Arduino MEGA placed inside the vehicle. The vehicle position will be updated every time as the vehicle moves. Then User will send SMS on registered number and they will receive the coordinate location. At the same time the data will get stored on SD card continuously. The location will be accessible to users by system via website over the internet.

Android app-based vehicle tracking using GPS and GSM:

The author of this paper has explained an embedded system, used to know the locationof the vehicle using technologies like GSM and GPS. System needs closely linked GPS and GSM module with a microcontroller. Initially, the GPS installed in the device will receive the vehicle location from satellite and store it in a microcontroller ‘s buffer. In order to track location, the registered mobile number has to send request, once authentication of number get completed, the location will be sent to mobile number in the form of SMS. Then GSM get deactivated and GPS get activated again. The SMS consist of latitude and longitude value of vehicle. This value received in the SMS can be viewed via android app and this coordinate will be plotted in the app automatically.

Survey paper:

On vehicle tracking system using GPS and android This paper propose a GPS based vehicletracking system to help organization for finding addresses of their vehicles and locate their positions on mobile devices. The author states system will give the exact location of vehicle along with distance between user and vehicle. The system will have single android mobile, GPS and GSM modems along with processor that is installed in vehicle. When vehicle get activated and starts moving, the location of the vehicle will be updated continuously to a server using GPRS service. Monitoring unit will access the database from server to check the vehicle location. The location information present on database will be plotted using Google maps on monitoring device. Monitoring unit can be a Web application or Android application or a through which user will get to know the actual position of the proposed vehicle.

Review of Accident Alert and Vehicle Tracking System:

In this paper, the author has described the system that can track the vehicle and detect an accident. There will be automatic detection of traffic accidents using vibration sensors or a piezoelectric sensor. This sensor will first sense the occurrence of an accident and give its output tothe microcontroller. As soon as vehicle meets accident the GPS module will detect the latitude andlongitudinal position of a vehicle. Then the GSM module sends latitude and longitude position of the vehicle to the ambulance which is near to that location. This message sending operation will beautomatically done and an alert message may send to the central emergency dispatch server. This system is familiar with vibration sensor, Raspberry Pi, GPS and GSM modules to detect traffic accidents.

2.1 REVIEW ON RELATED LITERATURE

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Table 1.1 Literature Survey

Author/ Title/ Publication	Technology used	Research Gap
1) Akshatha S.A, "GPS based vehicle tracking and monitoring system", Volume: 04 Issue: 04 | Apr - 2017.	1) GPS technology. 2) Raspberry Pi technology.	1) Only the comparison result can be displayed by the display unit, no map was shown. 2) Need more input for comparison.
2) Hazza Alshamisi, Veton Këpuska, "Real Time GPS Vehicle Tracking System", Volume 6, Issue 3, March 2017.	1) GPS technology. 2) GSM technology. 3) Web technology.	1) Fully web-based. 2) Unable to see location in case of internet failure. 3) Difficult in hardware implementation.
Author/ Title/ Publication	**Technology used**	**Research Gap**
3) Jessica Saini, Mayank Agarwal, Akriti Gupta, Dr. Manjula R, "Android app based Vehicle tracking using GPS and GSM", volume 6, issue 09, September 2017.	1) GPS technology. 2) GSM technology. 3)Microcon-troller.	1) Due to a certain limitation in hardware, app location on the app has an error of approximate-ly 10 meters. 2) Hardware requirement costly.
4) Amol Dhumal, Amol Naikoji, "Survey Paper on Vehicle Tracking System using", Volume 3 Issue 11, November 2014.	1) GPS technology. 2) GPRS technology.	1) The tracking device is not internally built on the vehicle.

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5) Prashant Kokane, Prof. Yogesh Thorat "Review on Accident Alert and Vehicle Tracking System", Vol. 3, Issue October - December 2015.	1) GPS technology. 3) GSM technology. 4) Vibration sensor.	1) The absence of initial tracking, the system will only track vehicle after meeting an accident. 2) Chance of damaging hardware while meeting accident and unable to track.

Table:1- Literature survey of VTS

2.2 CONCLUSION ON REVIEWS

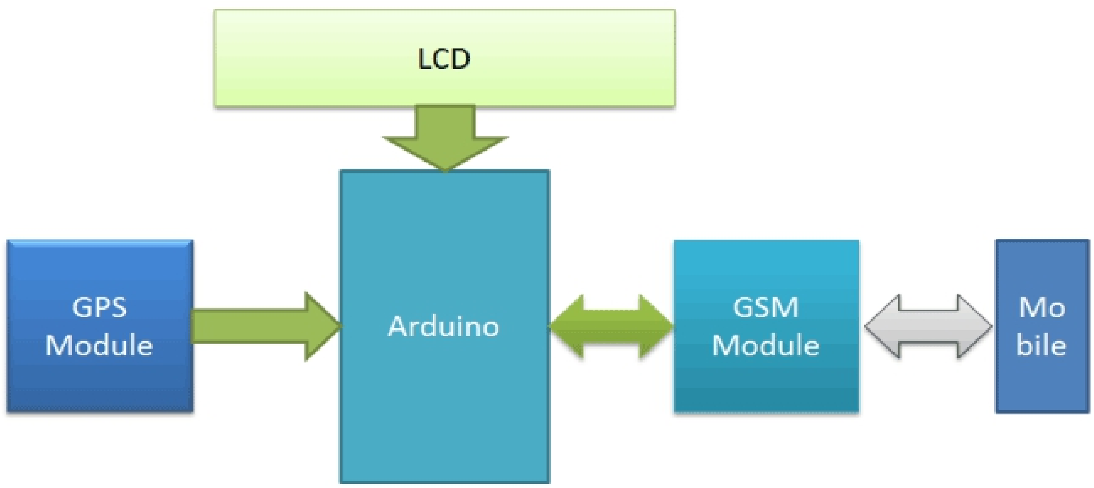
The aim of the paper is to give an overview of vehicle tracking system. This system used to track the vehicle by using GPS which is one of the biggest technological advancements to track the activities of the vehicle. This system can be used in both cases of personal as well as business purpose to improve safety and security. This technology can also help to advance the system of transportation and can be used in many organizations for security purpose and tracking purpose. This system allows organizations to track their vehicles and to get the exact location of the vehicle.

CHAPTER 3

PROJECT DESIGN

3.0 OVERVIEW OF THE DESIGN

Arduino is used for controlling whole the process with a **GPS Receiver and GSM module**. GPS Receiver is used for detecting coordinates of the vehicle, GSM module is used for sending the coordinates to user by SMS. And an optional 16x2 LCD is also used for displaying status messages or coordinates. We have used GPS Module SKG13BL and GSM Module SIM800A.



Block Diagram of VTS

When we ready with our hardware after programming, we can install it in our vehicle and power it up. Then we just need to send a SMS, "Track Vehicle", to the system that is placed in our vehicle. We can also use some prefix (#) or suffix (*) like #Track Vehicle*, to properly identify the starting and ending of the string, like we did in these projects:

GSM Based Home Automation and Wireless Notice Board :

Sent message is received by GSM module which is connected to the system and sends message data to Arduino. Arduino reads it and extract main message from the whole message. And then compare it with predefined message in Arduino. If any match occurs then Arduino reads coordinates by extracting $GPGGA String from GPS module data (GPS working explained above) and send it to user by using GSM module. This message contains the coordinates of vehicle location.

Circuit Explanation for Interfacing GSM and GPS with Arduino:

Here Tx pin of **GPS Module** is directly connected to digital pin number 10 of Arduino. By using Software Serial Library here, we have allowed serial communication on pin 10 and 11, and made them Rx and Tx respectively and left the Rx pin of GPS Module open. By default, Pin 0 and 1 of Arduino are used for serial communication but by using Software Serial library, we can allow serial communication on other digital pins of the Arduino. 12 Volt supply is used to power the GPS Module.

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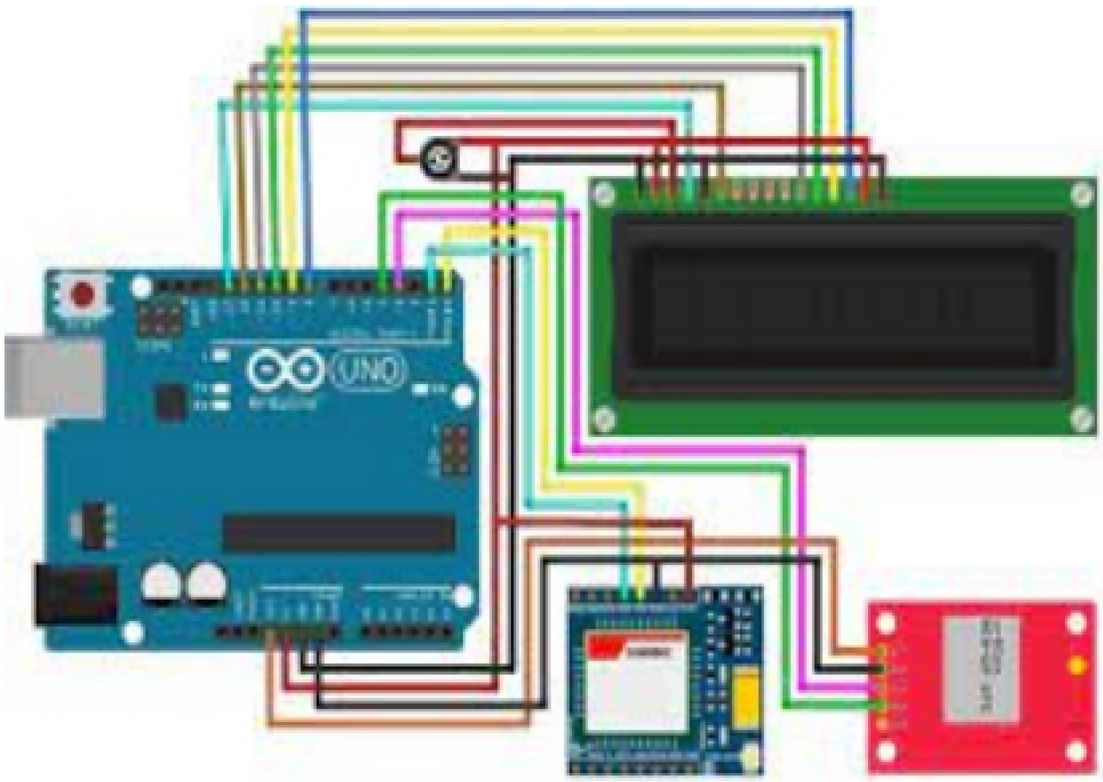


Fig 25: Interfacing GSM and GPS with Arduino

GSM Module:

Tx and Rx pins of are directly connected to pin Rx and Tx of Arduino. GSM module is also powered by 12v supply.

LCD Display:

An optional LCD's data pins D4, D5, D6 and D7 are connected to pin number 5, 4, 3, and 2 of Arduino. Command pin RS and EN of LCD are connected with pin number 2 and 3 of Arduino and RW pin is directly connected with ground. A Potentiometer is also used for setting contrast or brightness of LCD.

3.1EQUIPMENT ANALYSIS

- In this project the basic components used are Arduino UNO and GSM, GPS Modules. But in extension of this we can also use components based on the requirement and the price that are willing to support by the customer.
    - Extension is that we can also use LCD (16*2) to display the virtual location of the vehicle.

Fig:26- Additional components

- Elements involved are Arduino uno, , GSM & GPS Modules.
- The program used to make this project is c language.
- The cost we estimated was around 4,000 but due to some changes our expenses went till 6,000.
- The problem already told and mentioned is that the dot at the end of the google maps link.
- Project can be extended at any means necessary. For example, many extensions can be made to this project but those extensions will be coming up with a certain cost. So if the buyer or the consumer is ready to take the burden of the cost and feels safety is more important than he can go with it.

3.2 DESIGN THE MODULES

ARDUINO UNO:

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input /output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9 -volt battery, though it accepts voltages between 7 and 20 volts. It is similar to the Arduino Nano and Leonardo. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website.

Fig 27: Arduino UNO

Layout and production files for some versions of the hardware are also available. The word "uno" means "one" in Italian and was chosen to mark the initial release of Arduino Software'The Uno board is the first in a series of USB-based Arduino boards; it and version 1.0 of the Arduino IDE were the reference versions of Arduino, which have now evolved to newer releases. The ATmega328 on the board comes pre-programmed with a bootloader that allows uploading new code to it without the use of an external hardware programmer

Global Positioning System:

The Global Positioning System (GPS), originally Navstar GPS is a satellite-based radionavigation system owned by the United States government and operated by the United States Space Force. It is one of the global navigation satellite systems (GNSS) that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. Obstacles such as mountains and buildings block the relatively weak GPS signals. The GPS does not require the user to transmit any data, and it operates independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the GPS positioning information. The GPS provides critical positioning capabilities to military, civil, and commercial users around the world. The United States government created the system, maintains it, and makes it freely accessible to anyonewith a GPS receiver.

GPS MODULE (SKG13BL):

The **SKG13BL** is a complete **GPS module** that features with super sensitivity, ultra-low power and small form factor. The **GPS** signal is applied to the antenna input of **module**, the serial interface output NMEA protocol data or customer protocol data with position, velocity and time information.

Fig 28: GPS Module

GSM MODULE:

A **GSM modem** is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective, a GSM modem looks just like a mobile phone.

When a GSM modem is connected to a computer, this allows the computer to use the GSM modem to communicate over the mobile network. While these GSM modems are most frequently used to provide mobile internet connectivity, many of them can also be used for sending and receiving SMS and MMS messages.

GSM Module (SIM800A):

SIM800 is a complete Quad-band GSM/GPRS solution in a SMT type which can be embedded in the customer applications. **SIM800** support Quad-band 850/900/1800/1900MHz, it can transmit Voice, SMS and data information with low power consumption.

Fig 29: GSM Module

3.3 MODULE FUNCTIONALITIES:

ARDUINO UNO:

Pin Category	Pin Name	Details
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
Input/Output Pins	Digital Pins 0 - 13	Can be used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide reference voltage for input voltage.

Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)

DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz

Table:2-pins of Arduino Uno

- **Serial Pins 0 (Rx) and 1 (Tx):** Rx and Tx pins are used to receive and transmit TTL serial data. They are connected with the corresponding ATmega328P USB to TTL serial chip.
- **External Interrupt Pins 2 and 3:** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- **PWM Pins 3, 5, 6, 9 and 11:** These pins provide an 8-bit PWM output by using analogWrite() function.
- **SPI Pins 10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK):** These pins are used for SPI communication.
- **In-built LED Pin 13:** This pin is connected with an built-in LED, when pin 13 is HIGH – LED is on and when pin 13 is LOW, its off.

Along with 14 Digital pins, there are 6 analog input pins, each of which provide 10 bits of resolution, i.e. 1024 different values. They measure from 0 to 5 volts but this limit can be increased by using AREF pin with analog Reference () function.

- Analog pin 4 (SDA) and pin 5 (SCA) also used for TWI communication using Wire library.

Arduino Uno has a couple of other pins as explained below:

- **AREF:** Used to provide reference voltage for analog inputs with analogReference() function.
- **Reset Pin:** Making this pin LOW, resets the microcontroller.

GSM MODULE : SIM800A

- Bands: GSM 850MHz, EGSM 900MHz, DCS 800MHz, PCS 1900MH.
- GPRS class 2/10.
- Voltage Supply : 9VDC to 12VDC with atleast 2A Peak Current Capability.
- 5V interface for direct communication with MCU kit.
- Built-in SIM Card holder.
- Built-in Network Status LED.
- Inbuilt Powerful TCP/IP protocol stack for internet data transfer over GPRS.
- Low power.
- Operating temperature: -40C to +85C.
- External Finger type antenna.

GPS MODULE - SKG13BL

- Ultra high sensitivity: -165dBm.
- Extremely fast TTFF at low signal level.
- Built-in 12 multi-tone active interference canceller.
- Ultra low power consumption .
- ±10ns high accuracy time pulse (1PPS).
- Brand: Robocraze.
- Color: Blue And Black.
- Supply Voltage: 3.3V or 12V DC.
- Operating Temperature: -40C to 85C.

CHAPTER 4

PROJECT IMPLEMENTATION

4.0 IMPLEMENTATION STAGES

In the development of the vehicle tracking system controlled by a microcontroller, hardware and software design techniques are needed.

A. **Arduino Microcontroller the Atmega328P based Arduino UNO**

Microcontroller is used as the brain to control the vehicle tracking system. Arduino Shields are used for the GPS and the GSM/GPRS modules. A software program to control them is written in the C programming language, compiled and then saved into the microcontroller's flash memory.

B. GPS module

The Global Positioning System in vehicle tracking systems is commonly used to provide users with information such as the location coordinates, speed, time, and so on, anywhere on Earth. In this work, a GPS module and a GPS receiver available from the Spark fun website, is adopted to implement the in-vehicle device. The GPS module has the GPS receiver with antenna. There are two slide switches and one push button switch.

The GPS module is identical to the one offers detail about the GPS module. The switch for UART and DLINE selection. When the DLINE is selected, Rx and Tx in the GPS module will be connected to microcontroller digital pins 2 and 3, respectively. If the UART was selected, Rx and Tx in the GPS module will be connected to microcontroller digital pins 0 and 1, respectively. In this work, Tx and Rx in a GSM/GPRS module uses microcontroller digital pins 2 and 3. So, the GPS switch 1 must be set to the UART position, otherwise if DLINE position is selected its digital pins will overlap that of the GSM/GPRS module. Even when UART is selected, while trying to uploaded program code to the Arduino, users will see error message in the microcontroller because the UART uses programming, but nothing should get damaged. For these reasons, the GPS module should select the switch in the UART position after the source code is uploaded. The GPS receiver. It is required for getting the location information. The GPS receiver module uses the 20 channel EM-406A SiRF receive Once the microcontroller and the GPS module have everything assembled, the GPS module is almost ready to get the vehicle's location information. The Tiny GPS library was used to communicate with and access data from the GPS module. The EM-406 works at 4800 bps, but if users are using another type of GPS, they should identify the correct baud rate for their specific device.

C. GSM/GPRS module

The GSM/GPRS module is responsible of establishing connections between an in-vehicle device and a remote server for transmitting the vehicle's location information, using TCP/IP connection through the GSM/GPRS network.

4.1 SOFTWARE EXPLANATION

In this project, Proteus software was used for both the simulation and the PCB design while the Arduino compiler were used to program and compile the microcontroller.

The Arduino IDE is a cross-platform application written in C language, and is derived from the IDE for the processing programming language and the wiring project. It is designed to introduce programming to artists and other beginners that have little knowledge of software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the board with a single click. The Arduino IDE comes with a C/C++ library called "Wiring", which makes many common input/output operations much easier.

4.2 RESULTS

The vehicle tracking system works mainly by receiving messages from a mobile phone. There is a message command by which we can track the vehicle. And this command is to send an SMS; "TRACK" to the registered SIM card number in the GSM modem. This command initiates the GPS modem and receives the latitude and longitude position and this information will then be sent as SMS to the mobile device. Whenever theft occurs or on demand request of the vehicle's location, the device sends a message to the vehicle owner's mobile device as shown on the mobile phone screen in Fig. 30 as follows:

Vehicle tracking alert:

Your vehicle current location is:

Latitude: 17.47389

Longitude :78.48272

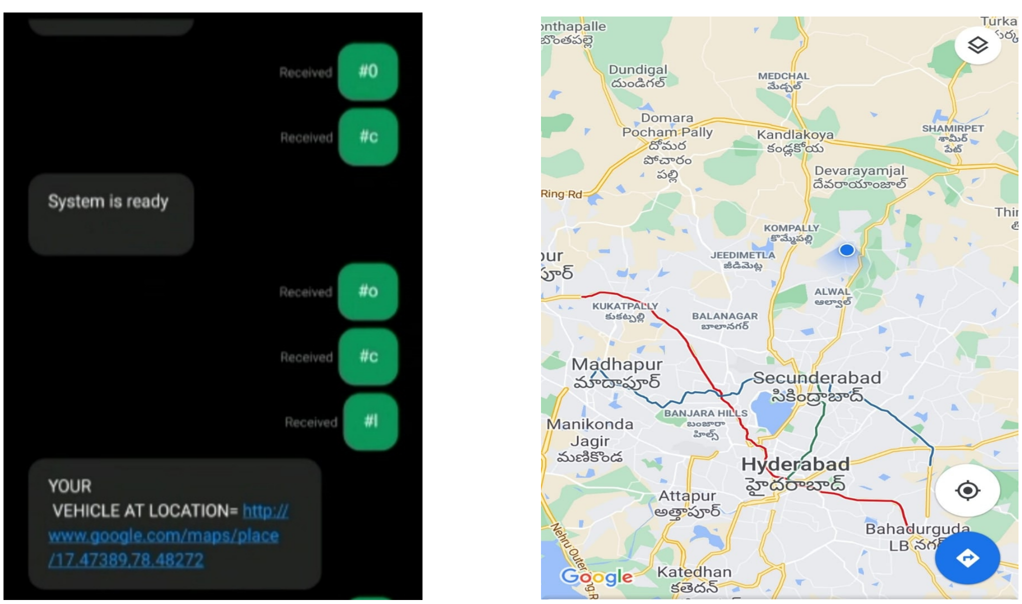


Fig:30 output screens

CHAPTER 5
PROJECT TESTING

5.0 OVERVIEW OF TESTING METHODS

Fig. 31 shows the assembling of the different modules of the proposed vehicle tracking system and Fig 32 shows the system when sending SMS. In testing, we fixed the completed vehicle tracking device in a bike as shown in Fig.32 and allow the bike to be driven away to a different location. We then send an SMS with a registered mobile phone to the GSM modem with a registered SIM card with a" TRACK VEHICLE" and an SMS was received by the mobile phone. The SMS gave the latitude, longitude and time as shown in Fig. 30.

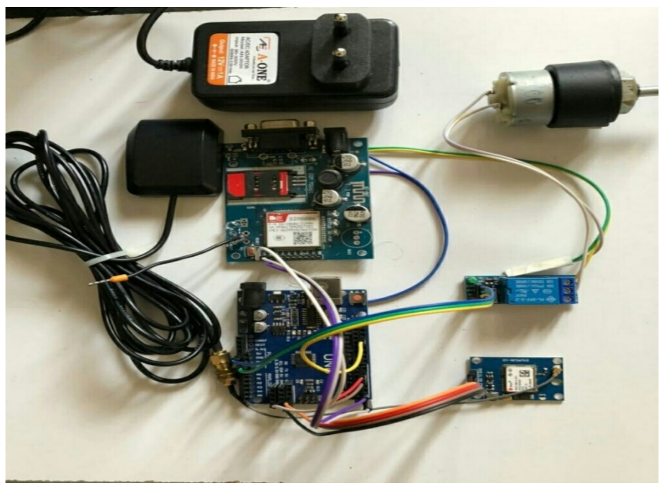


Fig-31: Image of the complete assembly of the different modules of the proposed vehicle tracking system.

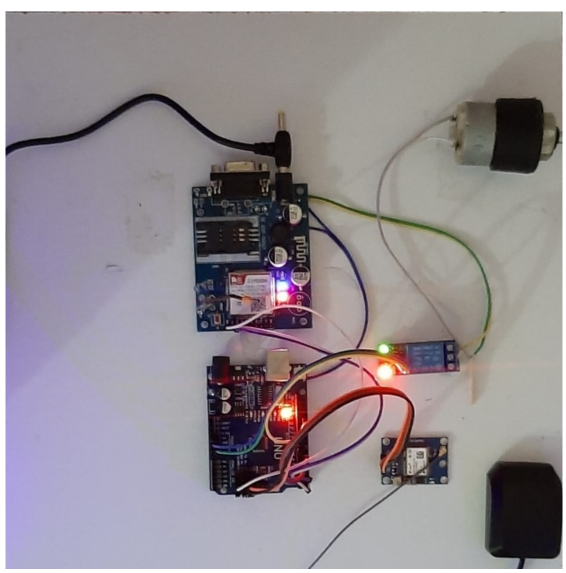


Fig - 32: Image of the system when sending an SMS.

5.1 OPERATION AND TESTING

OPERATION :

Whenever a vehicle is parked, it is kept at vehicle tracking security mode. Once the vehicle is stolen, the position of the vehicle changes, the owner can send an SMS to the vehicle to know the location or position of the vehicle. The SMS sent would pass through the GSM service provider and then reach the vehicle, which is travelling, because the vehicle has a GSM device with a SIM card. This GSM modem will receive the SMS and send to the microcontroller in the vehicle. The microcontroller will receive this SMS and compare the password and the command. If the information matches the already programmed one, then it will perform the request required by the owner. It will then send the required location; latitude, longitude and time to the registered number of the owner and the results will be display on the screen of the owner’s mobile phone. The owner can then send a message to stop the engine of the vehicle.

TESTING:

1. Connect the circuit to GPS and GSM modem.
2. Switch on the circuit and you will see LED glow.
3. Switch on the GPS module and wait for 10-15 minutes for initialisation.
4. Switch on the GSM modem.
5. Dial the mobile number in the GSM modem. After two rings, the ringing stops automatically. Wait for a few seconds. You will get an SMS alert in your mobile.
6. Check your SMS inbox. You will see the latitude and longitude data in the form of SMS text.
7. Open a standard map and locate the point on the map. You can also enter latitude and longitude values in a software.

5.2 ADVANTAGES, APPLICATIONS AND DRAWBACKS

ADVANTAGES:

1. Flexible and reliable.
2. This application is easy to install and easy to operate .
3. More realiable than manual operation.
4. In this project losses are minimal.
5. This project can implement for security of supply.
6. Automatically controlled band easy to use.

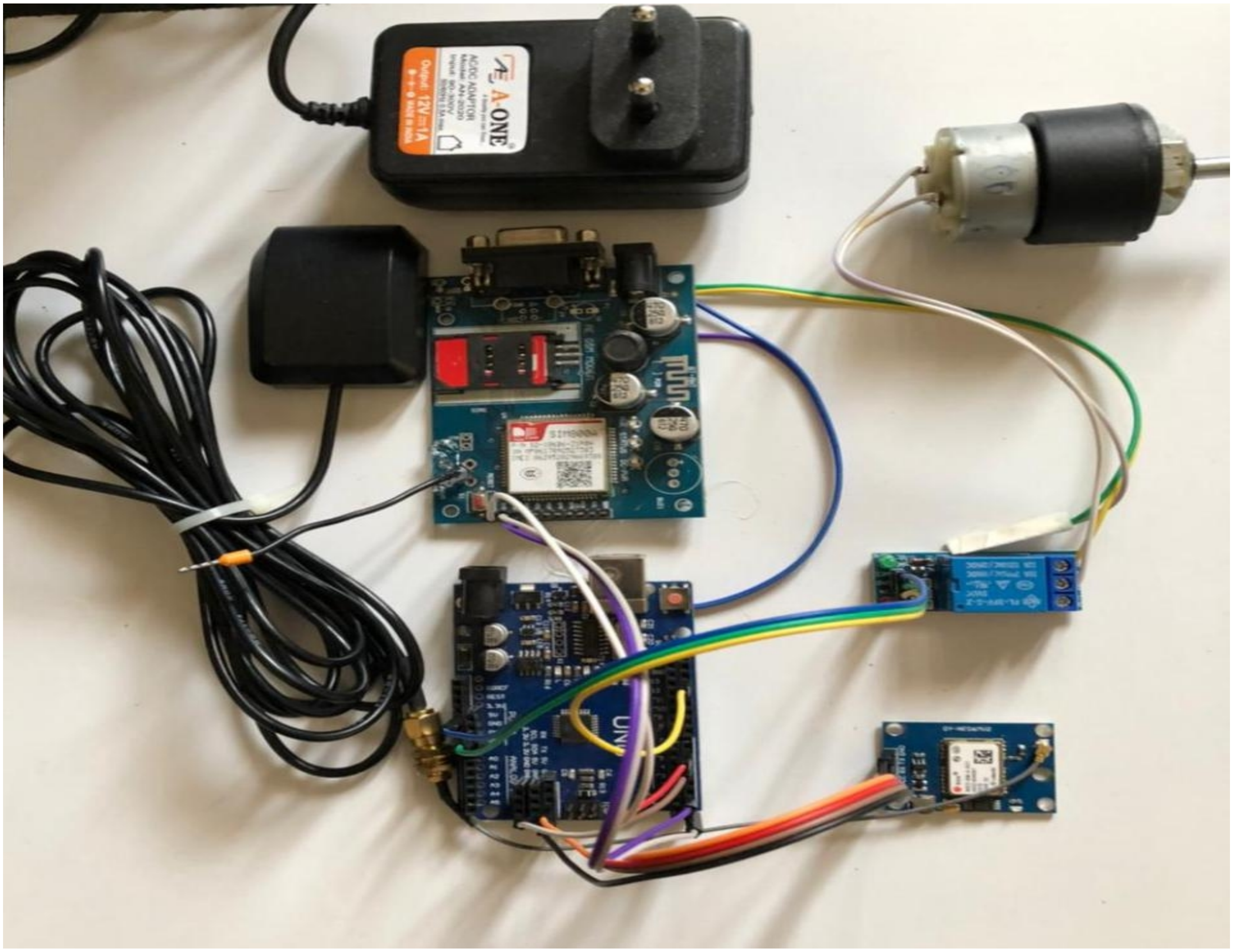
APPLICATIONS:

1.Remote Data Monitor and Control.
2. AMR(Automatic meter reading).
3. Power station monitoring and control.
4. Remote POS(point big scale) terminals.
5. Traffic signals monitor and control.
6. Central heating system supervision.
7.Power distribution network supervision.

