An Induction Generator-Based AC/DC Hybrid Electric Power Generation System for Electric Aircraft

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Abstract

In more electric aircraft (MEA) system, both ac and dc electric powers with multiple voltage levels