DRAWBACKS:

1. GPS location can be inaccurate sometimes.
2. Battery might drain out.
3. Employees might feel offended.
4. Monitoring travel data might consume time and labour.
5. Environmental conditions.

5.3 SNAPSHOT OF VEHICLE TRACKING SYSTEM



CHAPTER 6

CONCLUSION AND FUTURE ENHANCEMENT

CONCLUSION

We have successfully developed and implemented a vehicle tracking system that gives feedback information of the location of stolen vehicle using GPS-GSM technology. It is user friendly, easily installable, easily accessible and can be used for various other purposes. The system is not limited to find the location of the target but also calculates the distance travelled between two stations. It can also be applied for better management of fleet with a return of large profit, better scheduling or route planning to enable large job schedule. If this project is properly implemented it will improve safety, reduce vehicle loss due to theft, increase productivity, reduce diversion of routes by transport company's drivers. We are still working on the possibility of improving on the system to give SMS feedback to the vehicle owner when an accident occurs. This will help to reduce the delay in evacuation of accident victims to hospital and reduce the chances of losing life.

FUTURE ENHANCEMENT

While doing this survey, it was found that vehicle tracking is a huge field. There are number of techniques that can be used to track the vehicle. The technique should be cheaper and also efficient. Due to the increasing ratio of vehicle in today's world, the vehicle tracking system will have a great scope in future. A various type of database can be created to record the route of the vehicle. The hardware can be replaced by installing the device with sensors like fire sensors and proximity sensors. Proximity sensors will be exceedingly supportive in case whenever vehicle will meet with an accident. It is possible to make the device wearable by reducing the size of the hardware so that not only for finding the location of the vehicle but the device could also be used to find the shortest path to reach the destination.

PUBLICATION

Proposed Title :VEHICLE TRACKING SYSTEM

Conference Name: International conference on "Recent Developments in Power Engineering (ICRDPE-21)",organized by Department of Electrical And Electronics, **ST.MARTIN'S ENGINEERING COLLEGE,** HYDERABAD.

Acceptance Letter for online oral presentation & journal publication

Online Mega international Conference* "Recent Developments in Power Engineering" *(ICRDPE–21) on 09th & 10th July 2021

Dear: Mr Daniel Manoj Nethala

Title of the paper: VEHICLE TRACKING SYSTEM

Paper ID: ICRDPE21-EE-024

With heartiest congratulations we are pleased to inform you that based on the recommendations of the expert reviewers, your paper has been accepted for journal publication and oral presentation in online mega International Conference on "Recent Developments in Power Engineering" ***(ICRDPE-21).***

ICRDPE-21conference received over 200+ submissions from different parts of the world and regions so far, reviewed by international experts; the acceptance ratio is controlled below 20%. Your paper will be submitted for **Journal publications free of cost** in the appropriate given Journals after registration. **You will be given registration kit, International conference proceedings with ISBN (Soft copy), and international certificate of publication.**

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ICRDPE- 21 Organizing Committees
icrdpe21eee@smec.ac.in

(Organized by Department of EEE)

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APPENDICES

```
#include <SoftwareSerial.h>
 #include <TinyGPS.h>

SoftwareSerial gpsSerial(5,6);
TinyGPS gps;
char* lati = new char[20];
char* longi = new char[20];
float latitude,longitude;

 char inchar;
 int relay=13;
 int c=1;

 void setup()
 {
 Serial.begin(9600);
 gpsSerial.begin(9600);
 pinMode(relay, OUTPUT);
 delay(3000);
 Serial.println("AT+CMGF=1");
 delay(200);
 Serial.println("AT+CNMI=2,2,0,0,0");
 delay(200);
 }

 void loop()
 {
  while(c==1)
```

```
 {
 getlat();
 if((latitude>0)&&(latitude<100))
 {
  systemon();
  Serial.println("system on");
  c=c+1;
 }
 }

while(c==2)
{
if(Serial.available()>0)
{
inchar=Serial.read();
if (inchar=='#')
  {
  delay(10);
  inchar=Serial.read();

if (inchar=='c')
  {
  digitalWrite(relay, LOW);
  }
else if (inchar=='o')
  {
  digitalWrite(relay, HIGH);
  }
else if (inchar=='l')
  {
```

```
  sendlocation();
  }
 c=3;
 Serial.println("got msg");
 Serial.println("AT+CMGD=1,4"); // delete all SMS
 }
 }
 }
 c=2;
 }



 void getlat()
{
     while(gpsSerial.available())
     {
      if(gps.encode(gpsSerial.read()))
      {
       gps.f_get_position(&latitude,&longitude);
       dtostrf(latitude,7,5,lati);
       dtostrf(longitude,7,5,longi);
      }
      }
}

void sendlocation()
{
  Serial.println("AT+CMGF=1");
  delay(1000);
```

```
  Serial.println("AT+CMGS=\"+917981342555\"\r");
  delay(1000);
  Serial.println("YOUR");
  delay(100);
  Serial.print(" VEHICLE AT LOCATION= http://www.google.com/maps/place/");
  delay(100);
  Serial.print(lati);
  delay(100);
  Serial.print(",");
  delay(100);
  Serial.print(longi);
  delay(100);
  Serial.println((char)26);
  delay(1000);
}

void systemon()
{
  Serial.println("AT+CMGF=1");    //Sets the GSM Module in Text Mode
  delay(1000);  // Delay of 1000 milli seconds or 1 second
  Serial.println("AT+CMGS=\"+917981342555\"\r"); // Replace x with mobile number
  delay(1000);
  Serial.println("System is ready");// The SMS text you want to send
  delay(100);
  Serial.println((char)26);// ASCII code of CTRL+Z
  delay(1000);
}
```

A

PROJECT REPORT

On

ENERGY MANAGEMENT STRATEGY OF A PHOTOVOLTAIC ELECTRIC VEHICLE CHARGING STATION

Submitted by

1) Mr. K R SAI RUSHAB	**(18K85A0209)**
2) Mr. D SAI TEJA	**(17K81A0211)**
3) Mr. G RAJASHEKAR	**(17K81A0218)**

Inpartial fulfillment for the award of the

degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

Mrs. G ESHA M.TECH., (Ph.D)

ASSISTANT PROFESSOR

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ST.MARTIN'S ENGINEERING COLLEGE
(An Autonomous Institute)

Dhulapally, Secunderabad – 500100

JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled ENERGY MANAGEMENT STRATEGY OF A PHOTOVOLTAIC ELECTRIC VEHICLE CHARGING STATION, is being submitted by 1.**Mr. K R SAI RUSHAB 18K85A0209, 2.Mr. D SAI TEJA 17K81A0211, 3.Mr. G RAJASHEKAR 17K81A0218** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY IN** ELECTRICAL AND ELECTRONICS ENGINEERING is recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Mrs. G ESHA
Department of Electrical and electronics engineering

Head of the Department
Dr. N Ramachandra

Department of Electrical and electronics engineering

Internal Examiner

External Examiner

Place:

Date:

DECLARATION

We, the student of **Bachelor of Technology** in Department of Electrical and electronics', session: 2017 – 2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled **"**energy management strategy of a photovoltaic electric vehicle charging station" is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

1)Mr. K R SAI RUSHAB (18K85A0209)
2)Mr. D SAI TEJA (17K81A0211)
3) Mr. G RAJASHEKAR (17K81A0218)

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1. K R SAI RUSHAB
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ABSRACT

The adoption of the photovoltaic electric vehicle charging stationshas been on the rise. In this paper, a grid connected electric vehicle charging stationpowered a by photovoltaic solar system and a pack of batteries as storage system, is evaluated and analyzed. The most important parameter for supervising the system is the direct current bus voltage. The grid or the energy storage system can supply the electric vehicle charging station to maintain the bus voltage at its level. This supervision is tested by simulating the charging system under different irradiance conditions taking into account the cost of the energy transmission and the state of charge of the battery. The results validate the performance of the proposed energy management and the proper operation of electric vehicle charging station .

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CHAPTER 1
INTRODUCTION

1.1 BASIC INTRODUCTION

Plug–in electric vehicles (PEVs) which comprise all electric vehicles and plug-in hybrid electric vehicles provide the chance to modify the transportation energy demands from petroleum to electricity. Although, the impact of charging the electric vehicles (EVs) via the electrical grid, especially during the peak demand period cannot be neglected, it cause many problems such as harmonics, voltage outages and fluctuations . The use of charging stations integrated with distributed generation based on renewable energy sources (RES), to boost the power generation, can be a viable solution to mitigate this problem. In addition, the combination of these distributed energy sources into the charging infrastructure has an important role to decrease the environmental effects and to enhance the efficiency of the charging system. Due to the stochastic nature of RES, there is a persistent need to add an energy storage system (ESS) which has a crucial role in the incorporation of electric vehicle charging station (EVCS). The photovoltaic (PV) power is known as the most competitive source of energy to support the grid utility thanks to the persistent decreasing tendency on the prices of the PV panels. Furthermore, the PV system, in terms of fuel and labor is approximately maintenance free.The use of the PV power to supply the EVs is improved by the advancement in the power conversion technologies. One of the important challenges for the EVCS, particularly the public ones, is making the charging duration as short as possible. There are many standards organizations in the world that work to define the electrical characteristics of EVCS i.e. the Society of Automotive Engineering (SAE), CHAdeMO association and International Electro technical Commission (IEC). The latter develops four modes of charging basing on the type of the charging rate, the level and the type of voltage, the mode of communication between the EVs and the CS and the presence of the protections and its location. These fast charging station (FCS) present two topologies normalized by the IEC 61851-1, the first is tied to a common AC bus suppling all the AC-DC converters ,on the other hand, the second topology is based on a common DC bus which feed the various DC-DC chargers. Experimental studies showed that the second architecture is the best option due to the reduced number of the conversion stages, the nature of loads and fluent integration of energy storage systems or distributed generation. Apart from that, the synchronous charge of a fleet of EVs can cause an increase in the peak power demand to the utility grid. Dealing with a fleet of EVs at different poles of charging needs a study on appropriate management strategy, so two ways have been suggested, i.e. centralized or decentralized management strategy. The latter strategy, applied to the EVCS, is based on local controllers, and each source of energy works independently from the others, in addition to that the energy flow management between the sources of energy is accomplished without the necessity of communication interface between the energy sources or between the energy management system (EMS) and sources of energy. It facilitate the extension of the charging system and the medium voltage direct current (MVDC) network by adding new element such as others sources of energy (ESS, RES) or new EVs, since the EMS does not need to be changed. Also, comparing these two strategies, it was concluded that the adoption of the decentralized strategy represents the most feasible option thanks to the benefit of not needing a communication interface. In our study, a PV-grid charging station is studied to maximize the use of the photovoltaic power whenever it possible and to use the grid or/and the ESS as a buffer system when the solar irradiance is unavailable or there is an excess of power, This strategy allows the buffer‘s connection taking into account the energy transmission cost (ETC) and the state of charge of the battery (SOC). The proposed approach promotes the smart grid concept by combining the RES with the utility grid. In order to get more revenues, Vehicle to Grid (V2G) technology can be also integrated where EVs owners can realize a balance of demand between charging and discharging modes. However, this approach would produce a short lifetime of the EV‘s battery and other unsolved problems. The rest of the paper is organized as follows. Section 2 describes the configuration of the EVCS. The models used for the simulation are summarized in section 3. The fourth section presents the decentralized EMS. Section 5 discusses the results of the simulation. Finally, section 6 reports the conclusions.

1.1.1 Photovoltaic effect

The photoelectric effect was first noted by French physicist Edmund Becquerel in 1839. He proposed that certain materials have property of producing small amounts of electric current when exposed to sunlight. In 1905, Albert Einstein explained the nature of light and the photoelectric effect which has become the basic principle for photovoltaic technology. In 1954 the first photovoltaic module was built by Bell Laboratories.

A photovoltaic system makes use of one or more solar panels to convert solar energy into electricity. It consists of various components which include the photovoltaic modules, mechanical and electrical connections and mountings and means of modifying the electrical output.

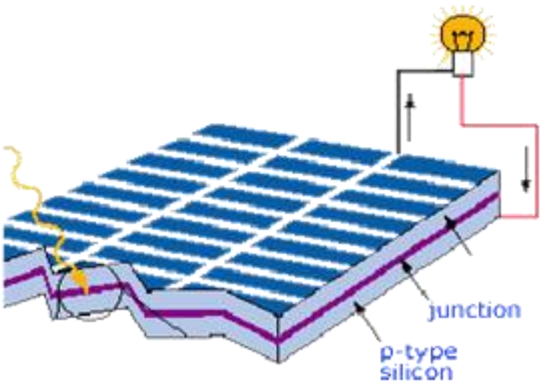


Fig.1.1 PV Module

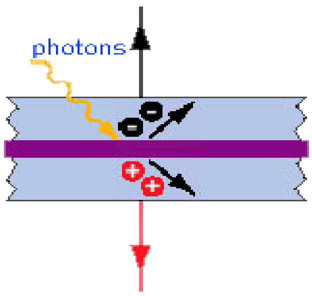


Fig 1.2 Basic structure of PV cell

The basic ingredients of PV cells are semiconductor materials, such as silicon. For solar cells, a thin semiconductor wafer creates an electric field, on one side positive and negative on the other. When light energy hits the solar cell, electrons are knocked loose from the atoms in the semiconductor material. When electrical conductors are connected to the positive and negative sides an electrical circuit is formed and electrons are captured in the form of an electric current that is, electricity. This electricity is used to power a load. A PV cell can either be circular or square in construction.

1.1.2 Photovoltaic module

Because of the low voltage generation in a PV cell (around 0.5V), several PV cells are connected in series (for high voltage) and in parallel (for high current) to form a PV module for desired output. In case of partial or total shading and at night there may be requirement of separate diodes to avoid reverse currents The p-n junctions of mono-crystalline silicon cells may have adequate reverse current characteristics and these are not necessary. There is wastage of power because of reverse currents which directs to over-heating of shaded cells. At higher temperatures solar cells provide less efficiency and installers aim to offer good ventilation behind solar panel. Usually there are of 36 or 72 cells in general PV modules. The modules consist of transparent front side, encapsulated PV cell and backside. The front side is usually made up of low-iron and tempered glass material. The efficiency of a PV module is less-then a PV cell. This is because of some radiation is reflected by the glass cover and frame shadowing etc.

1.1.3 Photovoltaic array

A photo voltaic array(PV system)is an inter connection of modules which is made up of many PVcells in series or parallel.The power produced by single module is not enough to meet the requirements of commercial applications, so modules are connected to form array to supply the load.In an array the connection of the modules is same as that of cells in a module.The modules in a PV array are usually first connected in series to obtain the desired voltages the individual modules are then connected in parallel to allow the system to produce more current. In urban uses, generally the arrays are mounted on a roof top. PV array output can directly feed to a DC motor in agricultural applications.

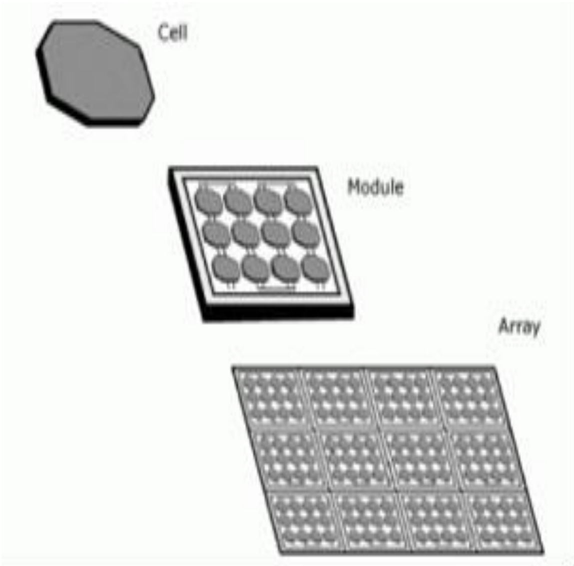


Fig 1.3 Photovoltaic system

1.1.4 Working of PV cell

The basic principle behind the operation of a PV cell is photo electric effect. In this effect electron gets ejected from the conduction band as are sult of the absorption of sunlight of a certain wave length by the matter (metallic or non-metallic solids, liquids or gases). So in a photovoltaic cell, when sunlight hits its surface, some portion of the solar energy is absorbed in the semi conductor material.

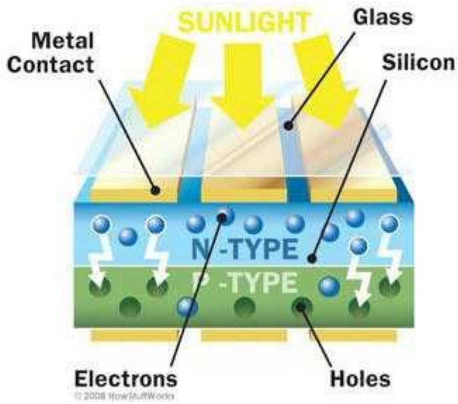


Fig 1.4.Working of PV cell

The electron from valence band jumps to the conduction band when absorbed energy is greater than the band gap energy of the semiconductor. By these hole-electrons pairs are created in the illuminated region of the semiconductor. The electrons created in the conduction band are now free to move. These free electrons are enforced to move in a particular direction by the action of electric field present in the PV cells. These electrons flowing comprise current and can be drawn for external use by connecting a metal plate on top and bottom of PV cell. This current and the voltage produces required power.

1.1.5 Modelling of PV panel

The photovoltaic system can generate direct current electricity without environmental impact when is exposed to sunlight. The basic building block of PV arrays is the solar cell, which is basically a p-n junction that directly convert slight energy into electricity.The output characteristic of PV module depends on the cell temperature, solar irradiation, and output voltage of the module. The figure shows the equivalent circuit of a PV array with a load

1.2 SOLAR CELLS

Photovoltaic are best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons. The photovoltaic effect refers to photons of light exciting electrons into a higher state of energy, allowing them to act as charge carriers for an electric current. The photovoltaic effect was first observed by Alexandre-Edmond Becquerel in 1839. The term photovoltaic denotes the unbiased operating mode of a photodiode in which current through the device is entirely due to the transuded light energy. Virtually all photovoltaic devices are some type of photodiode.

Solar cells produce direct current electricity from sun light which can be used to power equipment or to recharge a battery. The first practical application of photovoltaic’s was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for grid connected power generation. In this case an inverter is required to convert the DC to AC. There is a smaller market for off-grid power for remote dwellings, boats, recreational vehicles, electric cars, roadside emergency telephones, remote sensing, and cathodic protection of pipelines.

Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaic’s include mono crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide Copper solar cables connect modules (module cable), arrays (array cable), and sub-fields. Because of the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years.

Advantages and disadvantages

The 122 PW of sunlight reaching the Earth's surface is plentiful—almost 10,000 times more than the 13 TW equivalent of average power consumed in 2005 by humans. This abundance leads to the suggestion that it will not be long before solar energy will become the world's primary energy source. Additionally, solar electric generation has the highest power density (global mean of 170 W/m2) among renewable energies.

Solar power is pollution-free during use. Production end-wastes and emissions are manageable using existing pollution controls. End-of-use recycling technologies are under development and policies are being produced that encourage recycling from producers.

PV installations can operate for 100 years or even more with little maintenance or intervention after their initial set-up, so after the initial capital cost of building any solar power plant, operating costs are extremely low compared to existing power technologies.

Grid-connected solar electricity can be used locally thus reducing transmission/distribution losses (transmission losses in the US were approximately 7.2% in 1995). Compared to fossil and nuclear energy sources, very little research money has been invested in the development of solar cells, so there is considerable room for improvement. Nevertheless, experimental high efficiency solar cells already have efficiencies of over 40% in case of concentrating photovoltaic cells and efficiencies are rapidly rising while mass-production costs are rapidly falling.

In some states of the United States, much of the investment in a home-mounted system may be lost if the home-owner moves and the buyer puts less value on the system than the seller. The city of Berkeley developed an innovative financing method to remove this limitation, by adding a tax assessment that is transferred with the home to pay for the solar panels. Now known as PACE, Property Assessed Clean

Energy, 28 U.S. states have duplicated this solution. There is evidence, at least in California, that the presence of a home-mounted solar system can actually increase the value of a home. According to a paper published in April 2011 by the Ernest Orland Lawrence Berkeley National Laboratory titled An Analysis of the Effects of Residential Photovoltaic Energy Systems on Home Sales Prices in California.

The research finds strong evidence that homes with PV systems in California have sold for a premium over comparable homes without PV systems. More specifically, estimates for average PV premiums range from approximately $3.9 to $6.4 per installed watt (DC) among a large number of different model specifications, with most models coalescing near $5.5/watt. That value corresponds to a premium of approximately $17,000 for a relatively new 3,100 watt PV system (the average size of PV systems in the study).

1.3 PHOTOVOLTAIC INVERTER

The inverter is the heart of the PV system and is the focus of all utility-interconnection codes and standards. A Solar inverter or PV inverter is a type of electrical inverter that is made to change the direct current (DC) electricity from a photovoltaic array into alternating current (AC) for use with home appliances and possibly a utility grid. Since the PV array is a dc source, an inverter is required to convert the dc power to normal ac power that is used in our homes and offices.

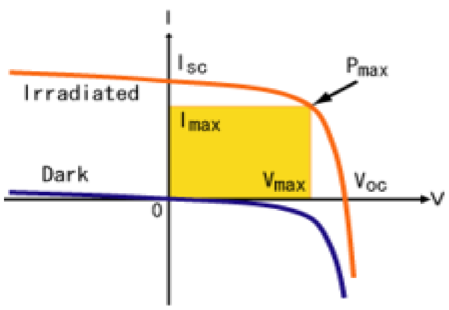
To save energy they run only when the sun is up and should be located in cool locations away from direct sunlight. The PCU is a general term for all the equipment involved including the inverter and the interface with the PV (and battery system if used) and the utility grid. It is very important to point out that inverters are by design much safer than rotating generators. Of particular concern to utility engineers is how much current a generator can deliver during a fault on their system. Inverters generally produce less than 20% of the fault current as a synchronous generator of the same nameplate capacity. This is a very significant difference.

INVERTER CLASSIFICATION

Solar inverters may be classified into three broad types :

- Stand-alone inverters, used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays and/or other sources, such as wind turbines, hydro turbines, or engine generators. Many stand-alone inverters also incorporate integral battery chargers to replenish the battery from an AC source, when available. Normally these do not interface in any way with the utility grid, and as such, are not required to have anti-islanding protection.
- Grid tie inverters, which match phase with a utility-supplied sine wave. Grid-tie inverters are designed to shut down automatically upon loss of utility supply, for safety reasons. They do not provide backup power during utility outages.
- Battery backup inverters. These are special inverters which are designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage, and are required to have anti-islanding protection.

1.4 MAXIMUM POWER POINT TRACKING (MPPT)



Graph no 1.1: I-V curve for a solar cell, showing the maximum power point P max.

Maximum power point tracking is a technique that solar inverters use to get the most possible power from the PV array. Any given PV module or string of modules will have a maximum power point: essentially, this defines current that the inverter should draw from the PV in order to get the most possible power (power is equal to voltage times current).

A maximum power point tracker (or MPPT) is a high efficiency DC to DC converter that presents an optimal electrical load to a solar panel or array and produces a voltage suitable for the load.

PV cells have a single operating point where the values of the current (I) and Voltage (V) of the cell result in a maximum power output. These values correspond to a particular load resistance, which is equal to V/I as specified by Ohm's Law. A PV cell has an exponential relationship between current and voltage, and the maximum power point (MPP) occurs at the knee of the curve, where the resistance is equal to the negative of the differential resistance (V/I = -dV/dI). Maximum power point trackers utilize some type of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell.

Traditional solar inverters perform MPPT for an entire array as a whole. In such systems the same current, dictated by the inverter, flows though all panels in the string. But because different panels have different IV curves, i.e. different MPPs (due to manufacturing tolerance, partial shading, etc.) this architecture means some panels will be performing below their MPP, resulting in the loss of energy.

Some companies (see power optimizer) are now placing peak power point converters into individual panels, allowing each to operate at peak efficiency despite uneven shading, soiling or electrical mismatch.

At night, an off-grid PV power system uses batteries to supply its loads. Although the battery pack voltage when fully charged may be close to the PV array's peak power point, this is unlikely to be true at sunrise when the battery is partially discharged. Charging may begin at a voltage considerably below the array peak power point, and a MPPT can resolve this mismatch.

When the batteries in an off-grid system are full and PV production exceeds local loads, a MPPT can no longer operate the array at its peak power point as the excess power has nowhere to go. The MPPT must then shift the array operating point away from the peak power point until production exactly matches demand. (An alternative approach commonly used in spacecraft is to divert surplus PV power into a resistive load, allowing the array to operate continuously at its peak power point.

In a grid-tied photovoltaic system, the grid is essentially a battery with near infinite capacity. The grid can always absorb surplus PV power, and it can cover shortfalls in PV production (e.g., at night). Batteries are thus needed only for protection from grid outages. The MPPT in a grid tied PV system will always operate the array at its peak power point unless the grid fails when the batteries are full and there are insufficient local loads. It would then have to back the array away from its peak power point as in the off-grid case (which it has temporarily become).Using a series of filters and multipliers and then used to calculate the array conductance. Then the algorithm decides the direction of movement of MPPT operating point. There is one disadvantage in this algorithm that the parasitic capacitance in each module is very small, and can perform well in large PV arrays where several PV modules are connected in parallel.

1.4.1 Voltage control maximum power point tracker

The maximum power point (MPP) of a PV module is assumed to lie about 0.75 times the open circuit voltage of the module. Hence a reference voltage can be generated by calculating the open circuit voltage and then the feed forward voltage control scheme can be implemented to bring the solar PV module voltage to the point of maximum power. The difficulty associated with this technique is that there is variation of open circuit voltage with the

Temperature As there is increase in temperature because of the change in open circuit voltage of the module, module’s open circuit is needed to be calculated frequently.

1.4.2 Current control maximum power point tracker

The module's peak power lies at the point which is about 0.9 times the short circuit current of the module. The module has to be short-circuited to measure this point. After that module current is adjusted to the value by using the current mode control which is approximately 0.9 times the short circuit current. In this case a high power resistor is required which can sustain the short-circuit current. This is the problem with this algorithm. The module has to be short circuited to measure the short circuit current as it goes on varying with the changes in irradiation level.

CHAPTER-2

CONVERTERS

2.1 DC-DC CONVERTER BASICS

A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc.

2.2 BUCK CONVERTER STEP-DOWN CONVERTER

In this circuit the transistor turning ON will put voltage V_{in} on one end of the inductor. This voltage will tend to cause the inductor current to rise. When the transistor is OFF, the current will continue flowing through the inductor but now flowing through the diode.

We initially assume that the current through the inductor does not reach zero, thus the voltage at V_x will now be only the voltage across the conducting diode during the full OFF time. The average voltage at V_x will depend on the average ON time of the transistor provided the inductor current is continuous.

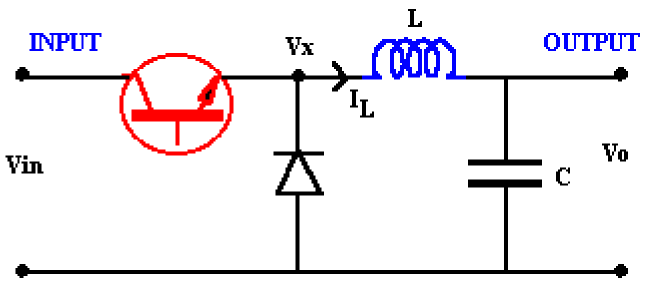
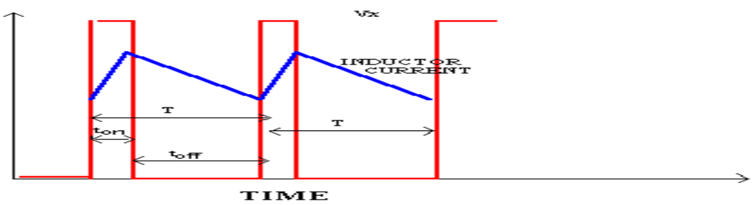


Fig 2.1 Buck Converter



Graph no. 2.1 : Voltage and current changes

2.3 BOOST CONVERTER STEP-UP CONVERTER

The schematic shows the basic boost converter. This circuit is used when a higher output voltage than input is required.

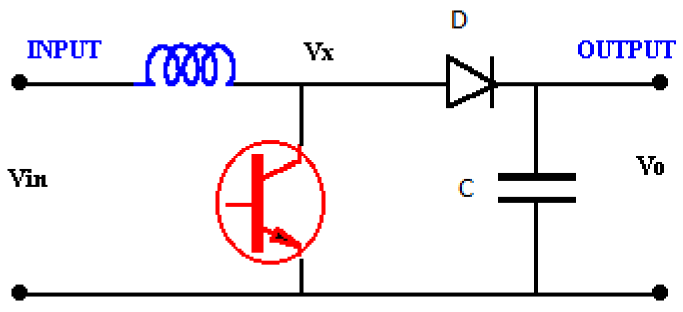
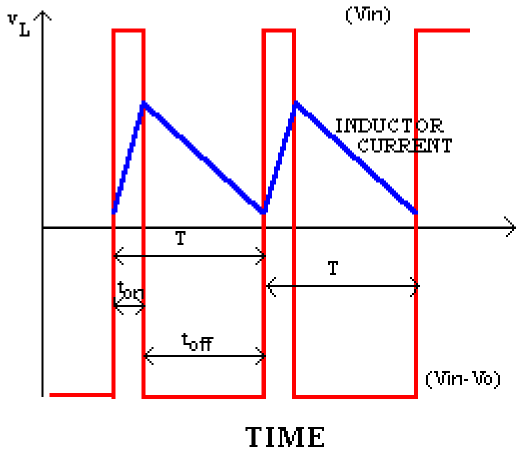


Fig 2.2 Boost Converter Circuit

While the transistor is ON $V_x = V_{in}$, and the OFF state the inductor current flows through the diode giving $V_x = V_o$. For this analysis it is assumed that the inductor current always remains flowing (continuous conduction). The voltage across the inductor is shown in Fig. 7 and the average must be zero for the average current to remain in steady state



Graph no. 2.2 : Voltage and current waveforms (Boost Converter)

Since the duty ratio "D" is between 0 and 1 the output voltage must always be higher than the input voltage in magnitude. The negative sign indicates a reversal of sense of the output voltage.

2.4 BUCK-BOOST CONVERTER

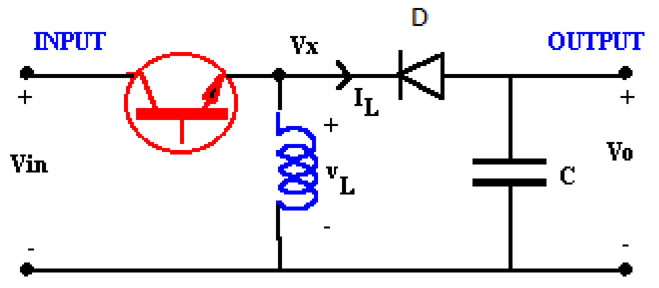
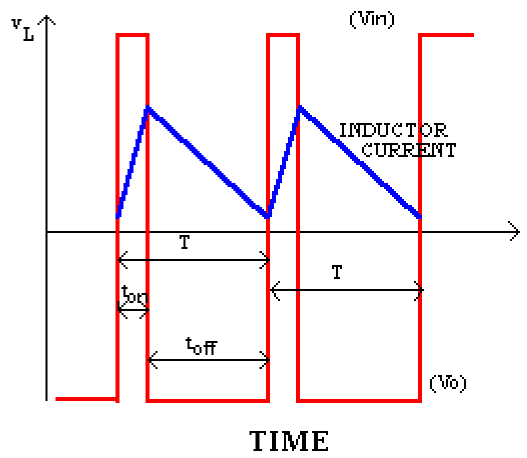


Fig 2.3 schematic for buck-boost converter

With continuous conduction for the Buck-Boost converter $V_x = V_{in}$ when the transistor is ON and $V_x = V_o$ when the transistor is OFF. For zero net current change over a period the average voltage across the inductor is zero



Graph no. 2.3 : Waveforms for buck-boost converter

2.5 BUCK CONVERTER

The buck, boost and buck-boost converters all transferred energy between input and output using the inductor, analysis is based of voltage balance across the inductor. The BUCK converter uses capacitive energy transfer and analysis is based on current balance of the capacitor. The circuit in Fig. below(BUCK converter) is derived from DUALITY principle on the buck-boost converter.

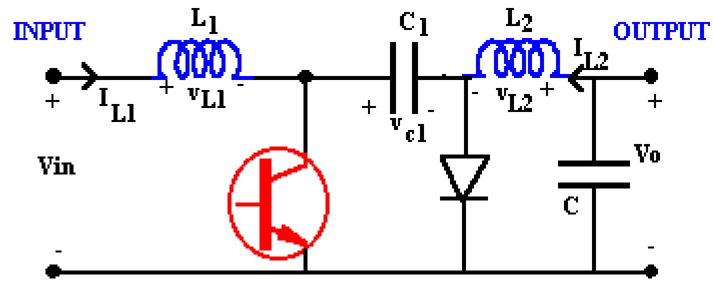


Fig 2.4 BUCK Converter

If we assume that the current through the inductors is essentially ripple free we can examine the charge balance for the capacitor C1. For the transistor ON the circuit becomes

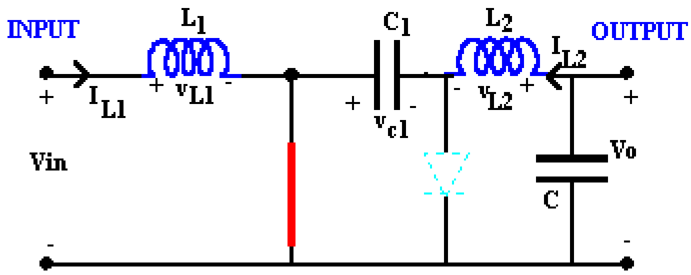


Fig 2.5 BUCK "ON-STATE"

and the current in C1 is I_{L1}. When the transistor is OFF, the diode conducts and the current in C1 becomes I_{L2}.

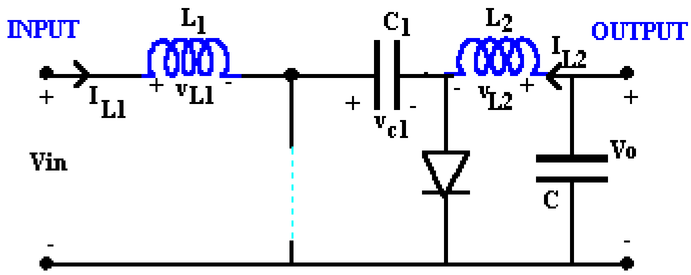


Fig 2.6 BUCK "OFF-STATE"

Since the steady state assumes no net capacitor voltage rise ,the net current is zero.

2.6 BOOST CONVERTER:

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

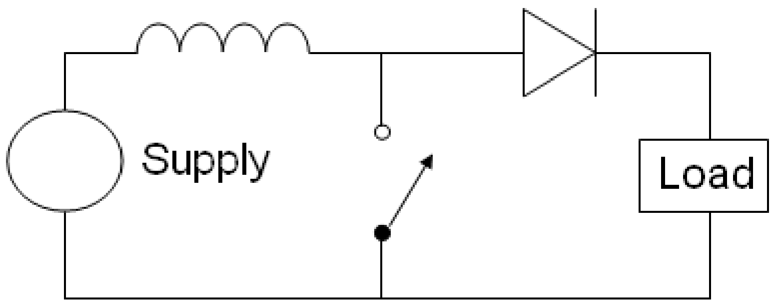


Figure 2.7 Boost converter

Power can also come from DC sources such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it “steps up” the source voltage. Since power ($P = VI$ or $P = UI$ in Europe) must be conserved, the output current is lower than the source current.

A boost converter may also be referred to as a 'Joule thief'. This term is usually used only with very low power battery applications, and is aimed at the ability of a boost converter to 'steal' the remaining energy in a battery. This energy would otherwise be wasted since a normal load wouldn't be able to handle the battery's low voltage.*

- This energy would otherwise remain untapped because in most low-frequency applications, currents will not flow through a load without a significant difference of potential between the two poles of the source (voltage.)

2.6.1 BLOCK DIAGRAM

The basic building blocks of a boost converter circuit are shown in Fig.

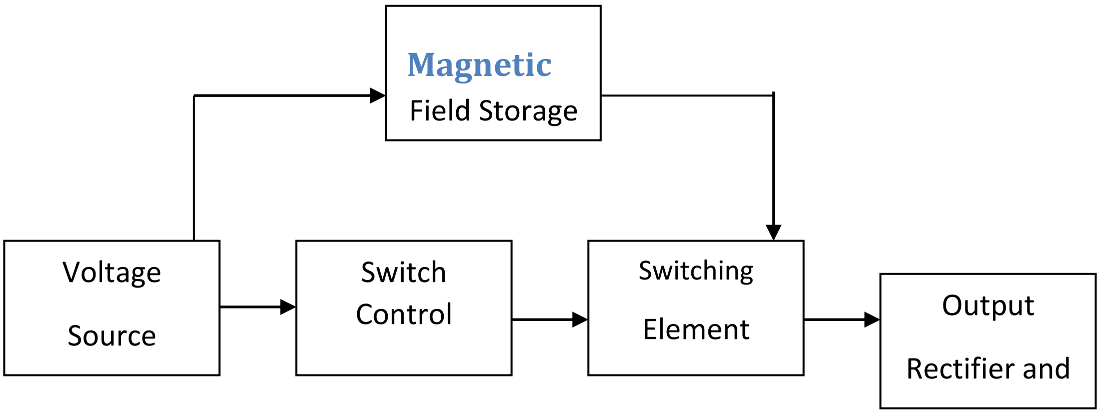


Fig.2.8 Block diagram

The voltage source provides the input DC voltage to the switch control, and to the magnetic field storage element. The switch control directs the action of the switching element, while the output rectifier and filter deliver an acceptable DC voltage to the output.

Operating principle:

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy (somewhat like a resistor), when being discharged, it acts as an energy source (somewhat like a battery). The voltage it produces during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different input and output voltages.

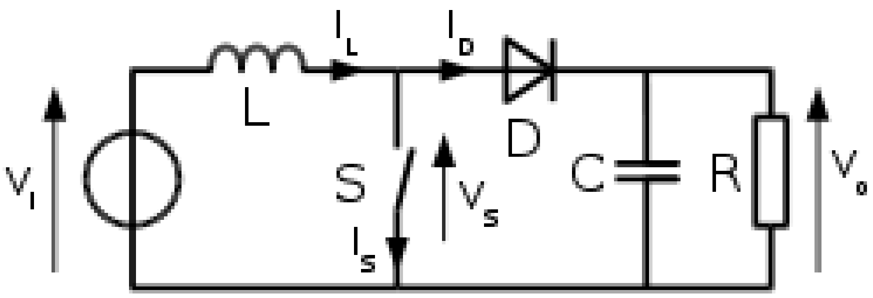


Fig 2.9: Boost converter schematic

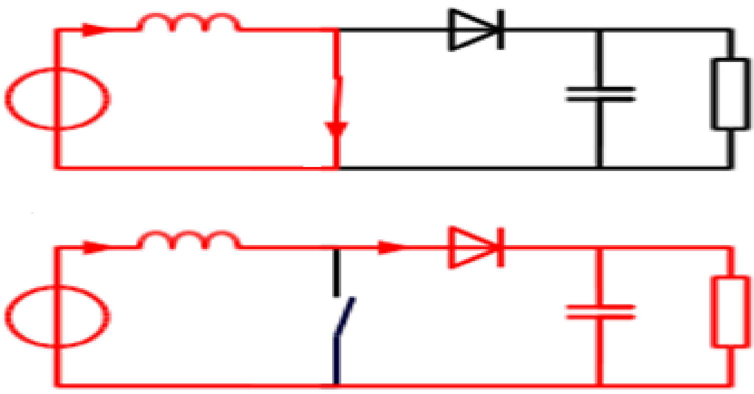


Fig.2.10 The two configurations of a boost converter, depending on the state of the switch.

- In the On-state, the switch S (see figure) is closed, resulting in an increase in the inductor current;
- In the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R. This result in transferring the energy accumulated during the On-state into the capacitor.

The input current is the same as the inductor current as can be seen in figure. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter

CHAPTER-3

MODELLING OF CASE STUDY

3.1 CIRCUIT TOPOLOGY

DESCRIPTION AND MODELLING OF THE EVCS

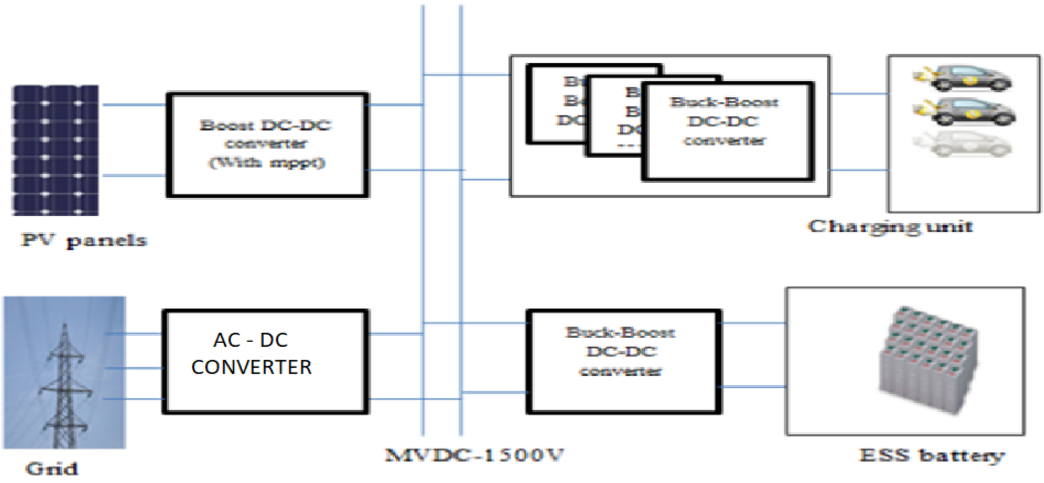


Figure 3.1: . Configuration of EVCS

Description of the EVCS :

The configuration of the FCS is depicted in fig 3.1. It is composed of three 50 kW fast charging units (FCU), a PV system, a Li-ion ESS, and the grid connection. All of the elements are tied to 1500 V MVDC common bus via their corresponding converter, which ensures the charge of a group of EVs with a high power supply and adopts their outputs voltages to the DC link, also it control the power balance between them and the DC bus. Furthermore, the grid connection consists of a bi-directional DC/AC converter and a transformer. According to the IEC 61851-1, all the FCU are defined as DC level 2(voltage inferior to 500V, current inferior to 200 A) and it adopts the fourth mode (fast charging with an external charger in DC), in addition to that, the rated capacity of the EV's battery is around 23 kWh.

B. PV system

The model of the PV system used in this project is a singlediode model, it consists of just one diode, one controllable source of current and a couple of resistances, the first is in parallel (Rsh) and the second is in series (Rs). The following expression is used to calculate the PV system output current (Ipv):

$$I_{pv} = I_{ph} - I_{sat} \times \left(e^{q\left(\frac{V + I_{pv} \times R_s}{NKT_{pv}}\right)} \right) - \left(\frac{V + R_S I_{pv}}{R_{sh}} \right)$$

$$I_{ph} = I_{ph0}\left(1 + K_0\left(T - 300\right)\right)$$

$$I_{sat} = K_1 T^3 e^{\left(\frac{-qV_g}{KT}\right)}$$

are the solar induced current, the solar induced current at 300° K, and the diode saturation current, respectively and Vg is the voltage applied to the terminals of the diode. K0 and K1 are both constants whose values depend on the PV system, K is the Boltzmann constant, N represents the diode quality factor, q is known as the electron elementary charge, and finally Tpv is the operating temperature.

C. EV and ESS batteries Nowadays, the most competitive type of battery is Lithium battery due to its highest energy efficiency level, its density of power and its lightweight also its compactness . In addition to that, it allows the fast charging ability and provides a wide range of operating temperature, also it is characterized by its long life cycle, low self-discharge and it does not have a memory effect. The model of Li-ion battery consists of a variable voltage source and a resistance in Rint as presented in Fig.2, and the expression of the output voltage is the following:

$$V_{bat} = E_{bat} - R_{int} \times I_{bat}$$

$$E_{bat} = E_0 - K\frac{Q}{i_t - 0.1Q}i^* - K\frac{Q}{Q - i_t}i_t + Ae^{(-B\, i_t)}$$

Where E0 is the voltage of no load battery (V), K represents the polarization voltages (V), Q is the capacity of battery (Ah), A is the amplitude of the exponential zone (V), B is the exponential zone time constant inverse (Ah-1), Vbat is voltage of battery (V), Ibat is the current of battery (A), and ∫ i dt is the charge supplied and drawn by the battery (Ah). The SOC is the most important parameters of the battery which must be controlled to avoid an extra-charge or a deep battery discharging. Its expression is presented in the following equation:

$$SOC(\%) = SOC_0(\%) - 100 \times \left(\frac{\int i_{bat}\, dt}{Q} \right)$$

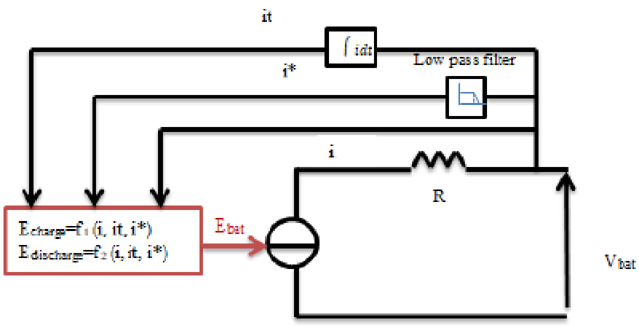
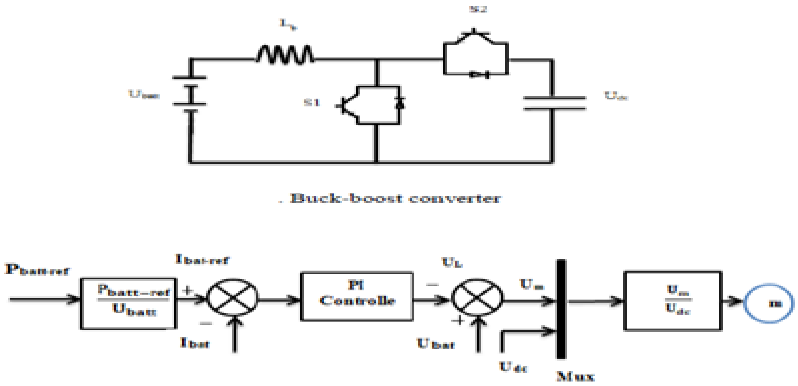


Figure 3.2: Standard battery model.

In this project, through buck-boost converter the dc link side is connected to the batteries, the principal objective of the control of this converter is to maintain constant the dc bus voltage as its reference value in addition to discharge/charge current from/to the batteries according to the desired load power.



Control scheme and schematic diagram.

Figure 3.3 : schematic diagram of the converter.

The schematic diagram of the converter is represented in above figure and its control scheme is depicted in Fig.4, which is made via the keys S1 and S2. For the mode of charging, the converter establishes the buck mode (S1=0, S2=1), and for charging process it establishes the boost mode (S1=1, S2=0).

3.2 ENERGY MANAGEMENT SYSTEM

In this study, the chosen model of the charging infrastructure based on the grid-connected photovoltaic charging topology consists of several sources of energy i.e. PV system, ESS and the grid, where the control was established by a PI controllers. This structure was used to test the comportment of the decentralized strategy. This type of control is characterized by the independent work of each source of energy, so it provide the management of the energy flow between the sources of energy without the requirement for communication structure among the sources of energy , or between the latter and the EMS. Thus, the extension of the MVDC network is simpler and smoother due to the unnecessary of a new system of communication also the EMS does not require any modification. Moreover, the DC bus voltage is the only variable in common between the different sources of energy (all the energy sources are tied to the DC bus), which was chosen as the key parameter for supervising the system.

Thus, the most important element of the studied strategy is that the change in the state of charge of the ESS (ESS SOC) allows the transition among the modes of operation. The supervising strategy was developed to maximize the usage of PV power for EV charging and minimize the grid dependency, in which the utility connection is conditioned by the cost of energy transmission (ETC). This strategy is depicted in the following diagram fig.5. When an EV is plugged into the charger, the PV system is used to supply the EVs when it is possible. If more power is needed, the deficit of power is generated by the battery or by the utility grid during off-peak hours (when the ETC is low). If no electric vehicle is pluggedin, the PV energy is stored in the ESS; finally if the ESS SOC reaches its highest level, the excess of PV power is given to the grid.

Parameter	value
PV system converter,L	$20*10^{-3}$ H
PV system converter,C	$62*10^{-6}$ F
DC bus capacitor	0.05 F
ESS converter,L	$0.1*10^{-3}$
EV converter,L	$0.13*10^{3}$

Table no. 1 Main parameters of EVCS

parameter	Li-Ion 3.6V, 1.5Ah
E_0(V)	3.3037
R(Ω)	0.024
A(V)	0.30231
B (Ah^{-1})	40.708
K(Ω)	0.1

Table no. 2 Parameters of Li-Ion battery

CHAPTER 4

PI CONTROLLER

A variation of Proportional Integral Derivative (PID) control is to use only the proportional and integral terms as PI control. The PI controller is the most popular variation, even more than full PID controllers. The value of the controller output u(t) is fed into the system as the manipulated variable input.

$$e(t)=SP-PV$$

$$u(t)=ubias+Kce(t)+Kc\tau I\int t0e(t)dt$$

The ubias term is a constant that is typically set to the value of u(t) when the controller is first switched from manual to automatic mode. This gives "bumpless" transfer if the error is zero when the controller is turned on. The two tuning values for a PI controller are the controller gain, Kc and the integral time constant τI. The value of Kc is a multiplier on the proportional error and integral term and a higher value makes the controller more aggressive at responding to errors away from the set point. The set point (*SP*) is the target value and process variable (*PV*) is the measured value that may deviate from the desired value. The error from the set point is the difference between the *SP* and *PV* and is defined as $e(t)=SP-PV$

4.1 DISCRETE PI CONTROLLER

Digital controllers are implemented with discrete sampling periods and a discrete form of the PI equation is needed to approximate the integral of the error. This modification replaces the continuous form of the integral with a summation of the error and uses Δt as the time between sampling instances and nt as the number of sampling instances.

$$u(t)=ubias+Kce(t)+Kc\tau Int\sum i=1ei(t)\Delta t$$

4.1.1 Overview Of Pi Control

PI control is needed for non-integrating processes, meaning any process that eventually returns to the same output given the same set of inputs and disturbances. A P-only controller is best suited to integrating processes. Integral action is used to remove offset and can be thought of as an adjustable ubias. Common tuning correlations for PI control are the ITAE (Integral of Time-weighted Absolute Error) method and IMC (Internal Model Control). IMC is an extension of lambda tuning by accounting for time delay. The parameters Kc, τp, and θp are obtained by fitting dynamic input and output data to a first-order plus dead-time (FOPDT) model.The general block diagram of the PI speed controller is shown in Figure.

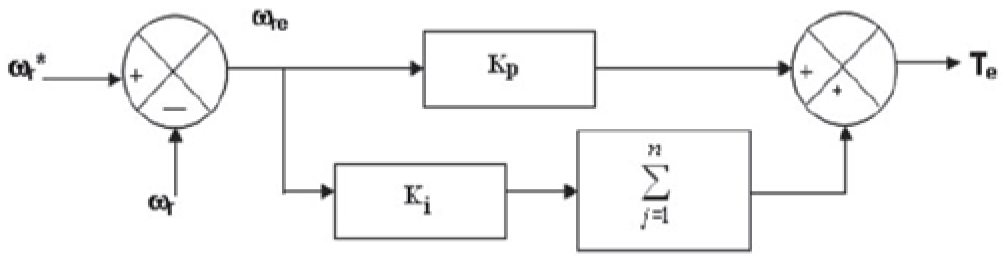


Fig.4.1.Block diagram of PI speed controller

The output Of the speed controller (torque command) at *n*-thinstant is expressed as follows

$$Te\,(n)=Te(n-1)+Kp\_\omega re(n)+Ki\omega re(n) \quad (10)$$

Where *Te* (*n*) is the torque output of the controller at the *n*-th instant, and *Kp*and K*i* the

proportional and integral gain constants, respectively.

A limit of the torque command is imposed as

$$T_{e(n+1)}=\begin{cases} T_{e\max} & \text{for} \quad T_{e(n+1)} \geq T_{e\max} \\ -T_{e\max} & \text{for} \quad T_{e(n+1)} \leq -T_{e\max} \end{cases}$$

The gains of PI controller shown in (10) can be selected by many methods such as trial and error method, Ziegler–Nichols method and evolutionary techniques-based searching. The numerical values of these controller gains depend on the ratings of the motor.

4.2 ADVANTAGES AND DISADVANTAGES

The integral term in a PI controller causes the steady-state error to reduce to zero, which is not the case for proportional-only control in general.

The lack of derivative action may make the system more steady in the steady state in the case of noisy data. This is because derivative action is more sensitive to higher-frequency terms in the inputs.

Without derivative action, a PI-controlled system is less responsive to real (non-noise) and relatively fast alterations in state and so the system will be slower to reach set point and slower to respond to perturbations than a well-tuned PID system may be.

4.2.1 Integral Action and PI Control

Like the P-Only controller, the Proportional-Integral (PI) algorithm computes and transmits a controller output (CO) signal every sample time, T, to the final control element (e.g., valve, variable speed pump). The computed CO from the PI algorithm is influenced by the controller tuning parameters and the controller error, e(t).

PI controllers have two tuning parameters to adjust. While this makes them more challenging to tune than a P-Only controller, they are not as complex as the three parameter PID controller.

Integral action enables PI controllers to eliminate offset, a major weakness of a P-only controller. Thus, PI controllers provide a balance of complexity and capability that makes them by far the most widely used algorithm in process control applications.

4.2.2 The PI Algorithm

While different vendors cast what is essentially the same algorithm in different forms, here we explore what is variously described as the dependent, ideal, continuous, position form

$$CO = CO_{bias} + Kc \cdot e(t) + \frac{Kc}{Ti} \int e(t)dt$$

Where:

CO = controller output signal (the wire out)

CObias = controller bias or null value; set by bumpless transfer as explained below

e(t) = current controller error, defined as SP – PV

SP = set point

PV = measured process variable (the wire in)

Kc = controller gain, a tuning parameter

Ti = reset time, a tuning parameter

The first two terms to the right of the equal sign are identical to the P-Only controller referenced at the top of this article.The integral mode of the controller is the last term of the equation. Its function is to integrate or continually sum the controller error, e(t), over time.Some things we should know about the reset time tuning parameter, Ti.

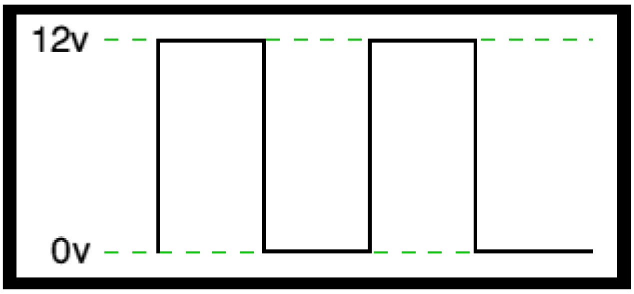
It provides a separate weight to the integral term so the influence of integral action can be independently adjusted. It is in the denominator so smaller values provide a larger weight to (i.e. increase the influence of) the integral term.It has units of time so it is always positive.

CHAPTER 5

PULSE WIDTH MODULATION

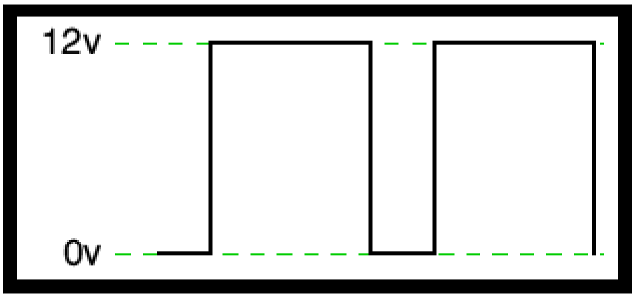
5.1 PWM INTRODUCTION

Pulse Width Modulation (PWM) is the most effective means to achieve constant voltage battery charging by switching the solar system controller’s power devices. When in PWM regulation, the current from the solar array tapers according to the battery’s condition and recharging needs consider a waveform such as this: it is a voltage switching between 0v and 12v. It is fairly obvious that, since the voltage is at 12v for exactly as long as it is at 0v, then a 'suitable device' connected to its output will see the average voltage and think it is being fed 6v - exactly half of 12v. So by varying the width of the positive pulse - we can vary the 'average' voltage.

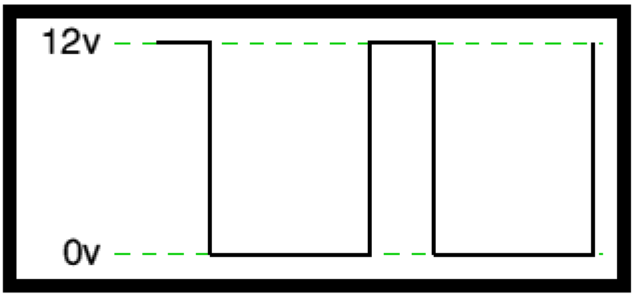


Graph no.5.1 : Average voltage exactly half of 12v

Similarly, if the switches keep the voltage at 12 for 3 times as long as at 0v, the average will be 3/4 of 12v - or 9v, as shown below.



Graph no.5.2 : Average voltage will be 3/4 of 12v

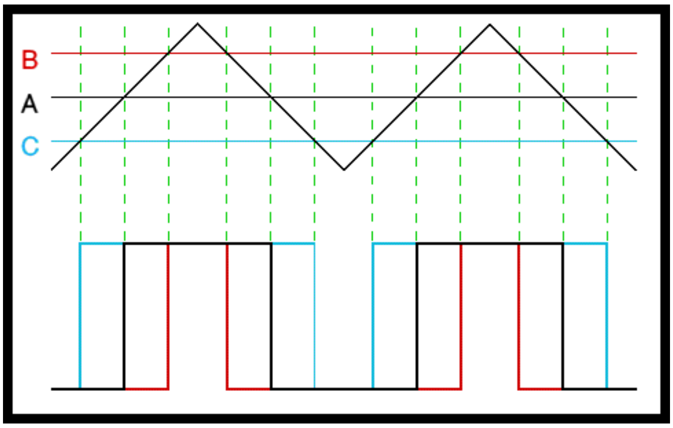


Graph no.5.3 : Average output voltage at 12v

And if the output pulse of 12v lasts only 25% of the overall time, then the average is by varying - or 'modulating' - the time that the output is at 12v (i.e. the width of the positive pulse) we can alter the average voltage. So we are doing 'pulse width modulation'. I said earlier that the output had to feed 'a suitable device'. A radio would not work from this: the radio would see 12v then 0v, and would probably not work properly. However a device such as a motor will respond to the average, so PWM is a natural for motor control.

5.1.1 Pulse Width modulator

So, how do we generate a PWM waveform? It's actually very easy, there are circuits available in the TEC site. First you generate a triangle waveform as shown in the diagram below. You compare this with a d.c voltage, which you adjust to control the ratio of on to off time that you require. When the triangle is above the 'demand' voltage, the output goes high. When the triangle is below the demand voltage.



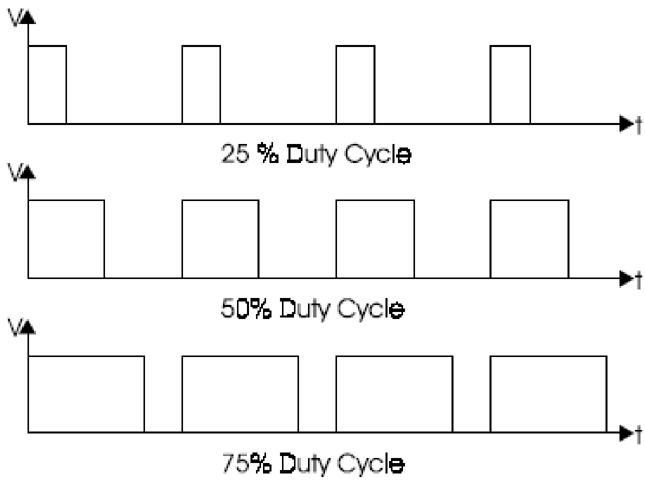
Graph no. 5.4 : Pulse Width modulator Wave form

When the demand speed it in the middle (A) you get a 50:50 output, as in black. Half the time the output is high and half the time it is low. Fortunately, there is an IC (Integrated circuit) called a comparator: these come usually 4 sections in a single package. One can be used as the oscillator to produce the triangular waveform and another to do the comparing, so a complete oscillator and modulator can be done with half an IC and maybe 7 other bits.

The triangle waveform, which has approximately equal rise and fall slopes, is one of the commonest used, but you can use a saw tooth (where the voltage falls quickly and rinses slowly). You could use other waveforms and the exact linearity (how good the rise and fall are) is not too important.

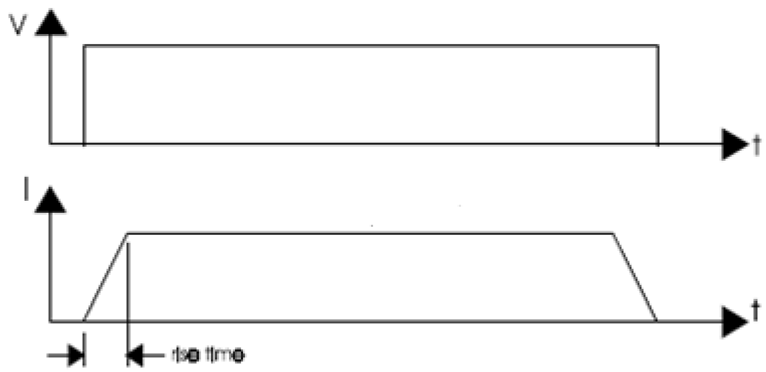
Traditional solenoid driver electronics rely on linear control, which is the application of a constant voltage across a resistance to produce an output current that is directly proportional to the voltage. Feedback can be used to achieve an output that matches exactly the control signal. However, this scheme dissipates a lot of power as heat, and it is therefore very inefficient.

A more efficient technique employs pulse width modulation (PWM) to produce the constant current through the coil. A PWM signal is not constant. Rather, the signal is on for part of its period, and off for the rest. The duty cycle, D, refers to the percentage of the period for which the signal is on. The duty cycle can be anywherefrom 0, the signal is always off, to 1, where the signal is constantly on. A 50% D results in a perfect square wave.



Graph no. 5.5 : Duty cycle variation

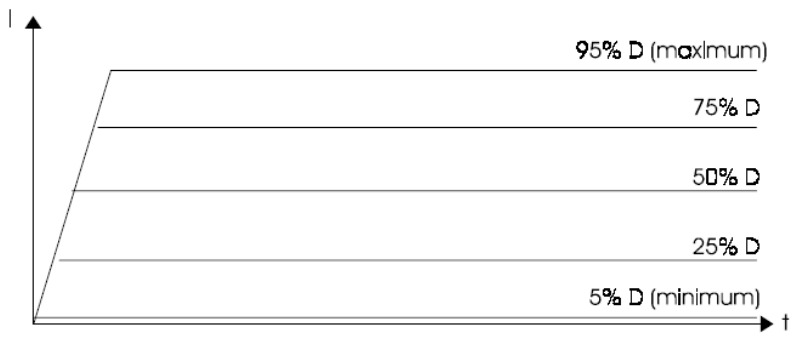
A solenoid is a length of wire wound in a coil. Because of this configuration, the solenoid has, in additionto its resistance, R, a certain inductance, L. When a voltage, V, is applied across an inductive element, thecurrent, I, produced in that element does not jump up to its constant value, but gradually rises to itsmaximum over a period of time called the rise time**.** Conversely, I does not disappearinstantaneously, even if V is removed abruptly, but decreases back to zero in the same amount of time asthe rise time.



Graph no.5.6 : Current steady state value

Therefore, when a low frequency PWM voltage is applied across a solenoid, the current through it will be increasing and decreasing as V turns on and off. If D is shorter than the rise time, I will never achieve its maximum value, and will be discontinuous since it will go back to zero during V's off period. In contrast, if D is larger than the rise time, I will never fall back to zero, so it will be continuous, and have a DC average value. The current will not be constant, however, but will have a ripple.

At high frequencies, V turns on and off very quickly, regardless of D, such that the current does not havetime to decrease very far before the voltage is turned back on. The resulting current through the solenoid istherefore considered to be constant. By adjusting the D, the amount of output current can be controlled.With a small D, the current will not have much time to rise before the high frequency PWM voltage takeseffect and the current stays constant. With a large D, the current will be able to rise higher before itbecomes constant.



Graph no. 5.7 The current will be able to rise higher before it becomes constant

5.1.2 DITHER

Static friction, stiction, and hysteresis can cause the control of a hydraulic valve to be erratic and unpredictable. Stiction can prevent the valve spool from moving with small input changes, and hysteresis can cause the shift to be different for the same input signal. In order to counteract the effects of stiction and hysteresis, small vibrations about the desired position are created in the spool. This constantly breaks the static friction ensuring that it will move even with small input changes, and the effects of hysteresis are average out.

Dither is a small ripple in the solenoid current that causes the desired vibration and there by increases the linearity of the valve. The amplitude and frequency of the dither must be carefully chosen. The amplitude must be large enough and the frequency slow enough that the spool will respond, yet they must also be small and fast enough not to result in a pulsating output.

The optimum dither must be chosen such that the problems of stiction and hysteresis are overcome without new problems being created. Dither in the output current is a byproduct of low frequency PWM, as seen above. However, the frequency and amplitude of the dither will be a function of the duty cycle, which is also used to set the output current level. This means that low frequency dither is not independent of current magnitude. The advantage of using high frequency PWM is that dither can be generated separately, and then superimposed on top of the output current.

This allows the user to independently set the current magnitude (by adjusting the D), as well as the dither frequency and amplitude. The optimum dither, as set by the user, will therefore be constant at all current levels.

5.1.3 PWM frequency is important :

The PWM is a large amplitude digital signal that swings from one voltage extreme to the other. And, this wide voltage swing takes a lot of filtering to smooth out. When the PWM frequency is close to the frequency of the waveform that you are generating, then any PWM filter will also smooth out your generated waveform and drastically reduce its amplitude. So, a good rule of thumb is to keep the PWM frequency much higher than the frequency of any waveform you generate.

Finally, filtering pulses is not just about the pulse frequency but about the duty cycle and how much energy is in the pulse. The same filter will do better on a low or high duty cycle pulse compared to a 50% duty cycle pulse. Because the wider pulse has more time to integrate to a stable filter voltage and the smaller pulse has less time to disturb it the inspiration was a request to control the speed of a large positive displacement fuel pump. The pump was sized to allow full power of a boosted engine in excess of 600 Hp.

At idle or highway cruise, this same engine needs far less fuel yet the pump still normally supplies the same amount of fuel. As a result the fuel gets recycled back to the fuel tank, unnecessarily heating the fuel. This PWM controller circuit is intended to run the pump at a low speed setting during low power and allow full pump speed when needed at high engine power levels.

5.1.4 Motor Speed Control (Power Control)

Typically when most of us think about controlling the speed of a DC motor we think of varying the voltage to the motor. This is normally done with a variable resistor and provides a limited useful range of operation. The operational range is limited for most applications primarily because torque drops off faster than the voltage drops.

Most DC motors cannot effectively operate with a very low voltage. This method also causes overheating of the coils and eventual failure of the motor if operated too slowly. Of course, DC motors have had speed controllers based on varying voltage for years, but the range of low speed operation had to stay above the failure zone described above.

Additionally, the controlling resistors are large and dissipate a large percentage of energy in the form of heat. With the advent of solid state electronics in the 1950's and 1960's and this technology becoming very affordable in the 1970's & 80's the use of pulse width modulation (PWM) became much more practical. The basic concept is to keep the voltage at the full value and simply vary the amount of time the voltage is applied to the motor windings. Most PWM circuits use large transistors to simply allow power On & Off, like a very fast switch.

This sends a steady frequency of pulses into the motor windings. When full power is needed one pulse ends just as the next pulse begins, 100% modulation. At lower power settings the pulses are of shorter duration. When the pulse is On as long as it is Off, the motor is operating at 50% modulation. Several advantages of PWM are efficiency, wider operational range and longer lived motors. All of these advantages result from keeping the voltage at full scale resulting in current being limited to a safe limit for the windings.

PWM allows a very linear response in motor torque even down to low PWM% without causing damage to the motor. Most motor manufacturers recommend PWM control rather than the older voltage control method. PWM controllers can be operated at a wide range of frequencies. In theory very high frequencies (greater than 20 kHz) will be less efficient than lower frequencies (as low as 100 Hz) because of switching losses.

The large transistors used for this On/Off activity have resistance when flowing current, a loss that exists at any frequency. These transistors also have a loss every time they "turn on" and every time they "turn off". So at very high frequencies, the "turn on/off" losses become much more significant. For our purposes the circuit as designed is running at 526 Hz. Somewhat of an arbitrary frequency, it works fine.

Depending on the motor used, there can be a hum from the motor at lower PWM%. If objectionable the frequency can be changed to a much higher frequency above our normal hearing level (>20,000Hz).

5.1.5 PWM Controller Features

This controller offers a basic "Hi Speed" and "Low Speed" setting and has the option to use a "Progressive" increase between Low and Hi speed. Low Speed is set with a trim pot inside the controller box. Normally when installing the controller, this speed will be set depending on the minimum speed/load needed for the motor. Normally the controller keeps the motor at this Lo Speed except when Progressive is used and when Hi Speed is commanded (see below). Low Speed can vary anywhere from 0% PWM to 100%.

Progressive control is commanded by a 0-5 volt input signal. This starts to increase PWM% from the low speed setting as the 0-5 volt signal climbs. This signal can be generated from a throttle position sensor, a Mass Air Flow sensor, a Manifold Absolute Pressure sensor or any other way the user wants to create a 0-5 volt signal. This function could be set to increase fuel pump power as turbo boost starts to climb (MAP sensor). Or, if controlling a water injection pump, Low Speed could be set at zero PWM% and as the TPS signal climbs it could increase PWM%, effectively increasing water flow to the engine as engine load increases. This controller could even be used as a secondary injector driver (several injectors could be driven in a batch mode, hi impedance only), with Progressive control (0-100%) you could control their output for fuel or water with the 0-5 volt signal.

Progressive control adds enormous flexibility to the use of this controller. Hi Speed is that same as hard wiring the motor to a steady 12 volt DC source. The controller is providing 100% PWM, steady 12 volt DC power. Hi Speed is selected three different ways on this controller: 1) Hi Speed is automatically selected for about one second when power goes on. This gives the motor full torque at the start. If needed this time can be increased (the value of C1 would need to be increased). 2) High Speed can also be selected by applying 12 volts to the High Speed signal wire. This gives Hi Speed regardless of the Progressive signal.

When the Progressive signal gets to approximately 4.5 volts, the circuit achieves 100% PWM – Hi Speed.

5.1.6 Advantages of this technology :

The benefits noted above are technology driven. The more important question is how the PWM. Technology Jumping from a 1970’s technology into the new millennium offers:

• Longer battery life:

– reducing the costs of the solar system

– reducing battery disposal problems

More battery reserve capacity :

– increasing the reliability of the solar system

– reducing load disconnects

– opportunity to reduce battery size to lowerthe system cost

• Greater user satisfaction:

– get more power when you need it for less money

CHAPTER 6

ENERGY STORAGE TECHNOLOGIES

This chapter provides an overview of commonly used energy storage technologies. It looks into various factors that differentiate storage technologies, such as cost, cycle life, energy density, efficiency, power output, and discharge duration. One energy storage technology in particular, the battery energy storage system (BESS), is studied in greater detail together with the various components required for grid-scale operation. The advantages and disadvantages of different commercially mature battery chemistries are examined. The chapter ends with a review of best practice for recycling and reuse lithium-ion batteries.

6.1 STORAGE TYPES

Energy storage devices can be categorized as mechanical, electrochemical, chemical, electrical, or thermal devices, depending on the storage technology used (Figure 1.1). Mechanical technology, including pumped hydropower generation, is the oldest technology. However, a limitation of this technology is its need for abundant water resources and a different geographic elevation, as well as the construction of power transmission lines to households that consume electricity. Recently, transmission-line construction cost has surpassed the cost of installing a pumped hydropower generation facility.

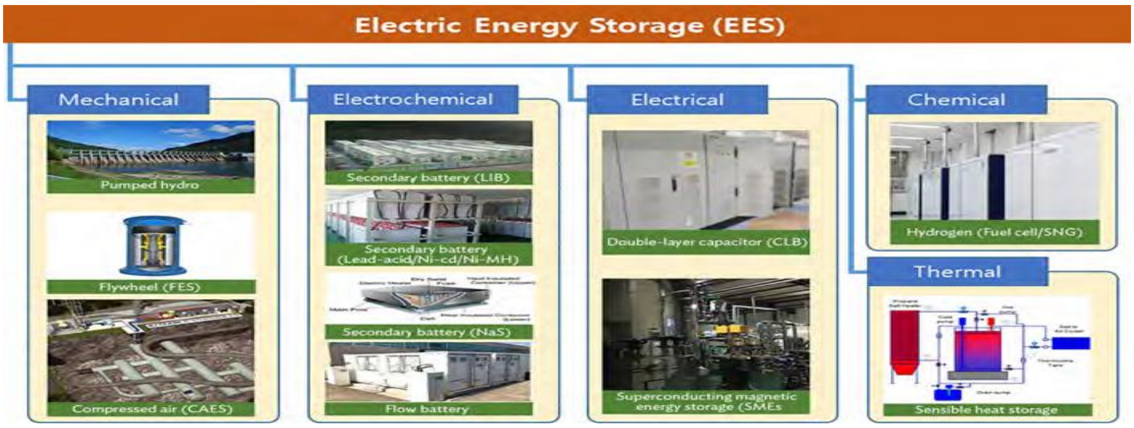


Figure 6.1: Classification of Storage Technologies, By Energy Type

In addition to the recent spread of mobile information technology (IT) devices and electric vehicles, the increased mass production of lithium secondary batteries and their lowered costs have boosted demand for energy storage devices using such batteries. Lithium secondary batteries convert electric energy to chemical energy, and vice versa, using electrochemical technologies. Such technologies also include lead storage batteries and sodium–sulfur batteries. Chemical technologies include energy storage technologies such as fuel cells, and mechanical technologies include electric double-layer capacitors. The performance of energy storage devices can be defined by their output and energy density. Their use can be differentiated by place and duration of use, as defined by the technology adopted. In Figure 1.2, the applications (in the tan-colored boxes) are classified according to output, usage period, and power requirement, and the energy storage devices (in the amber-colored boxes) according to usage period, power generation, and system and/or network operation.

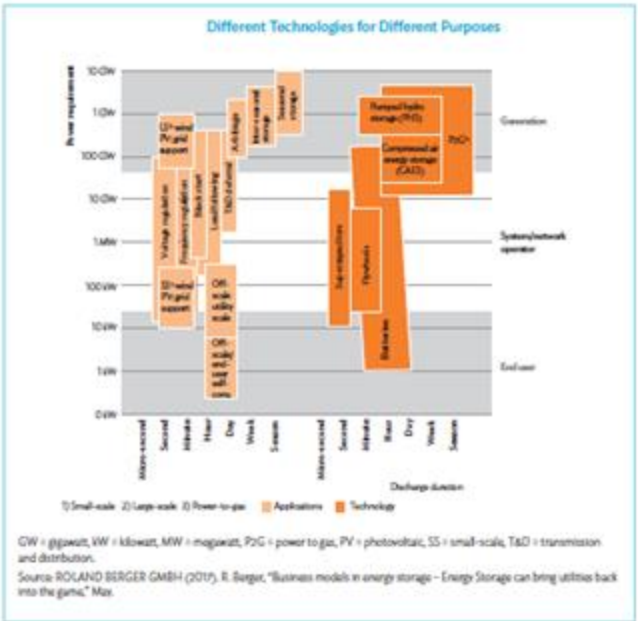


Figure 6.2: Different technologies for different purposes.

Discharge Time	Energy-to-Power Ratio	Technologies
Short (seconds to minutes)	Less than 1 (e.g., a capacity of less than 1 kWh for a system with a power of 1 kW)	DLCs, SMES, FES
Medium (minutes to hours)	Between 1 and 10 (e.g., between 1 kWh and 10 kWh for a 1 kW system)	FES, EES such as PbA, Li-ion, and Na–S batteries EES technologies have relatively similar technical features. They have advantages over other technologies in the kW–MW and kWh–MWh range.
Long (days to months)	Considerably greater than 10	Redox flow batteries are situated between storage systems with medium discharge times and those with long discharge times. But their rather low energy density limits the energy-to-power ratio to values between about 5 and 30. DLCs and FES have high power density but low energy density. Li-ion batteries have both high energy density and high power density. This explains the broad range of applications where these batteries are now deployed. Na–S and Na–NiCl2 batteries have higher energy densities than mature battery types such as PbA and Ni–Cd, but they have lower power density than Ni–MH and Li-ion batteries. Metal–air cells have the highest potential in terms of energy density.

Table no 3: Discharge Time and Energy-to-Power Ratio of Different Battery Technologies

6.2 COMPONENTS OF A BATTERY ENERGY STORAGE SYSTEM (BESS)

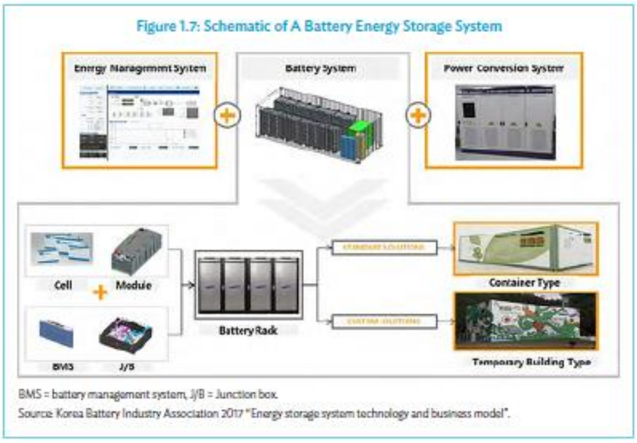


Figure 6.3: Schematic of A Battery Energy Storage System

6.2.1 Energy Storage System Components ESS components (Figure 1.8) are grouped according to function into battery components, components required for reliable system operation, and grid connection components. • The battery system consists of the battery pack, which connects multiple cells to appropriate voltage and capacity; the battery management system (BMS); and the battery thermal management system (B-TMS). The BMS protects the cells from harmful operation, in terms of voltage, temperature, and current, to achieve reliable and safe operation, and balances varying cell states-of-charge (SOCs) within a serial connection. The B-TMS controls the temperature of the cells according to their specifications in terms of absolute values and temperature gradients within the pack. • The components required for the reliable operation of the overall system are system control and monitoring, the energy management system (EMS), and system thermal management. System control and monitoring is general (IT) monitoring, which is partly combined into the overall supervisory control and data acquisition (SCADA) system but may also include fire protection or alarm units. The EMS is responsible for system power flow control, management, and distribution. System thermal management controls all functions related to the heating, ventilation, and air-conditioning of the containment system. • The power electronics can be grouped into the conversion unit, which converts the power flow between the grid and the battery, and the required control and monitoring components— voltage sensing units and thermal management of power electronics components (fan cooling).

6.2.2 Grid Connection for Utility-Scale BESS Projects Figure 1.9 gives an overview of grid connection topologies for utility-scale BESS, which typically consist of multiple battery packs and inverter units, all adding up to the total system energy and power. Power electronics units dedicated to individual battery packs can be installed (Figure 1.9a) or the battery packs can be connected in parallel to a common direct-current (DC) bus (Figure 1.9b). Figure 1.9c shows an example of grid connection to a low-voltage level, and Figure 1.9d, connection to higher grid levels via a transformer.

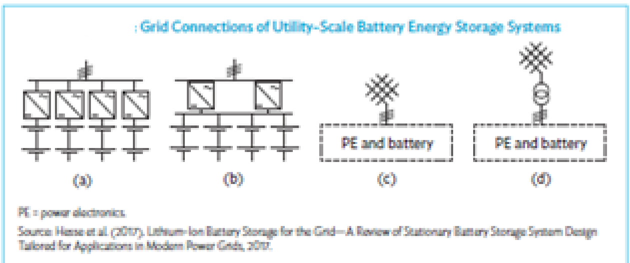


Figure 6.4 Grid connections :

CHAPTER-7

MATLAB SOFTWARE

7.1 INTRODUCTION TO MATLAB

Matlab is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include Math and computation Algorithm development Data acquisition Modeling, simulation, and prototyping Data analysis, exploration, and visualization Scientific and engineering graphics Application development, including graphical user interface building.

Matlab is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or Fortran.

The name matlab stands for matrix laboratory. Matlab was originally written to provide easy access to matrix software developed by the linpack and eispack projects. Today, matlab engines incorporate the lapack and blas libraries, embedding the state of the art in software for matrix computation.

Matlab has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, matlab is the tool of choice for high-productivity research, development, and analysis.

Matlab features a family of add-on application-specific solutions called toolboxes. Very important to most users of matlab, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of matlab functions (M-files) that extend the matlab environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

The matlab system consists of five main parts:

Development Environment. This is the set of tools and facilities that help you use matlab functions and files. Many of these tools are graphical user interfaces. It includes the matlab desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files, and the search path.

The matlab Mathematical Function Library. This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

The matlab Language. This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

Matlab has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on your matlab applications.

The matlab Application Program Interface (API). This is a library that allows you to write C and Fortran programs that interact with matlab. It includes facilities for calling routines from matlab (dynamic linking), calling matlab as a computational engine, and for reading and writing MAT-files.

7.2 INTRODUCTION SIMULINK:

Simulink is a software add-on to matlab which is a mathematical tool developed by The Math works,(http://www.mathworks.com) a company based in Natick. Matlab is powered by extensive numerical analysis capability. Simulink is a tool used to visually program a dynamic system (those governed by Differential equations) and look at results. Any logic circuit, or control system for a dynamic system can be built by using standard building blocks available in Simulink Libraries. Various toolboxes for different techniques, such as Fuzzy Logic, Neural Networks, dsp, Statistics etc. are available with Simulink, which enhance the processing power of the tool. The main advantage is the availability of templates / building blocks, which avoid the necessity of typing code for small mathematical processes.

7.3 CONCEPT OF SIGNAL AND LOGIC FLOW:

In Simulink, data/information from various blocks are sent to another block by lines connecting the relevant blocks. Signals can be generated and fed into blocks dynamic / static).Data can be fed into functions. Data can then be dumped into sinks, which could be scopes, displays or could be saved to a file. Data can be connected from one block to another, can be branched, multiplexed etc. In simulation, data is processed and transferred only at Discrete times, since all computers are discrete systems. Thus, a simulation time step (otherwise called an integration time step) is essential, and the selection of that step is determined by the fastest dynamics in the simulated system.

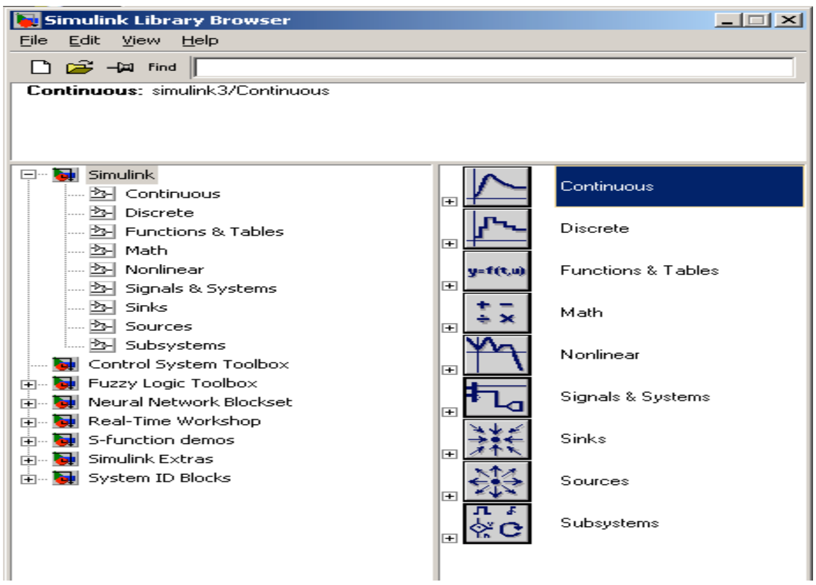


Fig 7.1 Simulink library browser

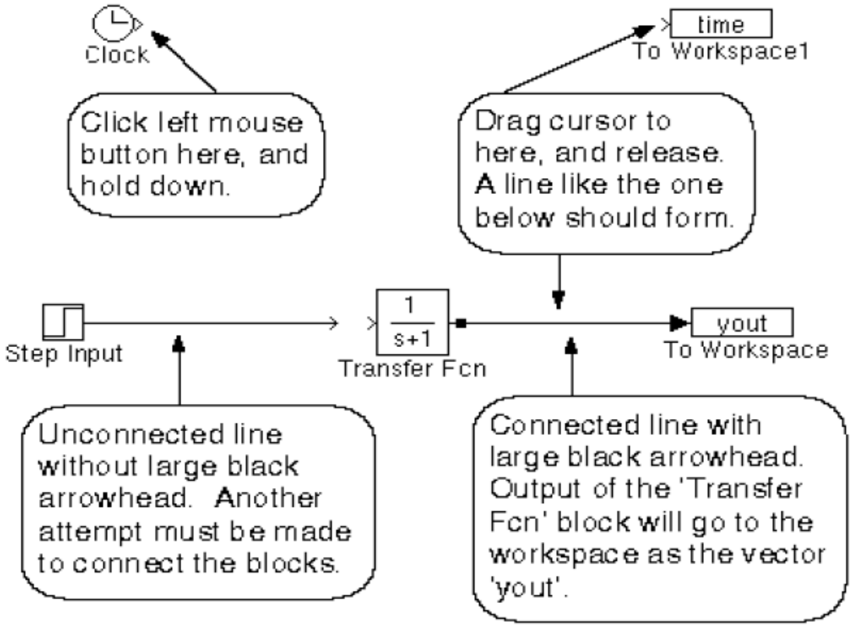


Fig 7.2 Connecting blocks

To connect blocks, left-click and drag the mouse from the output of one block to the input of another block.

7.4 SOURCES AND SINKS:

The sources library contains the sources of data/signals that one would use in a dynamic system simulation. One may want to use a constant input, a sinusoidal wave, a step, a repeating sequence such as a pulse train, a ramp etc. One may want to test disturbance effects, and can use the random signal generator to simulate noise. The clock may be used to create a time index for plotting purposes. The ground could be used to connect to any unused port, to avoid warning messages indicating unconnected ports.

The sinks are blocks where signals are terminated or ultimately used. In most cases, we would want to store the resulting data in a file, or a matrix of variables. The data could be displayed or even stored to a file. the stop block could be used to stop the simulation if the input to that block (the signal being sunk) is non-zero. Figure 3 shows the available blocks in the sources and sinks libraries. Unused signals must be terminated, to prevent warnings about unconnected signals.

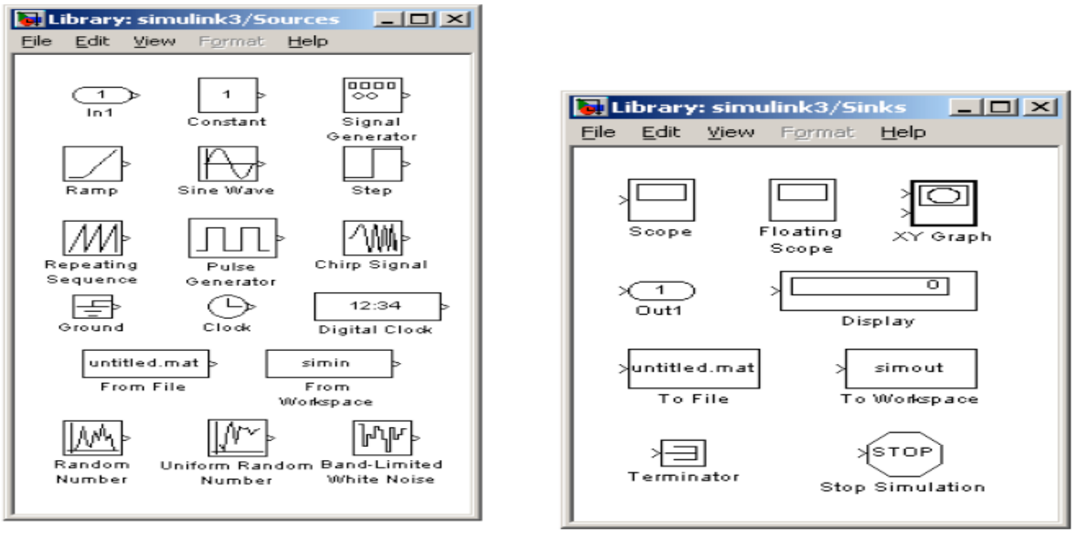


Fig 7.3 Sources and sinks

7.5 CONTINUOUS AND DISCRETE SYSTEMS:

All dynamic systems can be analyzed as continuous or discrete time systems. Simulink allows you to represent these systems using transfer functions, integration blocks, delay blocks etc.

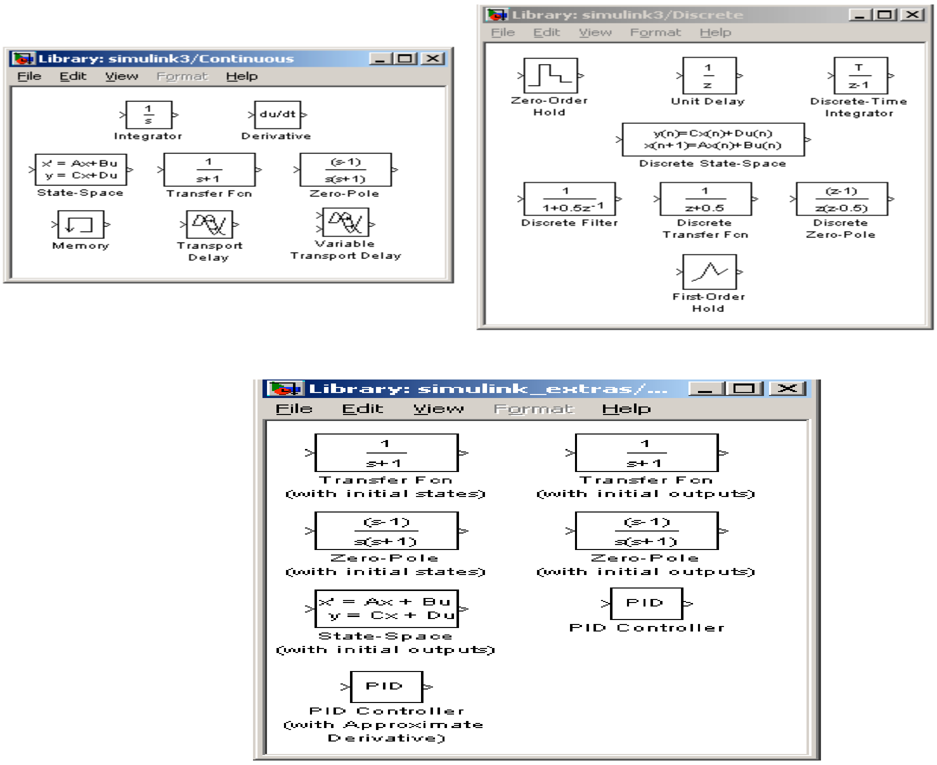


Fig 7.4 continuous and discrete systems

7.6 Non-linear operators:

A main advantage of using tools such as Simulink is the ability to simulate non-linear systems and arrive at results without having to solve analytically. It is very difficult to arrive at an analytical solution for a system having non-linearity's such as saturation, signup function, limited slew rates etc. In Simulation, since systems are analyzed using iterations, non-linearity's are not a hindrance. One such could be a saturation block, to indicate a physical limitation on a parameter, such as a voltage signal to a motor etc. Manual switches are useful when trying simulations with different cases. Switches are the logical equivalent of if-then statements in programming.

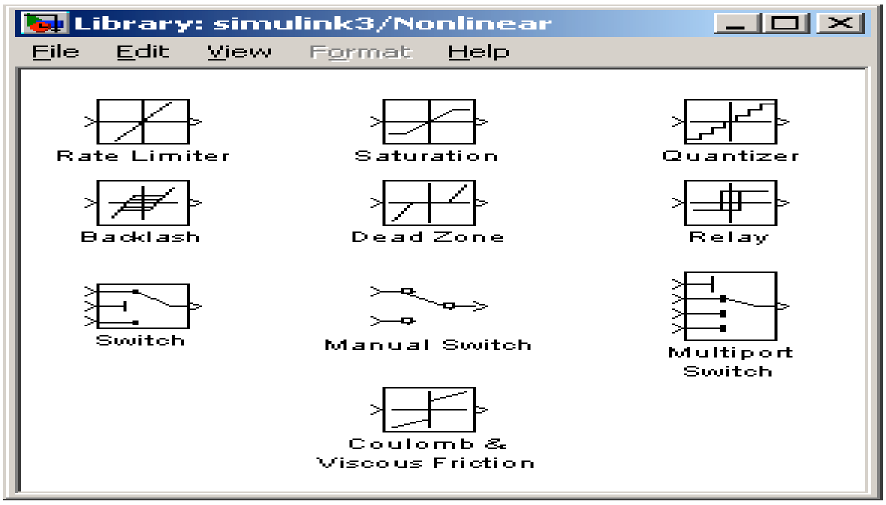


Fig 7.5 simulink blocks

7.6.1 Mathematical operations:

Mathematical operators such as products, sum, logical operations such as and, or, etc. .can be programmed along with the signal flow. Matrix multiplication becomes easy with the matrix gain block. Trigonometric functions such as sin or tan inverse (at an) are also available. Relational operators such as 'equal to', 'greater than' etc. can also be used in logic circuits

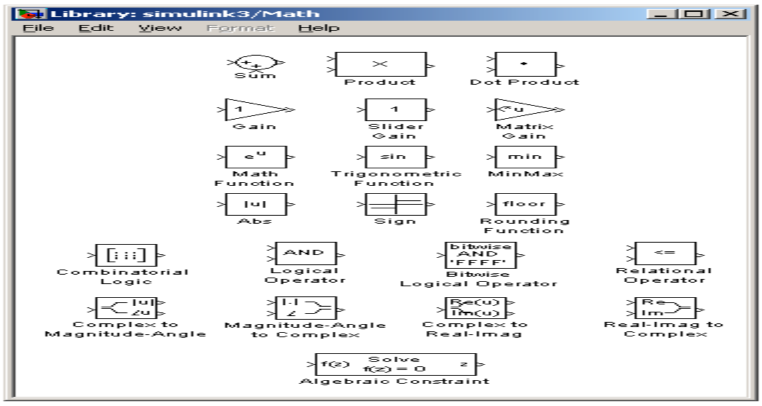


Fig 7.6 Simulink math blocks :

7.6.2 SIGNALS & DATA TRANSFER:

In complicated block diagrams, there may arise the need to transfer data from one portion to another portion of the block. They may be in different subsystems. That signal could be dumped into a goto block, which is used to send signals from one subsystem to another.

Multiplexing helps us remove clutter due to excessive connectors, and makes matrix(column/row) visualization easier.

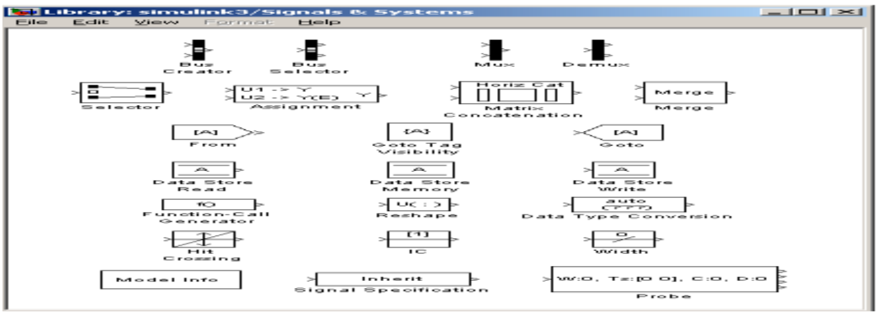


Fig 7.7 signals and systems

7.6.3 Making subsystems

Drag a subsystem from the Simulink Library Browser and place it in the parent block where you would like to hide the code. The type of subsystem depends on the purpose of the block. In general one will use the standard subsystem but other subsystems can be chosen. For instance, the subsystem can be a triggered block, which is enabled only when a trigger signal is received.

Open (double click) the subsystem and create input / output PORTS, which transfer signals into and out of the subsystem. The input and output ports are created by dragging them from the Sources and Sinks directories respectively. When ports are created in the subsystem, they automatically create ports on the external (parent) block. This allows for connecting the appropriate signals from the parent block to the subsystem.

7.6.4 Setting simulation parameters:

Running a simulation in the computer always requires a numerical technique to solve a differential equation. The system can be simulated as a continuous system or a discrete system based on the blocks inside. The simulation start and stop time can be specified. In case of variable step size, the smallest and largest step size can be specified. A Fixed step size is recommended and it allows for indexing time to a precise number of points, thus controlling the size of the data vector. Simulation step size must be decided based on the dynamics of the system. A thermal process may warrant a step size of a few seconds, but a DC motor in the system may be quite fast and may require a step size of a few milliseconds.

CHAPTER-8

MATLAB & SIMULATION RESULTS

8.1 SIMULATION CIRCUITS

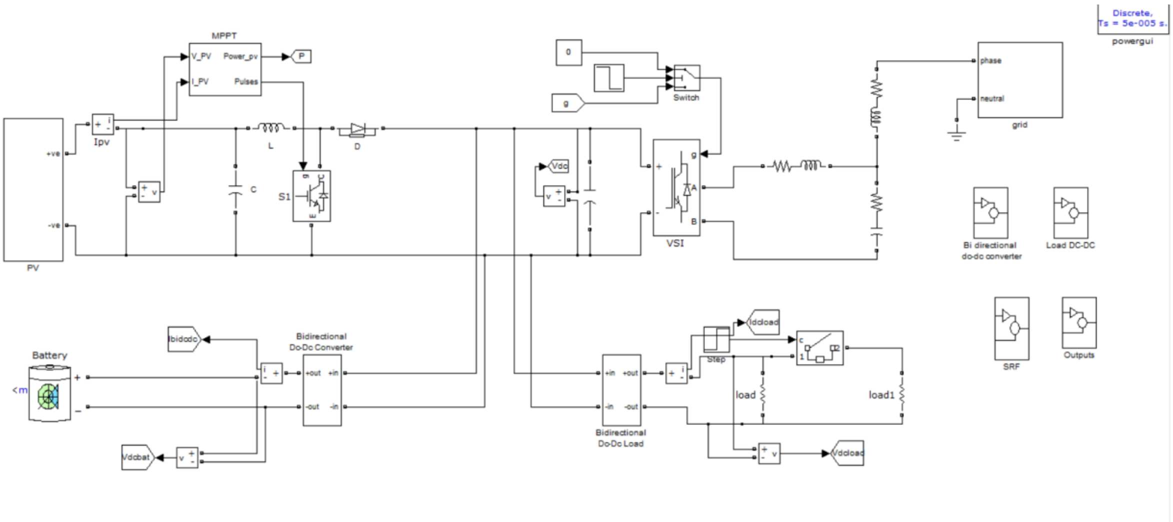


Figure 8.1: Simulation circuit

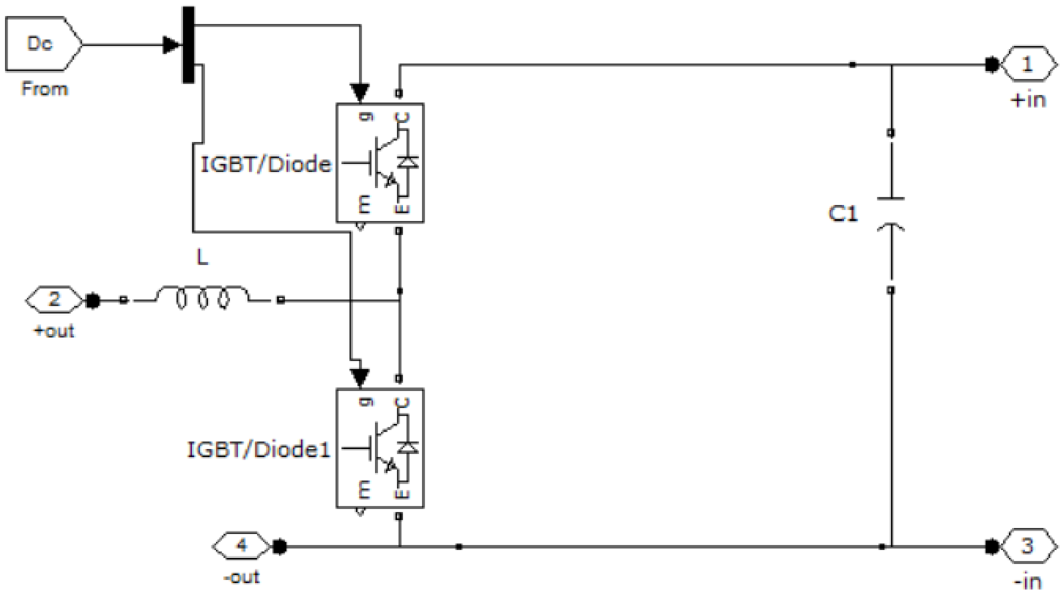


Figure 8.2: Buck boost converter

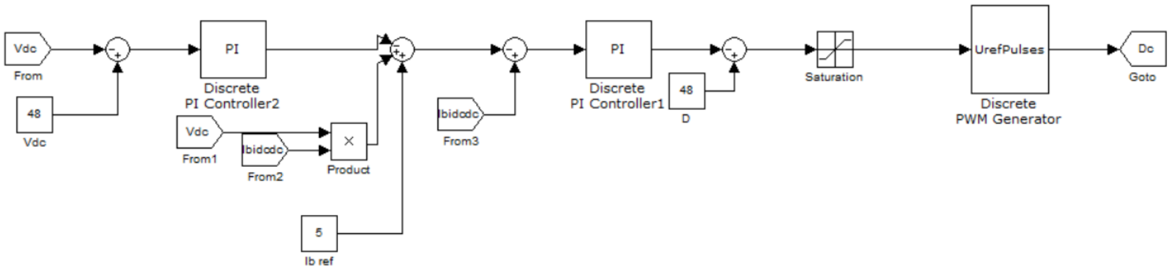


Figure 8.3: Battery controller

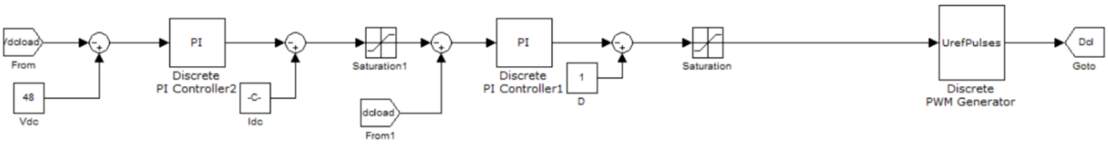
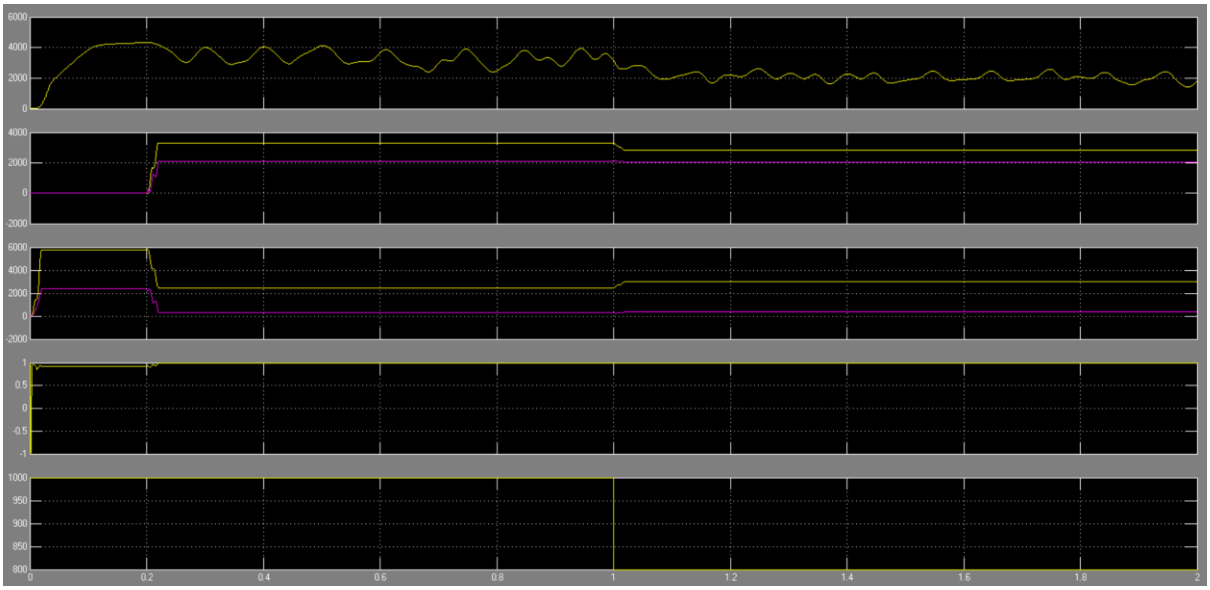
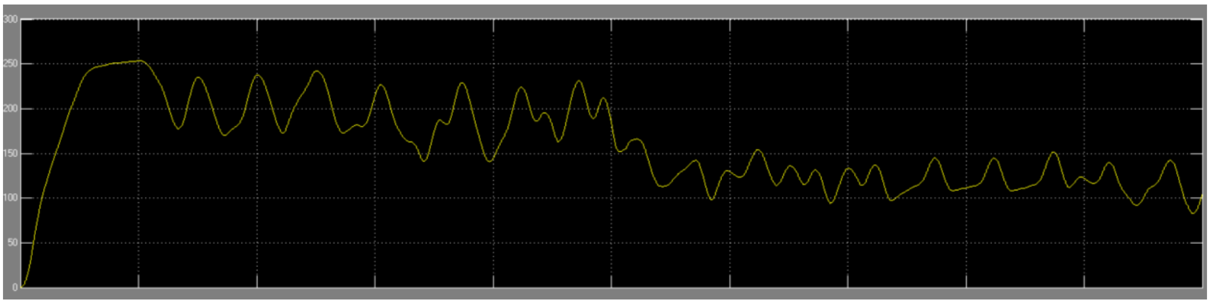


Figure 8.4: Load dc-dc controller

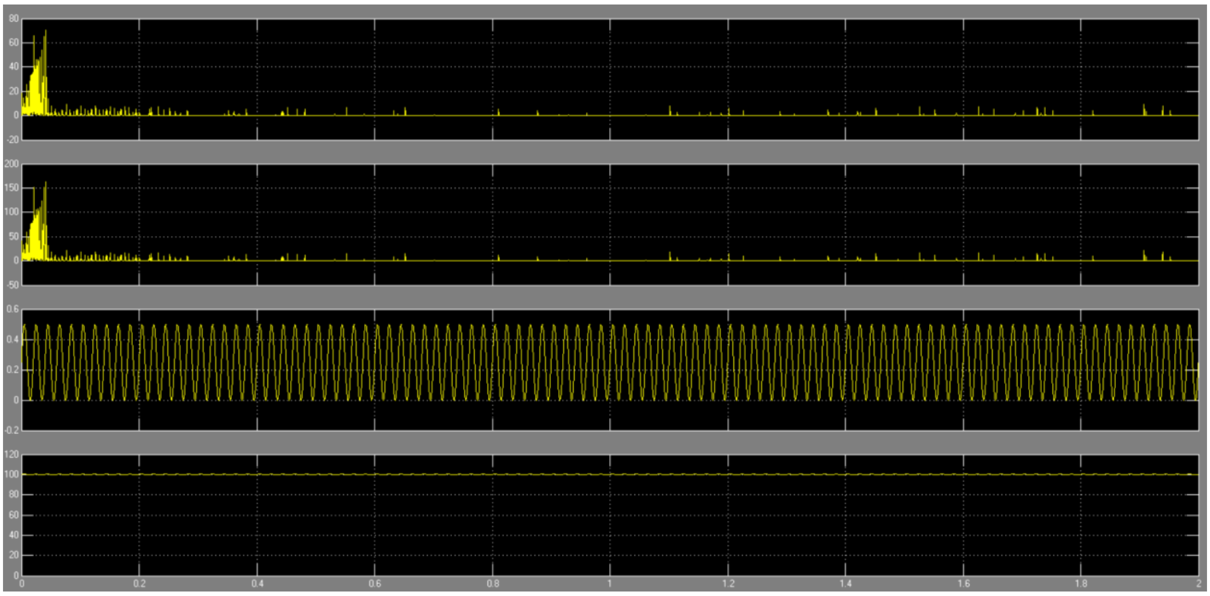
8.2 SIMULATION RESULTS



Graph no. 8.1 : Power utilisation



Graph no. 8.2: Dc voltalage variation



Graph no. 8.3: Battery and load requirments

CHAPTER 9
CONCLUSION AND FUTURE SCOPE

CONCLUSION

In this project, the modelling and the configuration of the EVCS was presented to evaluate thier corresponding EMS which was based on a decentralized supervision and composed by independent control systems for each element: PV system, ESS, EV and the utility grid. This certainly smoothed the integration of new elements in the charging infrastructure (new EV chargers or other sources of energy) as well as its real implementation and application. More particularly, this decentralized control had an effective and a simple control scheme. To control the power sources of the EVCS, a PI controllers were used. Depending on the ESS SOC and the ETC, the DC bus voltage, as the key parameter of supervision, is controlled by a specific source of power (PV system, ESS or the grid) while the batteries of EVs were being charged.

FUTURE SCOPE

1. Electric vehicle charging station will modifies the transportation energy demand from petroleum to the electricity.

2. We can promote the smart grid concept by combining the renewable energy sources and the utility grid.

CHAPTER 10

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A

PROJECT REPORT

On

ALCOHOL DETECTION WITH MESSAGING SYSTEM AND VEHICLE CONTROL

Submitted by

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in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Under The Guidance of

Mr. V. Vishnu Vardhan, M.Tech

ASSISTANT PROFESSOR

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINNERING

ST. MARTIN'S ENGINEERING COLLEGE

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JUNE 2021

BONAFIDE CERTIFICATE

This is to certify that the project entitled ALCOHOL DETECTION WITH MESSAGING SYSTEM AND VEHICLE CONTROL, is being submitted By **Ms. R.Manasa -Regd.No:17K81A0235, Ms. G.Kavya-Regd.No:18K85A0201, Mr. V.Sudha Kiran-Regd.No:18K85A0211, Mr. J.Anil Reddy-Regd.No:18K85A0216, Mr. K.Yuvis-Regd.No:18K85A0217** in partial fulfillment of the requirement for the award of the degree of **BACHELOR OF TECHNOLOGY** in ELECTRICAL AND ELECTRONICS ENGINNERING *is* recorded of bonafide work carried out by them. The result embodied in this report have been verified and found satisfactory.

Mr. V. Vishnu Vardhan
Assistant Professor
Department of EEE

Dr.N. Ramchandra
HOD & Professor
Department of EEE

Internal Examiner

External Examiner

Place: Dhulapally

Date:

DECLARATION

We, the students of **Bachelor of Technology** in Department of ELECTRICAL AND ELECTRONICS ENGINEERING, session: 2017–2021, St. Martin's Engineering College, Dhulapally, Kompally, Secunderabad, hereby declare that work presented in this Project Work entitled ALCOHOL DETECTION WITH MESSAGING SYSTEM AND VEHICLE CONTROL is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering Ethics. This result embodied in this project report has not been submitted in any university for award of any degree.

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ABSTRACT

- Driving under the influence of alcohol has affected and killed countless of people's lives. If you drink and drive, not only do you possibly put yourself at risk, but your passengers and pedestrians, and other people, who were on the roads. Just think about that. Every thirty minutes someone's life is cut short and families are devastated. So, here we implemented a Alcohol Detection system in order to control drunk and driving as much as we can.
- The Alcohol Detection system works on a simple principle, if a driver has been drinking, the alcohol breath analyser sensor will detect the level of alcohol in the driver's breath and if it crosses a set threshold, an alert will come and the vehicle engine will stop immediately. This project is designed for the safety of the people seating inside/outside the vehicle
- Drunk Driving is one of the biggest threats to Road Safety. Applications of Automatic Engine Locking System Through Alcohol Detection can be used anywhere to reduce the probability of road accidents.
    - "Automatic Engine Locking System Through Alcohol Detection project" can be used in various vehicles for detecting whether the driver has consumed alcohol or not.

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Embedded System:

An embedded system can be defined as a computing device that does a specific focused job. Appliances such as the air-conditioner, VCD player, DVD player, printer, fax machine, mobile phone etc. are examples of embedded systems. Each of these appliances will have a processor and special hardware to meet the specific requirement of the application along with the embedded software that is executed by the processor for meeting that specific requirement. The embedded software is also called “firm ware”. The desktop/laptop computer is a general-purpose computer. You can use it for a variety of applications such as playing games, word processing, accounting, software development and so on. In contrast, the software in the embedded systems is always fixed listed below:

Embedded systems do a very specific task, they cannot be programmed to do different things. Embedded systems have very limited resources, particularly the memory. Generally, they do not have secondary storage devices such as the CDROM or the floppy disk. Embedded systems have to work against some deadlines. A specific job has to be completed within a specific time. In some embedded systems, called real-time systems, the deadlines are stringent. Missing a deadline may cause a catastrophe-loss of life or damage to property. Embedded systems are constrained for power. As many embedded systems operate through a battery, the power consumption has to be very low.

Some embedded systems have to operate in extreme environmental conditions such as very high temperatures and humidity.

1.2 Application Areas:

Nearly 99 per cent of the processors manufactured end up in embedded systems. The embedded system market is one of the highest growth areas as these systems are used in very market segment- consumer electronics, office automation, industrial automation, biomedical engineering, wireless communication, data communication, tele communications, transportation, military and so on.

1.2.1 Telecommunications:

In the field of telecommunications, the embedded systems can be categorized as subscriber terminals and network equipment. The subscriber terminals such as key telephones, ISDN phones, terminal adapters, web cameras are embedded systems. The network equipment includes multiplexers, multiple access systems, Packet Assemblers Dissemblers (PADs), sate11ite modems etc. IP phone, IP gateway, IP gatekeeper etc. are the latest embedded systems that provide very low-cost voice communication over the Internet.

1.2.2 Office Automation:

The office automation products using embedded systems are copying machine, fax machine, key telephone, modem, printer, scanner etc. the data packets from incoming pores, analyse the packets and send them towards the destination after doing necessary protocol conversion. Most networking equipment's, other than the end systems (desktop computers) we use to access the networks, are embedded systems.

1.2.3 Consumer Appliances:

At home we use a number of embedded systems which include digital camera, digital diary, DVD player, electronic toys, microwave oven, remote controls for TV and air conditioner, VCO player, video game consoles, video recorders etc. Today's high-tech car has about 20 embedded systems for transmission control, engine spark control, airconditioning, navigation etc. Even wristwatches are now becoming embedded systems. The palmtops are powerful embedded systems using which we can carry out many general-purpose tasks such as playing games and word processing

1.2.4 Wireless Technologies:

Advances in mobile communications are paving way for many interesting applications using embedded systems. The mobile phone is one of the marvels3 of the last decade of the 20'h century. It is a very powerful embedded system that provides voice communication while we are on the move. The Personal Digital Assistants and the palmtops can now be used to access multimedia services over the Internet. Mobile communication infrastructure such as base station controllers, mobile switching centers are also powerful embedded systems.

1.2.5 Security:

Security of persons and information has always been a major issue. Weneed to protect our homes and offices; and also, the information we transmit and store. Developing embedded systems for security applications is one of the most lucrative businesses nowadays. Security devices at homes, offices, airports etc. for authentication and verification are embedded systems.

1.2.6 Finance:

Financial dealing through cash and cheques are now slowly paving way for transactions using smart cards and ATM (Automatic Teller Machine, also expanded as Any Time Money) machines. Smart card, of the size of a credit card, has a small micro-controller and memory; and it interacts with the smart card reader! ATM machine and acts as an electronic wallet. Smart card technology has the capability of ushering in a cashless society. Well, the list goes on. It is no exaggeration to say that eyes wherever you go, you can see, or at least feel, the work of an embedded system!

1.3 Overview of Embedded System Architecture:

Every embedded system consists of custom-built hardware built around a Central Processing Unit (CPU). This hardware also contains memory chips onto which the software is loaded. The software residing on the memory chip is also called the ‘firmware’.

1.4 Objectives of the Study:

- To achieve the greater good to the life of mankind.
- By detecting the alcohol content people might just take care of themselves to limit their drinking
- Not only one person’s life can be saved but the other person who is a victim of the accident Life can be saved.

1.5 Scope of the Study:

- An effective solution is provided to develop the intelligent system for vehicles which will monitor various parameters of vehicle.
- The designed system would finish the function of communicating with the base station via GPS, GSM and control of various parameters.
- The whole Control system has the advantage of small volume and high reliability.
- Future scope of this system is to control the accidents and providing useful details about the accidental vehicle, thereby reducing the rate of accidents taking place due to drunken driving.

1.6 Material Requirement:

Hardware Components:

- ARDUINO UNO
- ALCOHOL SENSOR (MQ3 SENSOR)
- BUZZER
- PCB (PRINTED CIRCUIT BOARD)
- JUMPER WIRES
- TRANSISTOR
- ADAPTER (12V)
- GSM MODULE
- GPS MODULE

Software Components:

- ARDUINO IDE (INTEGRATED DEVELOPMENT ENVIRONMENT)

ARDUINO UNO:

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. It is similar to the Arduino Nano and Leonardo. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available.

Technical specifications:

Operating Voltage: 5 Volts

Input Voltage: 7 to 20 Volts

Digital I/O Pins: 14 (of which 6 can provide PWM output)

UART: 1

I2C: 1

SPPI: 1

Analog Input Pins: 6

DC Current per I/O Pin: 20 Ma

DC Current for 3.3V Pin: 50 mA

Flash Memory: 32 KB of which 0.5 KB used by bootloader

SRAM: 2 KB

EEPROM: 1 KB

Clock Speed: 16 MHz

Length: 68.6 mm

Width: 53.4 mm

Weight: 25 g

Headers

General Pin functions:

LED: There is a built-in LED driven by digital pin 13. When the pin is high value, the LED is on, when the pin is low, it is off.

VIN: The input voltage to the Arduino/Genuino board when it is using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can Arduino UNO … supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 20V), the USB connector (5V), or the VIN pin of the board (7-20V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage the board.

3V3: A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.

GND: Ground pins. IOREF: This pin on the Arduino/Genuino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the

IOREF pin voltage and select the appropriate power source, or enable voltage translators on the outputs to work with the 5V or 3.3V.

Reset: Typically used to add a reset button to shields that block the one on the board.

Special pin functions Each of the 14 digital pins and 6 analog pins on the Uno can be used as an input or output, under software control (using … pinMode(), digitalWrite(), and digitalRead() functions).

They operate at 5 volts. Each pin can provide or receive 20 mA as the recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50K ohm. A maximum of 40mA must not be exceeded on any I/O pin to avoid permanent damage to the microcontroller.

The Uno has 6 analog inputs, labeled A0 through A5; each provides 10 bits of resolution (i.e. 1024 different values). By default, they measure from ground to 5 volts, though it is possible to change the upper end of the range using the AREF pin and the analogReference() function]

Fig:1- Arduino Uno

In addition, some pins have specialized functions:

Serial / UART: pins 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL serial chip.

External interrupts: pins 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.

PWM (pulse-width modulation): pins 3, 5, 6, 9, 10, and 11. Can provide 8-bit PWM output with the analogWrite() function.

SPI (Serial Peripheral Interface): pins 10 (SS), 11 (MOSI), 12 (MISO), and 13 (SCK). These pins support SPI communication using the SPI library.

TWI (two-wire interface) / I²C: pin SDA (A4) and pin SCL (A5). Support TWI communication using the Wire library.

AREF (analog reference): Reference voltage for the analog inputs.

ALCOHOL SENSOR (MQ3):

MQ3 is one of the most commonly used sensors in the MQ sensor series. It is a Metal Oxide Semiconductor (MOS) type of sensor. Metal oxide sensors are also known as Chemiresistors, because sensing is based on the change of resistance of the sensing material when exposed to alcohol. So by placing it in a simple voltage divider network, alcohol concentrations can be detected.

Fig:2- MQ3 Sensor

MQ3 alcohol sensor works on 5V DC and draws around 800mW. It can detect Alcohol concentrations anywhere from 25 to 500 ppm.

Here are the complete specifications:

Operating voltage	5V
Load resistance	200 KΩ
Heater resistance	33Ω ± 5%
Heating consumption	<800mw
Sensing Resistance	1 MΩ – 8 MΩ
Concentration Scope	25 – 500 ppm
Preheat Time	Over 24 hour

Table-1: Specifications of alcohol sensor

MQ3 Alcohol Sensor Module Hardware Overview:

Since the MQ3 alcohol sensor is not breadboard compatible, we recommend this handy little breakout board. It's very easy to use and comes with two different outputs. It not only provides a binary indication of the presence of alcohol but also an analog representation of its concentration in air.

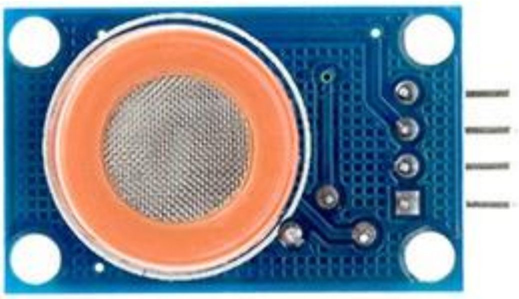

Fig:3-backside of sensor

The analog output voltage provided by the sensor (at AO pin) varies in proportion to the alcohol concentration. The higher the alcohol concentration in the air, the higher the output voltage; Whereas lower concentration gives lower output voltage.

MQ3 Alcohol Sensor Module Pinout:

Now let's have a look at the pinout.

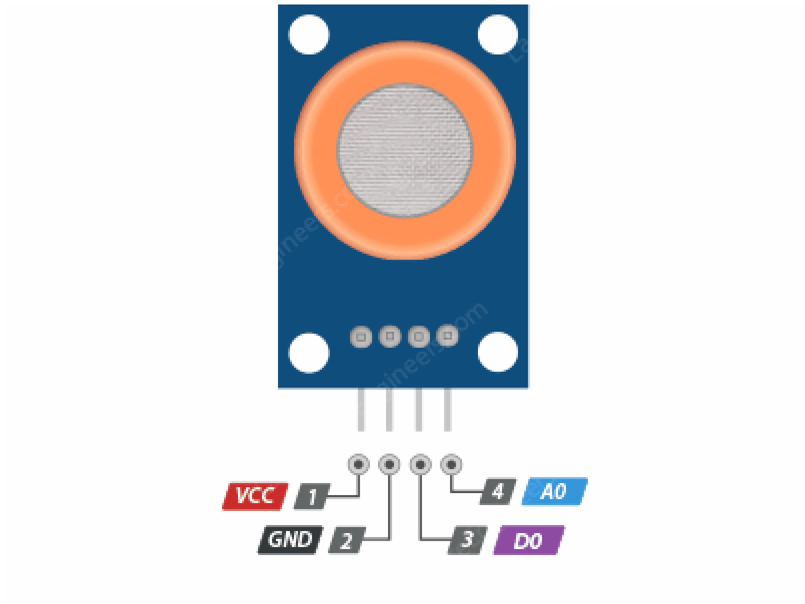

Fig:4- Pinout of MQ3 Sensor

VCC supplies power for the module. You can connect it to 5V output from your Arduino.

GND is the Ground Pin and needs to be connected to GND pin on the Arduino.

D0 provides a digital representation of the presence of alcohol.

A0 provides analog output voltage in proportional to the concentration of alcohol.

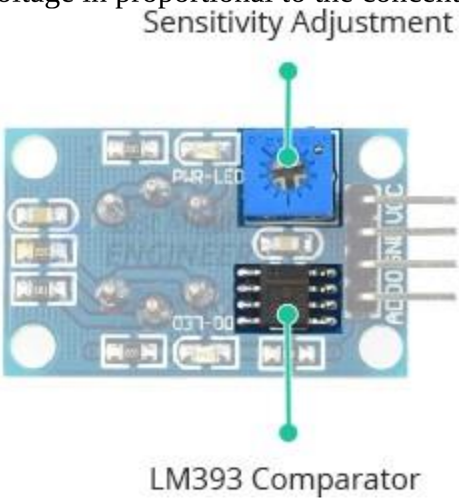

fig:5- sensitivity of MQ3 sensor

The module has a built-in potentiometer for adjusting the sensitivity of the digital output (DO). You can use it to set a threshold; so that when the alcohol concentration exceeds the threshold value, the module will output LOW otherwise HIGH.

BUZZER:

Piezoelectric buzzers, or piezo buzzers, as they are sometimes called, were invented by Japanese manufacturers and fitted into a wide array of products during the 1970s to 1980s. This advancement mainly came about because of cooperative efforts by Japanese manufacturing companies. In 1951, they established the Barium Titanate Application Research Committee, which allowed the companies to be "competitively cooperative" and bring about several piezoelectric innovations and inventions.

Fig:6- Buzzer

A piezoelectric element may be driven by an oscillating electronic circuit or other audio signal source, driven with a piezoelectric audio amplifier. Sounds commonly used to indicate that a button has been pressed are a click, a ring or a beep.

Interior of a readymade loudspeaker, showing a piezoelectric-disk-beeper (With 3 electrodes including 1 feedback-electrode (the central, small electrode joined with red wire in this photo), and an oscillator to self-drive the buzzer.

A piezoelectric buzzer/beeper also depends on acoustic cavity resonance or Helmholtz resonance to produce an audible beep.

While technological advancements have caused buzzers to be impractical and undesirable, there are still instances in which buzzers and similar circuits may be used. Present day applications include:

- Novelty uses
- Judging panels
- Educational purposes
- Annunciator panels
- Electronic metronomes
- Game show lock-out device
- Microwave ovens and other household appliances
- Sporting events such as basketball games
- Electrical alarms
- Joy buzzer (mechanical buzzer used for pranks).

PCB (PRINTED CIRCUIT BOARD):

A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate. Components are generally soldered onto the PCB to both electrically connect and mechanically fasten them to it.

Printed circuit boards are used in all but the simplest electronic products. They are also used in some electrical products, such as passive switch boxes.

Alternatives to PCBs include wire wrap and point-to-point construction, both once popular but now rarely used. PCBs require additional design effort to lay out the circuit, but manufacturing and assembly can be automated. Electronic computer-aided design software is available to do much of the work of layout. Mass-producing circuits with PCBs is cheaper and faster than with other wiring methods, as components are mounted and wired in one operation. Large numbers of PCBs can be fabricated at the same time, and the layout only has to be done once. PCBs can also be made manually in small quantities, with reduced benefits.

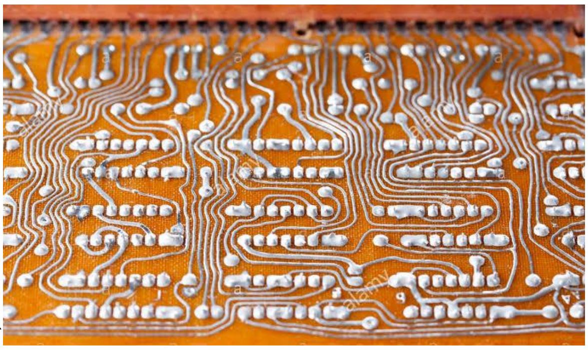

Fig:7-PCB

PCBs can be single-sided (one copper layer), double-sided (two copper layers on both sides of one substrate layer), or multi-layer (outer and inner layers of copper, alternating with layers of substrate). Multi-layer PCBs allow for much higher component density, because circuit traces on the inner layers would otherwise take up surface space between components. The rise in popularity of multilayer PCBs with more than two, and especially with more than four, copper planes was concurrent with the adoption of surface mount technology. However, multilayer PCBs make repair, analysis, and field modification of circuits much more difficult and usually impractical.

JUMPER WIRES:

A jump wire (also known as jumper, jumper wire, jumper cable, DuPont wire or cable) is an electrical wire, or group of them in a cable, with a connector or pin at each end (or sometimes without them – simply "tinned"), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering

Individual jump wires are fitted by inserting their "end connectors" into the slots provided in a breadboard, the header connector of a circuit board, or a piece of test equipment. Stranded 22AWG jump wires with solid tips

Types Jumper wires with crocodile clips Jump wires at the end of a multi-coloured ribbon cable are used to connect the pin header at the left side of a blue USB2Serial board to a white breadboard below. Another jumper cable ending in a USB micro male connector mates to the right side of the USB2Serial board. Red and black tinned jump wires can be seen on the breadboard.

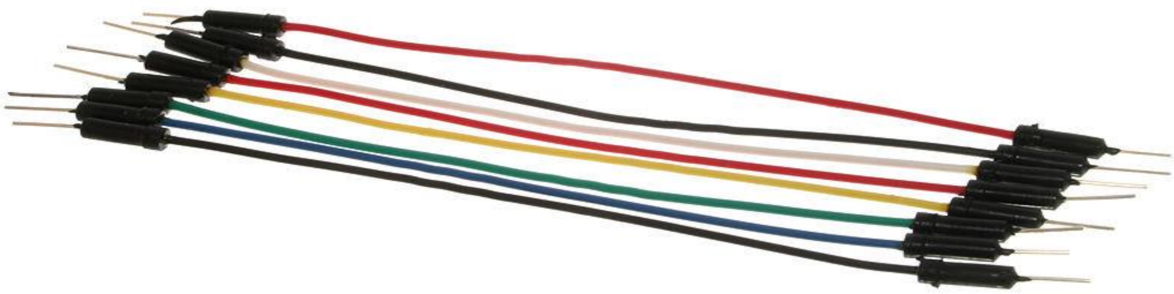

Fig:8- Jumper Wires

TYPES OF JUMPER WIRES:

There are different types of jumper wires. Some have the same type of electrical connector at both ends, while others have different connectors. Some common connectors are:

Solid tips – are used to connect on/with a breadboard or female header connector. The arrangement of the elements and ease of insertion on a breadboard allows increasing the mounting density of both components and jump wires without fear of shortcircuits. The jump wires vary in size and colour to distinguish the different working signals.

Crocodile clips – are used, among other applications, to temporarily bridge sensors, buttons and other elements of prototypes with components or equipment that have arbitrary connectors, wires, screw terminals, etc.

Banana connectors – are commonly used on test equipment for DC and lowfrequency AC signals.

Registered jack (RJnn) – are commonly used in telephone (RJ11) and computer networking (RJ45).

RCA connectors – are often used for audio, low-resolution composite video signals, or other low-frequency applications requiring a shielded cable.

RF connectors – are used to carry radio frequency signals between circuits, test equipment, and antennas.

RF jumper cables - Jumper cables is a smaller and more bendable corrugated cable which is used to connect antennas and other components to network cabling.

Jumpers are also used in base stations to connect antennas to radio units. Usually the most bendable jumper cable diameter is 1/2".

TRANSISTOR:

A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power. Transistors are one of the basic building blocks of modern electronics.[1] It is composed of semiconductor material usually with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals controls the current through another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal. Today, some transistors are packaged individually, but many more are found embedded in integrated circuits.

Austro-Hungarian physicist Julius Edgar Lilienfeld proposed the concept of a field-effect transistor in 1926, but it was not possible to actually construct a working device at that time.[2] The first working device to be built was a point-contact transistor invented in 1947 by American physicists John Bardeen and Walter Brattain while working under William Shockley at Bell Labs. The three shared the 1956 Nobel Prize in Physics for their achievement.[3] The most widely used type of transistor is the metal–oxide–semiconductor field-effect transistor (MOSFET), which was invented by Mohamed Atalla and Dawon

Kahng at Bell Labs in 1959.[4][5][6] Transistors revolutionized the field of electronics, and paved the way for smaller and cheaper radios, calculators, and computers, among other things.

Most transistors are made from very pure silicon, and some from germanium, but certain other semiconductor materials are sometimes used. A transistor may have only one kind of charge carrier, in a field-effect transistor, or may have two kinds of charge carriers in bipolar junction transistor devices. Compared with the vacuum tube, transistors are generally smaller and require less power to operate. Certain vacuum tubes have advantages over transistors at very high operating frequencies or high operating voltages. Many types of transistors are made to standardized specifications by multiple manufacturers.

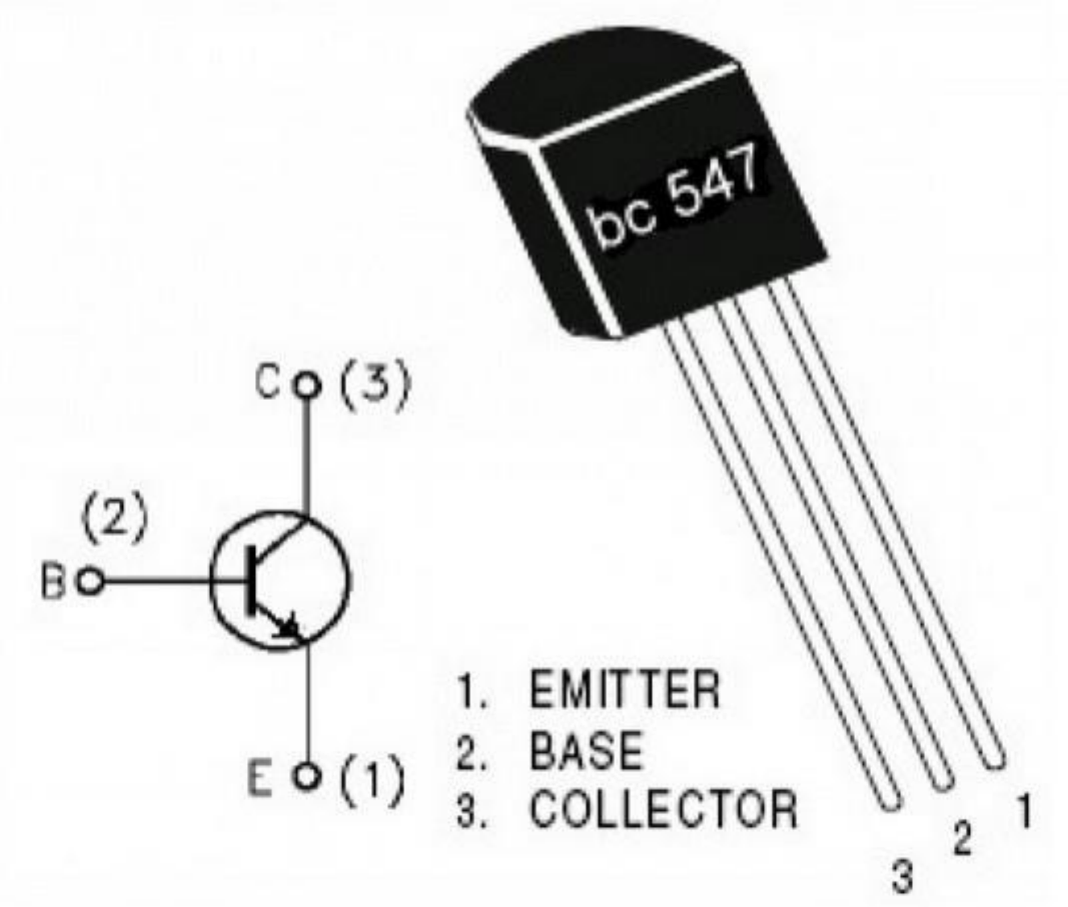

Fig:9- Transistor

Bipolar Junction Transistor, abbreviated as BJT. It is an NPN transistor.

It has three terminals named as:

- Emitter
- Collector
- Base

The maximum current gain of BC547 is 800A.

Collector-Emitter Voltage is 65V.

Collector-Base Voltage is 80V.

Emitter-Base Voltage is 8V.

Working of BC547

BC547 has two working states which are:

Forward Biased & Reverse Biased.

In a forward biased state, the collector and emitter are connected allowing current to pass through. While in a reverse biased state, it works as an open switch and doesn't allow the current to pass.

Applications of BC547:

BC547 is normally used for:

- Current Amplification.
- Fast switching.
- Pulse Width Modulation.

ADAPTER (12V):

An AC adapter, AC/DC adapter, or AC/DC converter[1] is a type of external power supply, often enclosed in a case similar to an AC plug. Other common names include plug pack, plug-in adapter, adapter block, domestic mains adapter, line power adapter, wall wart, power brick, and power adapter. Adapters for battery-powered equipment may be described as chargers or rechargers (see also battery charger). AC adapters are used with electrical devices that require power but do not contain internal components to derive the required voltage and power from mains power. The internal circuitry of an external power supply is very similar to the design that would be used for a built-in or internal supply.

External power supplies are used both with equipment with no other source of power and with battery-powered equipment, where the supply, when plugged in, can sometimes charge the battery in addition to powering the equipment.

Fig:10- Adapter

Use of an external power supply allows portability of equipment powered either by mains or battery without the added bulk of internal power components, and makes it unnecessary to produce equipment for use only with a specified power source; the same device can be powered from 120 VAC or 230 VAC mains, vehicle or aircraft battery by using a different adapter. Another advantage of these designs can be increased safety; since the hazardous 120 or 240 volt mains power is transformed to a lower, safer voltage at the wall outlet and the appliance that is handled by the user is powered by this lower voltage.

Modes of operation:

Fig:11- Modes of Operation

An AC adapter disassembled to reveal a simple, unregulated linear DC supply circuit: a transformer, four diodes in a bridge rectifier, and an electrolytic capacitor to smooth the waveform

Originally, most AC/DC adapters were linear power supplies, containing a transformer to convert the mains electricity voltage to a lower voltage, a rectifier to convert it to pulsating DC, and a filter to smooth the pulsating waveform to DC, with residual ripple variations small enough to leave the powered device unaffected. Size and weight of the device was largely determined by the transformer, which in turn was determined by the power output and mains frequency. Ratings over a few watts made the devices too large and heavy to be physically supported by a wall outlet. The output voltage of these adapters varied with load; for equipment requiring a more stable voltage, linear voltage regulator circuitry was added. Losses in the transformer and the linear regulator were considerable; efficiency was relatively low, and significant power dissipated as heat even when not driving a load.

Early in the twenty-first century, switched-mode power supplies (SMPSs) became almost ubiquitous for this purpose. Main's voltage is rectified to a high direct voltage driving a switching circuit, which contains a transformer operating at a high frequency and outputs direct current at the desired voltage. The high-frequency ripple is more easily filtered out than mains-frequency. The high frequency allows the transformer to be small, which reduces its losses; and the switching regulator can be much more efficient than a linear regulator. The result is a much more efficient, smaller, and lighter device. Safety is ensured, as in the older linear circuit, because a transformer still provides galvanic isolation.

A linear circuit must be designed for a specific, narrow range of input voltages (e.g., 220–240 VAC) and must use a transformer appropriate for the frequency (usually 50 or 60 Hz), but a switched-mode supply can work efficiently over a very wide range of voltages and frequencies; a single 100–240 VAC unit will handle almost any mains supply in the world.

However, unless very carefully designed and using suitable components, switching adapters are more likely to fail than the older type, due in part to complex circuitry and the use of semiconductors. Unless designed well, these adapters may be easily damaged by overloads, even transient ones, which can come from lightning, brief mains overvoltage (sometimes caused by an incandescent light on the same power circuit failing), component degradation, etc. A very common mode of failure is due to the use of electrolytic capacitors whose equivalent series resistance (ESR) increases with age; switching regulators are very sensitive to high ESR (the older linear circuit also used electrolytic capacitors, but the effect of degradation is much less dramatic). Well-designed circuits pay attention to the ESR, ripple current rating, pulse operation, and temperature rating of capacitors.

Many inexpensive switched-mode AC adapters do not implement adequate filtering and/or shielding for electromagnetic interference that they generate. The nature of these high speed, high-energy switching designs is such that when these preventative measures are not implemented, relatively high energy harmonics can be generated, and radiated, well into the radio portion of the spectrum. The amount of RF energy typically decreases with frequency; so, for instance, interference in the medium wave (US AM) broadcast band in the one-megahertz region may be strong, while interference with the FM broadcast band around 100 megahertz may be considerably less. Distance is a factor; the closer the interference is to a radio receiver, the more intense it will be. Even WiFi reception in the gigahertz range can be degraded if the receiving antennae are very close to a radiating AC adapter. A determination of if interference is coming from a specific AC adaptor can be made simply by unplugging the suspect adapter while observing the amount of interference received in the problem radio band. In a modern household or business environment, there may be multiple AC adapters in use; in such a case, unplug them all, then plug them back in one by one until the culprit or culprits is found.

GSM MODULE:

The Global System for Mobile Communications (GSM) is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation (2G) digital cellular networks used by mobile devices such as mobile phones and tablets. It was first deployed in Finland in December 1991.[2] By the mid-2010s, it became a global standard for mobile communications achieving over 90% market share, and operating in over 193 countries and territories.

2G networks developed as a replacement for first generation (1G) analog cellular networks. The GSM standard originally described a digital, circuit-switched network optimized for full duplex voice telephony. This expanded over time to include data communications, first by circuit-switched transport, then by packet data transport via General Packet Radio Service (GPRS), and Enhanced Data Rates for GSM Evolution (EDGE).

Subsequently, the 3GPP developed third-generation (3G) UMTS standards, followed by the fourth-generation (4G) LTE Advanced and the fifth-generation 5G standards, which do not form part of the ETSI GSM standard.

"GSM" is a trade mark owned by the GSM Association. It may also refer to the (initially) most common voice codec used, Full Rate.

As a result of the network's widespread use across Europe, the acronym "GSM" was briefly used a generic term for phones in France, the Netherlands and in Wallonia, Belgium.

SIM800L is a miniature cellular module which allows for GPRS transmission, sending and receiving SMS and making and receiving voice calls. Low cost and small footprint and quad band frequency support make this module perfect solution for any project that require long range connectivity. After connecting power module boots up, searches for cellular network and login automatically. On board LED displays connection state (no network coverage - fast blinking, logged in - slow blinking).

NOTICE: Be prepared to handle huge power consumption with peek up to 2A. Maximum voltage on UART in this module is 2.8V. Higher voltage will kill the module. Two antennas!

This module have two antennas included. First is made of wire (which solders directly to NET pin on PCB) - very useful in narrow places. Second - PCB antenna - with double sided tape and attached pigtail cable with IPX connector. This one have better performance and allows to put your module inside a metal case - as long the antenna is outside.

Fig:12-GSM Module

Specifications:

Supply voltage: 3.8V - 4.2V

Recommended supply voltage: 4V

Power consumption:

sleep mode < 2.0mA

idle mode < 7.0mA

GSM transmission (avg): 350 mA

GSM transmission (peek): 2000mA

Module size: 25 x 23 mm

Interface: UART (max. 2.8V) and AT commands

SIM card socket: microSIM (bottom side)

Supported frequencies: Quad Band (850 / 950 / 1800 /1900 MHz)

Antenna connector: IPX

Status signaling: LED

Working temperature range: -40 do + 85 ° C

Set includes:

- SIM800L module
- goldpin headers
- wire antenna

GPS MODULE:

The Global Positioning System (GPS), originally Navistar GPS, is a satellite-based radionavigation system owned by the United States government and operated by the United States Space Force. It is one of the global navigation satellite systems (GNSS) that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. Obstacles such as mountains and buildings block the relatively weak GPS signals.

The GPS does not require the user to transmit any data, and it operates independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the GPS positioning information. The GPS provides critical positioning capabilities to military, civil, and commercial users around the world. The United States government created the system, maintains it, and makes it freely accessible to anyone with a GPS receiver.[4]

The GPS project was started by the U.S. Department of Defense in 1973, with the first prototype spacecraft launched in 1978 and the full constellation of 24 satellites operational in 1993. Originally limited to use by the United States military, civilian use was allowed from the 1980s following an executive order from President Ronald Reagan after the Korean Air Lines Flight 007 incident. Advances in technology and new demands on the existing system have now led to efforts to modernize the GPS and implement the next generation of GPS Block

IIIA satellites and Next Generation Operational Control System (OCX).[6] Announcements from Vice President Al Gore and the Clinton Administration in 1998 initiated these changes, which were authorized by the U.S. Congress in 2000.

During the 1990s, GPS quality was degraded by the United States government in a program called "Selective Availability"; this was discontinued on May 1, 2000 by a law signed by President Bill Clinton.[7]

The GPS service is provided by the United States government, which can selectively deny access to the system, as happened to the Indian military in 1999 during the Kargil War, or degrade the service at any time.[8] As a result, several countries have developed or are in the process of setting up other global or regional satellite navigation systems. The Russian Global Navigation Satellite System (GLONASS) was developed contemporaneously with GPS, but suffered from incomplete coverage of the globe until the mid-2000s.[9] GLONASS can be added to GPS devices, making more satellites available and enabling positions to be fixed more quickly and accurately, to within two meters (6.6 ft).[10] China's BeiDou Navigation Satellite System began global services in 2018, and finished its full deployment in 2020.[11] There are also the European Union Galileo positioning system, and India's NavIC. Japan's Quasi-Zenith Satellite System (QZSS) is a GPS satellite-based augmentation system to enhance GPS's accuracy in Asia-Oceania, with satellite navigation independent of GPS scheduled for 2023.[12]

When selective availability was lifted in 2000, GPS had about a five-meter (16 ft) accuracy. The latest stage of accuracy enhancement uses the L5 band and is now fully deployed. GPS receivers released in 2018 that use the L5 band can have much higher accuracy, pinpointing to within 30 centimetres (11.8 in).

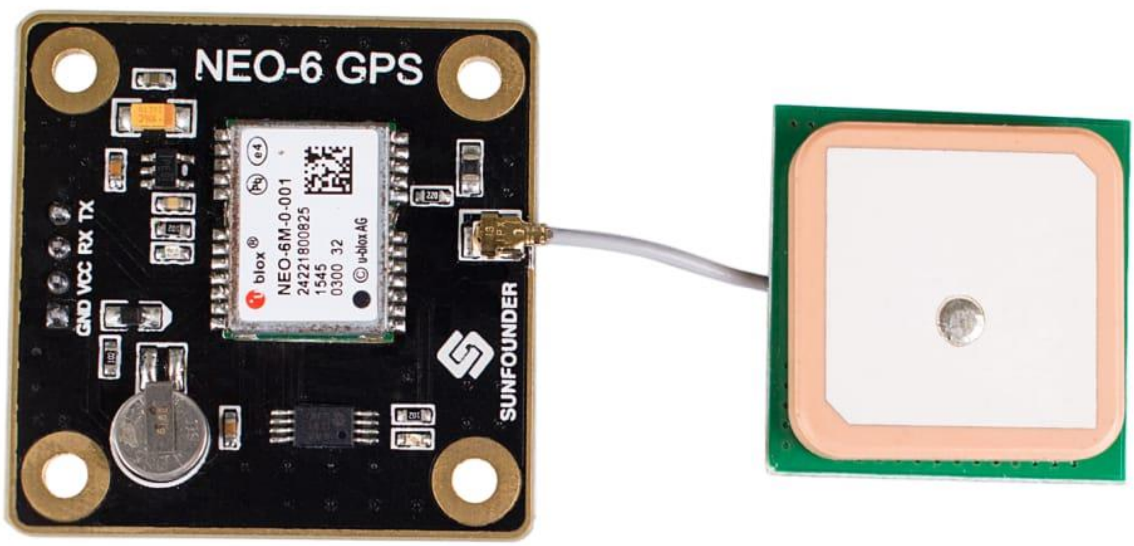

Fig:13- GPS Module

The NEO-6M GPS module is a well-performing complete GPS receiver with a built-in 25 x 25 x 4mm ceramic antenna, which provides a strong satellite search capability. With the power and signal indicators, you can monitor the status of the module. Thanks to the data backup battery, the module can save the data when the main power is shut down accidentally. Its 3mm mounting holes can ensure easy assembly on your aircraft, which thus can fly steadily at a fixed position, return to Home automatically, and automatic waypoint flying, etc. Or you can apply it on your smart robot car for automatic returning or heading to a certain destination, making it a real "smart" bot.

Features:

1) A complete GPS module with an active antenna integrated, and a built-in EEPROM to save configuration parameter data.

2) Built-in 25 x 25 x 4mm ceramic active antenna provides strong satellite search capability.

3) Equipped with power and signal indicator lights and data backup battery.

4) Power supply: 3-5V; Default baud rate: 9600bps.

5) Interface: RS232 TTL.

ARDUINO IDE (INTEGRATED DEVELOPMENT ENVIRONMENT):

Arduino Compiler : The Arduino IDE is a cross-platform application written in Java, and is derived from the IDE for the Processing programming language and the Wiring project. It is designed to introduce programming to artists and other newcomers unfamiliar with software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the board with a single click. There is typically no need to edit make files or run programs on a command-line interface. Although building on command-line is possible if required with some third-party tools such a Ino. The Arduino IDE comes with a C/C++ library called "Wiring" (from the project of the same name), which makes many common input/output operations much easier. Arduino programs are written in C/C++.

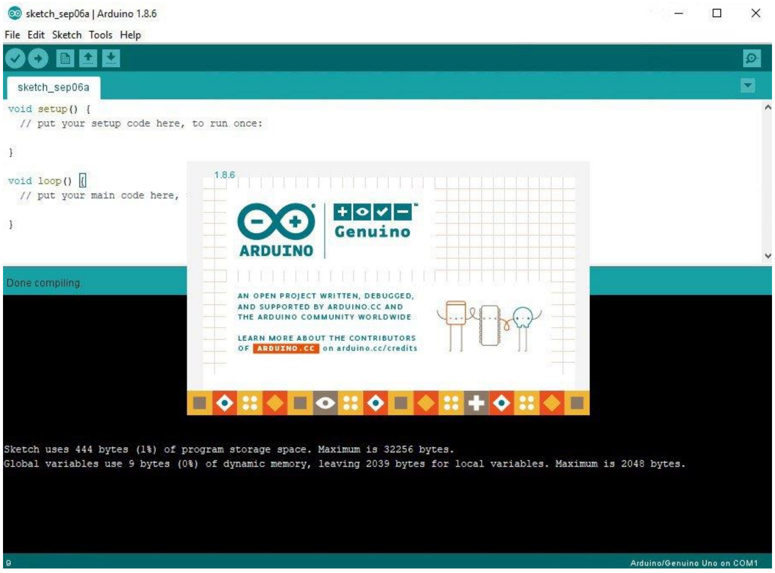

Fig:14-Arduino IDE

CHAPTER-2

LITERATURE SURVEY

2.1 Literature Review:

Several approaches have been proposed related to this issue in many papers. Of these, some specific papers have been analysed in the following paragraphs.

Vijay Savania proposed a system using an alcohol sensor placed in the vehicle along with the ultrasonic sensor used for car accident prevention. The resulting information is transmitted via SMS to the close by acquaintance through the GSM module.MS Malathi proposed a software environment indicating the alcohol sensor placed on the steering wheel detects the alcohol level and also a seat-belt detector is introduced for the safety of the driver during accidents by locking the seat-belt slot due to which the ignition can never be started. Dada Emmanuel Gbenga el al [6] proposed a prototype to detect alcohol and an engine locking mechanism by using an Arduino-Uno microcontroller interfaced with an alcohol sensor along with an LCD screen and a DC motor. In case alcohol is detected the engine is stopped, hence needs to be parked instantly

Aryan Mathur proposed a system imbedded on the steering wheel of the four wheeler to detect the alcohol level of the driver, the respective output is sent via signal to piezoelectric shaft and key casting is locked/unlocked. RF receiver receives the signals from the transmitters placed on the accident prone sites and the driver is alerted regarding the respective zones. Prof. Dr. D.G.Jha, proposed a model which aims at preventing the user from driving when drunk and reduces the number of accidents occurring due to drunken driving. In case, if the driver is intoxicated before but consumes the alcohol in motion, the sensor continues measuring and when the level crosses the limit, the vehicle starts slowing down and is stationed.

GPS based vehicle tracking and monitoring system- A solution for public transportationThe author of the paper provides a solution for tracking and monitoring the public transportation vehicles using devices such as Raspberry Pi and GPS Antenna. Raspberry Pi processing board can be used to receiving values and gives the result. This method can find a way to monitor the transportation vehicle from the location source to destination. In this paper, there is a use of GPS receiver module for receiving the latitude and longitude values of the present location of the vehicle continuously. A passenger of the vehicle will give different locations to the system between the source and destination locations. These values will be stored in the Raspberry Pi database and Raspberry Pi processor will compare the passenger specified values with the current vehicle location values and if the result is not the same then the passenger will be informed with warning message via display system that driver is driving in the wrong direction. Real-time GPS vehicle tracking system In this paper implementation and designing of a real-time GPS tracker system via Arduino was applied. This method was applicable for salesman tracking, private driver and for vehicle safety. The author of the paper also tried to solve the problem of owners who have expensive cars to observe and track the vehicle and find out vehicle movement and its past activities of vehicle. The system has GPS/GSM modules controlled by Arduino MEGA placed inside the vehicle. The vehicle position will be updated every time as the vehicle moves. Then User will send SMS on registered number and they will receives the coordinate location. At the same time the data will get stored on SD card continuously. The location will be accessible to users by system via website over the internet. Android app based vehicle tracking using GPS and GSM The author of this paper has explains an embedded system, used to know the location of the vehicle using technologies like GSM and GPS. System needs closely linked GPS and GSM module with a microcontroller. Initially, the GPS installed in the device will receive the vehicle location from satellite and store it in a microcontroller's buffer. In order to track location the registered mobile number has to send request, once authentication of number get completed, the location will be sent to mobile number in the form of SMS. Then GSM get deactivated and GPS get activated again. The SMS consist of latitude and longitude value of vehicle. This value received in the SMS can be viewed via android app and this coordinate will be plotted in the app automatically Survey paper on vehicle tracking system using GPS and android This paper propose a GPS based vehicle tracking system to help organization for finding addresses of their vehicles and locate their positions on mobile devices. The author states system will give the exact location of vehicle along with distance between user and vehicle. The system will have single android mobile, GPS and GSM modems along with processor that is installed in vehicle. When vehicle get activated and starts moving, the location of the vehicle will be updated continuously to a server using GPRS service. Monitoring unit will access the database from server to check the vehicle location. The location information present on database will be plotted using Google maps on monitoring device. Monitoring unit can be a Web application or Android application or a through which user will get to know the actual position of the proposed vehicle. Review of Accident Alert and Vehicle Tracking System In this paper, the author has described the system that can track the vehicle and detect an accident. There will be automatic detection of traffic accidents using vibration sensors or a piezoelectric sensor. This sensor will first sense the occurrence of an accident and give its output to the microcontroller. As soon as vehicle meets accident the GPS module will detect the latitude and longitudinal position of a vehicle. Then the GSM module sends latitude and longitude position of the vehicle to the ambulance which is near to that location. This message sending operation will be automatically done and an alert message may send to the central emergency dispatch server. This system is familiar with vibration sensor, Raspberry Pi, GPS and GSM modules to detect traffic accidents.

2.2 Conclusions on Review:

We conclude that achieving the goal of this project might bring some peace to the human mankind. It also saves so called challan to the people. Our project might be extended and future generation students can also take our project As earlier mentioned before small components liked led and lcd can be added to bring the project to a new extent. Advanced mechanical technology might also bring a major change in the braking and vehicle control system too

The aim of the paper is to give an overview of detecting. This system used to track the vehicle by using GPS which is one of the biggest technological advancements to track the activities of the vehicle. This system can be used in both cases of personal as well as business purpose to improve safety and security. This technology can also help to advance the system of transportation and can be used in many organizations for security purpose and tracking purpose. This system allows organizations to track their vehicles and to get the exact location of the vehicle.

Many processes and techniques are being used for overcoming the accidents that causes due to the over drinking of alcohol by the drivers. There are usually more than one method and technique; some adopt different technique like locking of steering, ignition interlock, vehicle interlock system and many more. The technique includes many considerations; some of these considerations include cost, appearance, application of technique and many more. In this project, we have tried our best to find out the golden mean through which we can restrict the driver, if he/she is not in his conscious mind due to the over concentration of alcohol. Through this way we can prevent the road accidents on daily basis. An effective solution is provided to develop the intelligent system for vehicles which will monitor various parameters of vehicle in-between constant time period and will send this data to the base unit as explained in this paper, by using hardware platform whose Core is Arduino, Alcohol sensor mq3, GPS & GSM module. The designed system would finish the function of communicating with the base station via GPS, GSM and control of various parameters. The whole Control system has the advantage of small volume and high reliability. Future scope of this system is to control the accidents and providing useful details about the accidental vehicle, thereby reducing the rate of accidents taking place due to drunken driving. This system brings innovation to the existing technology in the vehicles and also improves the safety features, hence proving to be an effective development in the automobile industry.

CHAPTER-3
PROJECT DESIGN

3.1 Overview of the Design:

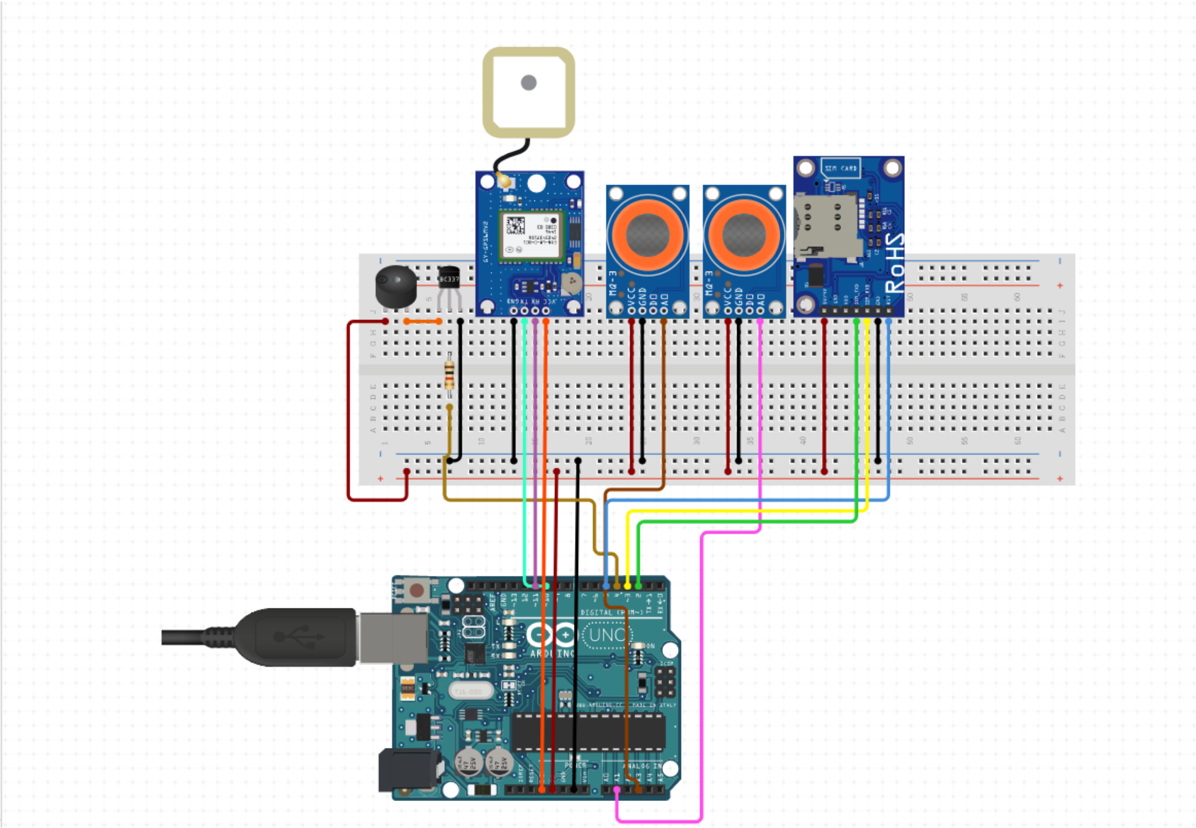

Fig:15- Circuit Diagram

Arduino is used for controlling whole the process with a **GPS Receiver and GSM module**. GPS Receiver is used for detecting coordinates of the vehicle, GSM module is used for sending the coordinates to user by SMS. And an optional 16x2 LCD is also used for displaying status messages or coordinates and the amount of alcohol consumed by the person. We have used GPS Module NEO-6M and GSM Module SIM800L.

When we ready with our hardware after programming, we can install it in our vehicle and power it up.

Sent message is received by GSM module which is connected to the system and sends message data to Arduino. Arduino reads it and extract main message from the whole message. And then compare it with predefined message in Arduino. If any match occurs then Arduino reads coordinates by extracting $GPGGA String from GPS module data (GPS working explained above) and send it to user by using GSM module. This message contains the coordinates of vehicle location.

3.2 Equipment Analysis:

- In the first stage of the project the basic components used are sensor, Arduino and buzzer. But in extension of the first stage we can also use two more components based on the requirement and the price that are willing to support by the customer
- LED light will be the first extension to the buzzer. Even when the frequency of buzzer gets any disturbances an led is placed parallel to the buzzer glowing alongside the ringing of the buzzer.
- Coming to the other extension of the first stage we can also use LCD (16x2) to display the amount of alcohol consumed by the person. But the initialization of some commands may be seen to the person drunk and may damage the total kit.

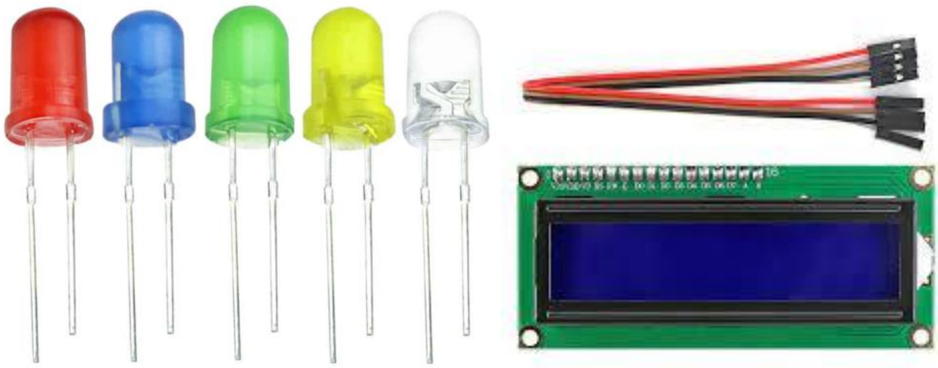

Fig:16- Additional components

- Originally three stages would be done but due to this pandemic only two stages can be done
- Elements involved are Arduino uno, MQ3 sensors, GSM & GPS Modules
- The program used to make this project is c language.
- Work completed till stage two
- The cost we estimated was around 4,000 but due to some changes our expenses went till 6,000
- The problem already told and mentioned is that the dot at the end of the google maps link.
- Project can be extended at any means necessary. For example, many extensions can be made to this project but those extensions will be coming up with a certain cost. So if the buyer or the consumer is ready to take the burden of the cost and feels safety is more important than he can go with it

3.3 Module Definition:

Arduino Uno Module:

Arduino Uno is a microcontroller board developed by Arduino.cc which is an open-source electronics platform mainly based on AVR microcontroller Atmega328. The first Arduino project was started in Interaction Design Institute Ivrea in 2003 by David Cuartielles and Massimo Banzi with the intention of providing a cheap and flexible way for students and professionals for controlling a number of devices in the real world.

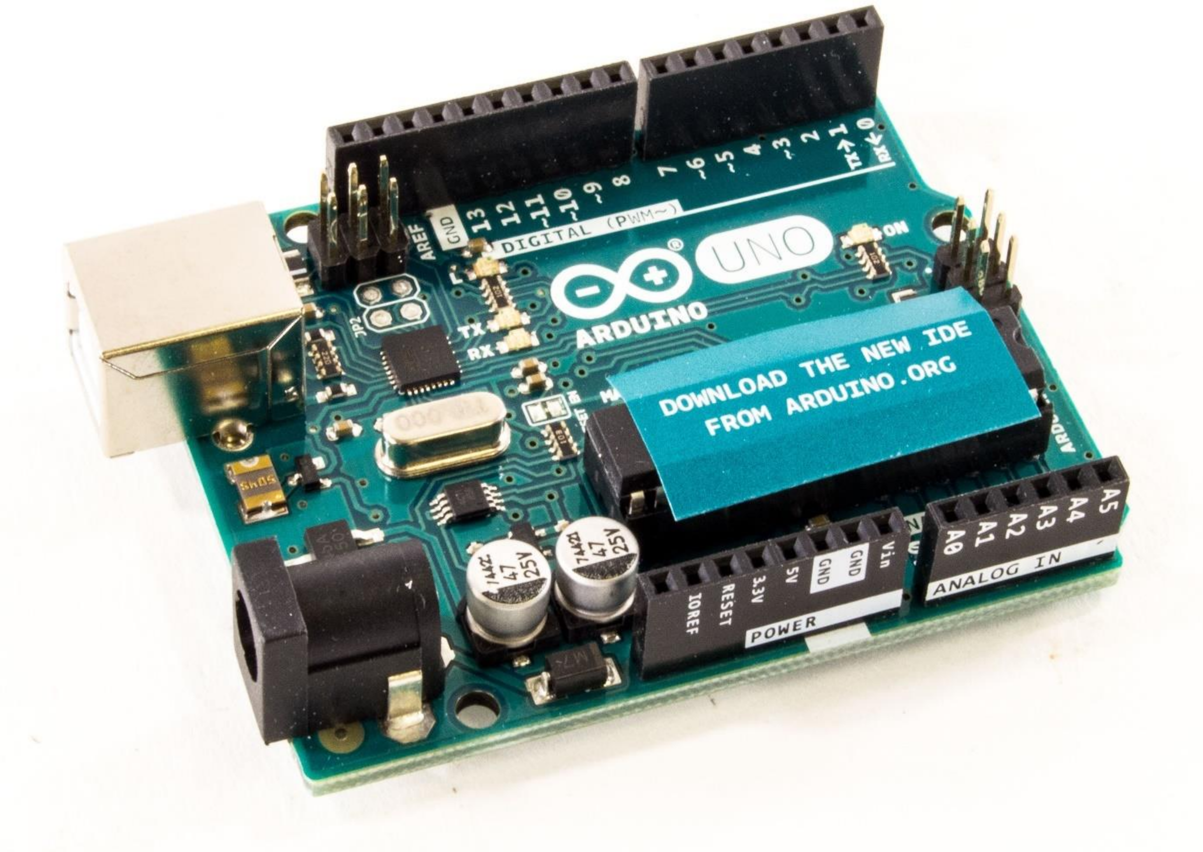

Fig:17- Pins of Arduino Uno

GPS Module:

A GSM module or a GPRS module is a chip or circuit that will be used to establish communication between a mobile device or a computing machine and a GSM or GPRS system.

Fig:18 Pins of GPS Module

GSM Module:

A GSM module or a GPRS module is a chip or circuit that will be used to establish communication between a mobile device or a computing machine and a GSM or GPRS system. The modem (modulator-demodulator) is a critical part here.

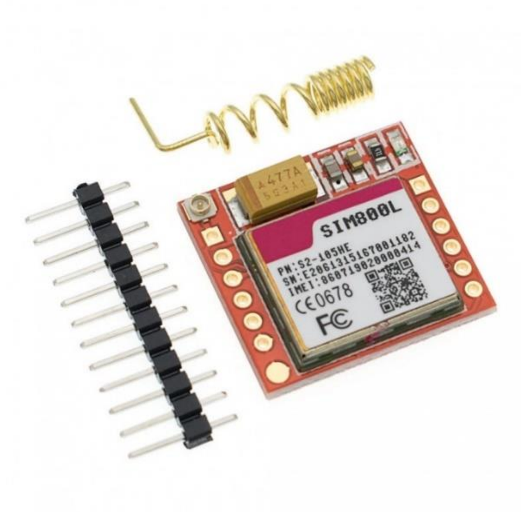

Fig:19- dismantled GSM Module

3.4 Module Functionalities:

Arduino Uno:

Pin Category	Pin Name	Details
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
Input/Output Pins	Digital Pins 0 - 13	Can be used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide reference voltage for input voltage.

Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Input Pins	6 (A0 – A5)

Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz

Table:2-pins of Arduino Uno

- **Serial Pins 0 (Rx) and 1 (Tx):** Rx and Tx pins are used to receive and transmit TTL serial data. They are connected with the corresponding ATmega328P USB to TTL serial chip.
- **External Interrupt Pins 2 and 3:** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- **PWM Pins 3, 5, 6, 9 and 11:** These pins provide an 8-bit PWM output by using analogWrite() function.
- **SPI Pins 10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK):** These pins are used for SPI communication.
- **In-built LED Pin 13:** This pin is connected with an built-in LED, when pin 13 is HIGH – LED is on and when pin 13 is LOW, its off.

Along with 14 Digital pins, there are 6 analog input pins, each of which provide 10 bits of resolution, i.e. 1024 different values. They measure from 0 to 5 volts but this limit can be increased by using AREF pin with analog Reference() function.

- Analog pin 4 (SDA) and pin 5 (SCA) also used for TWI communication using Wire library.

Arduino Uno has a couple of other pins as explained below:

- **AREF:** Used to provide reference voltage for analog inputs with analogReference() function.
- **Reset Pin:** Making this pin LOW, resets the microcontroller.

GPS Module:

Pin Name	Description
VCC	Positive power pin
RX	UART receive pin
TX	UART transmit pin
GND	Ground

Table:3- Pins of GPS Module

GSM Module:

The SIM800L module has total 12 pins that interface it to the outside world. The connections are as follows:

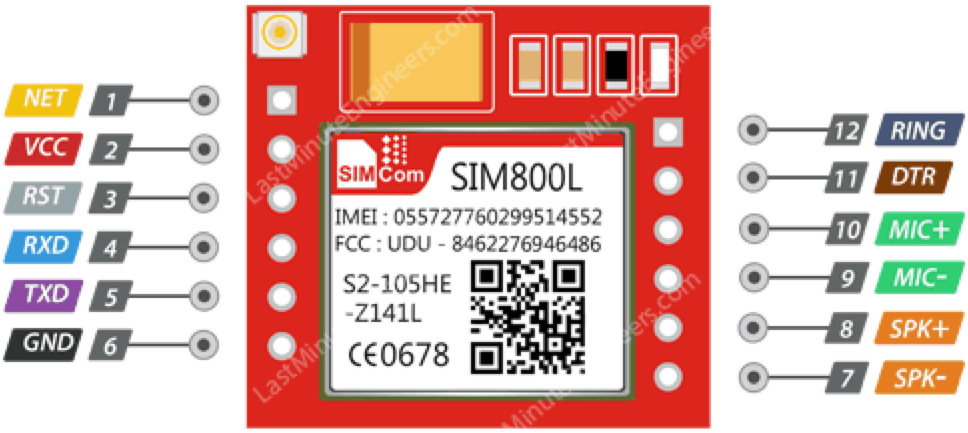

Fig:20-pins of GSM Module

NET is a pin where you can solder Helical Antenna provided along with the module.

VCC supplies power for the module. This can be anywhere from 3.4V to 4.4 volts. Remember connecting it to 5V pin will likely destroy your module! It doesn't even run on 3.3 V! An external power source like Li-Po battery or DC-DC buck converters rated 3.7V 2A would work.

RST (Reset) is a hard reset pin. If you absolutely got the module in a bad space, pull this pin low for 100ms to perform a hard reset.

RxD (Receiver) pin is used for serial communication.

TxD (Transmitter) pin is used for serial communication.

GND is the Ground Pin and needs to be connected to GND pin on the Arduino.

RING pin acts as a Ring Indicator. It is basically the ‘interrupt’ out pin from the module. It is by default high and will pulse low for 120ms when a call is received. It can also be configured to pulse when an SMS is received.

DTR pin activates/deactivates sleep mode. Pulling it HIGH will put module in sleep mode, disabling serial communication. Pulling it LOW will wake the module up.

MIC± is a differential microphone input. The two microphone pins can be connected directly to these pins.

SPK± is a differential speaker interface. The two pins of a speaker can be tied directly to these two pins.

CHAPTER-4

PROJECT IMPLEMENTATION

4.1 Implementation Stages

The project has been divided into stages to make the project easier. By this type of stages, we can make the project interesting and easy to understand.

STAGE:1 – Alcohol Detection:

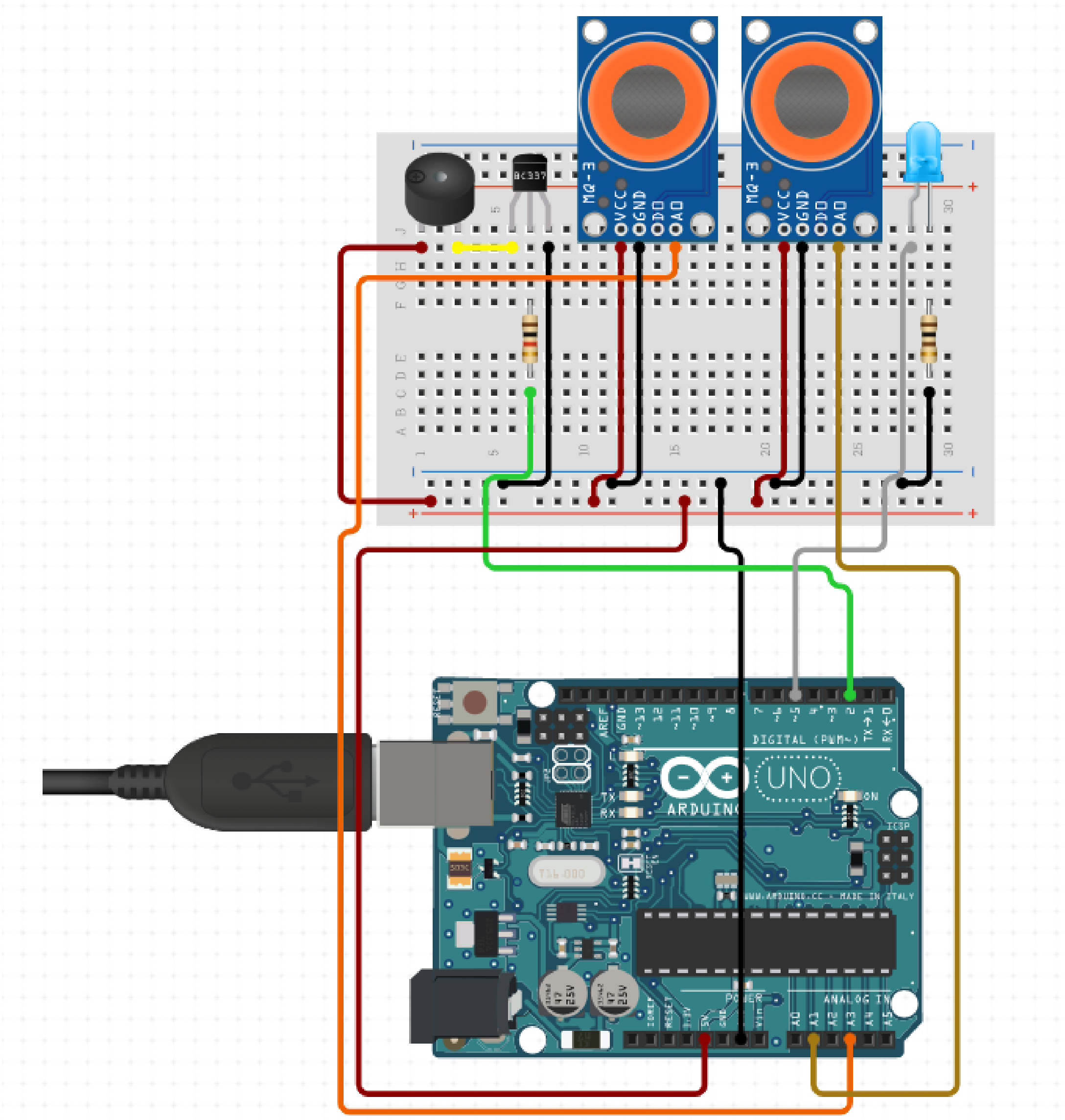

Fig:21- Circuit Diagram of Stage One

In stage one, components used are MQ3 sensors, buzzer, transistor and some sets of resistors just to make sure any additional currents might not be passed.

STAGE 2 – Messaging System:

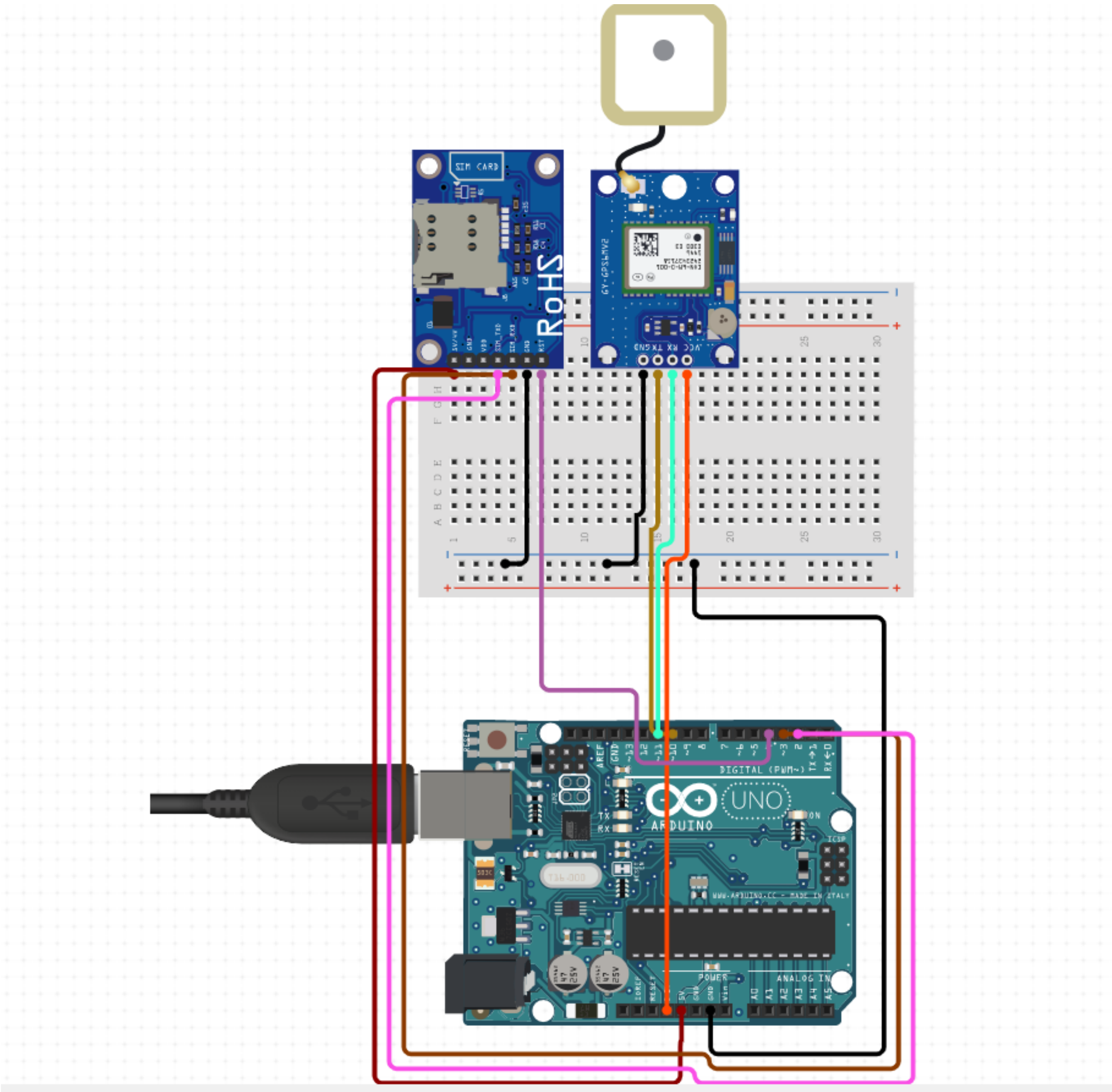

Fig:22- Circuit of Stage two

In stage two, the components used are only the modules which are GSM Module and GPS Module and antenna is used additionally for GPS Module.

4.2 Implementation Results:

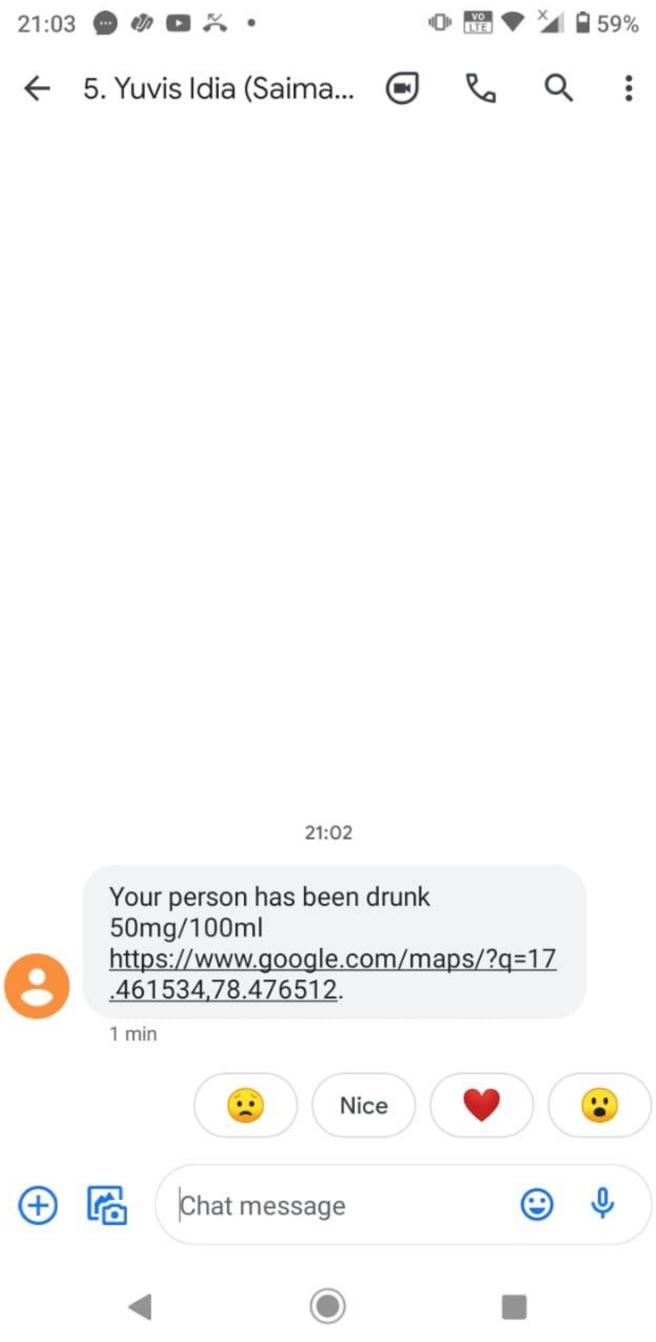

Fig:23- Message

The message sent by the GSM Module will be like this and next image shows upon when the google maps link is clicked.

This is the image when the google maps link is clicked and this is how it seems when pinpointing the location

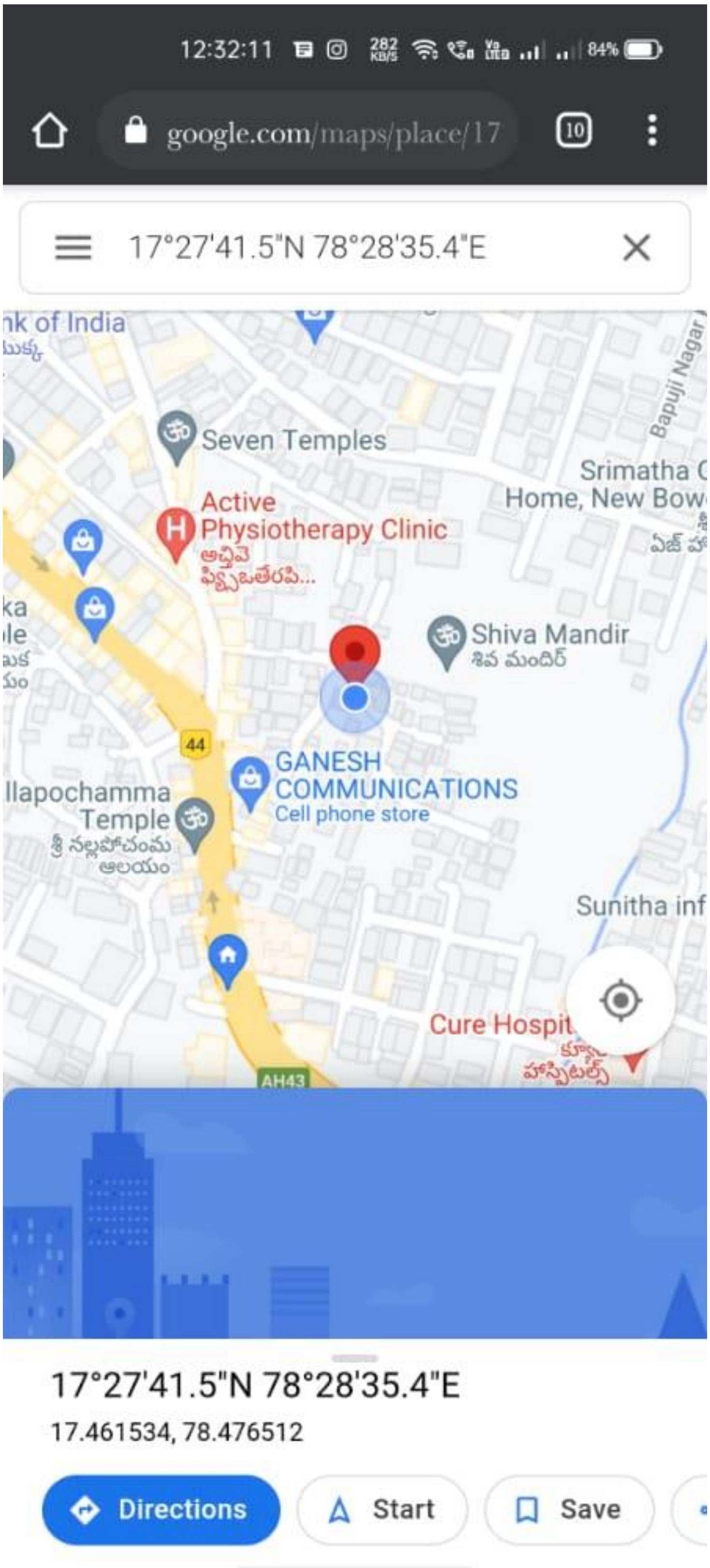

Fig:24- Google maps

CHAPTER – 5
PROJECT TESTING

5.1 Overview of Testing Methods:

The kit is small and simple and its simplicity depends on how many components you used in this project

- Connect the components as given in the circuit diagram and make sure you don't give any loose connections and ground terminals should be grounded to complete the connections.
- Now connect the Arduino cable to the Arduino Uno and dump the program given using the Arduino IDE software
- After uploading the program remove the cable and give the supply to the Arduino via external power supply (for our prototype we have used an adapter to make it run without laptop's supply).
- Now when supply is given you can see that the LEDs on Arduino Uno, MQ3 sensors, GSM Module and GPS Module will be blinking or will be turned out through out the time which means every component is working fine
- Coming to GPS Module the LEDs on it only turn ON when it receives the signal of the position, if the light doesn't glow then that means its not receiving any signal and further you have to change the position of the antenna until you get any signal.
- Coming to GPS Module the light will blink in three different ways, which are:
    1. Blinks for every 1 second, then it means that the module is getting the power supply but didn't connect to any cellular network yet.
    2. Blinks for every 2 seconds, then it means that its searching fir the requested GPRS connection.
    3. Blinks for every 3 seconds, which means that the module has made contact with the cellular network and ready to send the SMS.
- After getting all these conditions satisfied, your project/kit is ready to go and perform the operation.

CHAPTER – 6

CONCUSION AND FUTURE ENHANCEMENT

In this project work, we have implemented a complete working model using an Arduino Uno. The programming and interfacing have been mastered during the implementation.

This work includes the study of GSM modem using sensors. The biggest advantage of using this project is, whenever the sensor is activated, we will be getting the information from GSM modem to our mobile numbers which are stored in GSM network operators have roaming facilities, user can often continue to use their mobile phones when they travel to other countries etc... And also, instant defending system will be monitored by using defending protection motor which is operated by the relay signals.

Whenever the sensor is activated, buzzer alarm is activated and simultaneously the SMS will be sent to the registered number within 30 seconds.

We can implement up to any number of sensors integrated with same instant protection and also, we can add few more mobile numbers by upgrading the GSM mode.

We conclude that achieving the goal of this project might bring some peace to the human mankind.

It also saves so called challan to the people.

Our project might be extended and future generation students can also take our project

As earlier mentioned before small components liked led and lcd can be added to bring the project to a new extent.

Advanced mechanical technology might also bring a major change in the braking and vehicle control system too.

CAPTURING PUBLICATIONS

CONFERENCE:

Publishing in the conference of

INTERNATIONAL CONFERENCE ON “RECENT DEVELOPMENTS IN POWER ENGINNERING (ICRDPE - 21)”

Organized by the department of electrical and electronics engineering on 9th and 10th of July 2021.

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Alcohol Alert. (1998) Accident and Emergency. Issue 3. [The document suggests that the mixture of young people and alcohol is putting a huge strain on the NHS and urges imminent action. Despite noting that 'few departments routinely enquire about and record alcohol consumption' high figures are quoted to illustrate their concerns.]

All Party Parliamentary Beer Group (1999) Licensing law reform panel report. [The report of the All-Parliamentary Beer Group on licensing reform. Published in October 1999 has heavily influenced legislative proposals and initiated wide debate.]

Andreasson, S. et al. (2000) Over-serving patrons in licensed premises in Stockholm. Addiction.95(3):359-363. [Research designed to study the frequency of alcohol service to intoxicated patrons in licensed premises. Results showed the actors who were hired to simulate severe intoxication were served in 95% of licensed premises.]

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APPENDICES

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(12,11,5,4,3,2);

#include <SoftwareSerial.h>
SoftwareSerial sim808(7,8);

#define sensor A0
#define led 13
#define buz 9

char phone_no[] = "xxxxxxx";
String data[5];
#define DEBUG true
String state,timegps,latitude,longitude;

void setup()
{
  lcd.begin(16,2);
  Serial.begin(9600);
  sim808.begin(9600);
  pinMode(sensor, INPUT);
  pinMode(buz, OUTPUT);
  pinMode(led, OUTPUT);

  lcd.setCursor(0,0);
  lcd.print("ALCOHOL DETECTION");
  lcd.setCursor(0,1);
  lcd.print("WITH VEHICLE ");
  delay (5000);
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("CONTROL AND ");
```

```
lcd.setCursor(0,1);
lcd.print("ACCIDENT DETECTION");
delay (5000);
lcd.clear();
lcd.clear();
lcd.setCursor(0,0);
lcd.print("MESSAGING");
lcd.setCursor(0,1);
lcd.print("SYSTEM");
delay (5000);
lcd.clear();

lcd.setCursor(0,0);
lcd.print("Waiting For GPS");
lcd.setCursor(0,1);
lcd.print(" Signal ");
get_sim808();
show_coordinate();
delay(3000);
lcd.clear();
lcd.setCursor(0,0);
lcd.print("GPS is OK");
delay(1000);
lcd.clear();
lcd.print("Initializing");
lcd.setCursor(0,1);
lcd.print("GSM MODEM");
delay(1000);
sim808.print("AT+CSMP=17,167,0,0");
delay(100);
sim808.print("AT+CMGF=1\r");
delay(400);

sendData("AT+CGNSPWR=1",1000,DEBUG);
```

```
  delay(50);
  sendData("AT+CGNSSEQ=RMC",1000,DEBUG);
  delay(150);
  lcd.clear();
  lcd.print("Initialized");
  lcd.setCursor(0,1);
  lcd.print("Successfully");
  delay(2000);
  lcd.clear();
}

void loop()
{
  float adcValue=0;
  for(int i=0;i<10;i++)
  {
    adcValue+= analogRead(sensor);
    delay(10);
  }
    float v= (adcValue/10) * (5.0/1024.0);
    float mgL= 0.67 * v;
    Serial.print("BAC:");
    Serial.print(mgL);
    Serial.print(" mg/L");
    lcd.setCursor(0,0);
    lcd.print("BAC: ");
    lcd.print(mgL,4);
    lcd.print(" mg/L        ");
    lcd.setCursor(0,1);
    if(mgL > 0.8)
    {
      lcd.print("Drunk");
      Serial.println("Drunk");
      digitalWrite(buz, HIGH);
```

```
      digitalWrite(led, HIGH);
    }
    else
    {
      lcd.print("Normal");
      Serial.println("Normal");
      digitalWrite(buz, LOW);
      digitalWrite(led, LOW);
    }

void loop() {
  sendTabData("AT+CGNSINF",1000,DEBUG);
  if (state !=0==mgL) {
    Serial.println("State  :"+state);
    Serial.println("Time  :"+timegps);
    Serial.println("Latitude  :"+latitude);
    Serial.println("Longitude  :"+longitude);

    sim808.print("AT+CMGS=\"");
    sim808.print(phone_no);
    sim808.println("\"");

    delay(300);

    sim808.print("http://maps.google.com/maps?q=loc:");
    sim808.print(latitude);
    sim808.print(",");
    sim808.print (longitude);
    delay(200);
    sim808.println((char)26);
    delay(200);
    sim808.println();
    delay(20000);
    sim808.flush();
```

```
  } else {
    Serial.println("GPS Initialising...");
  }
}
void sendTabData(String command , const int timeout , boolean debug){

  sim808.println(command);
  long int time = millis();
  int i = 0;

  while((time+timeout) > millis()){
    while(sim808.available()){
      char c = sim808.read();
      if (c != ',') {
         data[i] +=c;
         delay(100);
      } else {
        i++;
      }
      if (i == 5) {
        delay(100);
        goto exitL;
      }
    }
  }exitL:
  if (debug) {
    state = data[1];
    timegps = data[2];
    latitude = data[3];
    longitude =data[4];
  }
}
String sendData (String command , const int timeout ,boolean debug){
```

```
  String response = "";
  sim808.println(command);
  long int time = millis();
  int i = 0;

  while ( (time+timeout ) > millis()){
    while (sim808.available()){
      char c = sim808.read();
      response +=c;
    }
  }
  if (debug) {
     Serial.print(response);
     }
     return response;
}
```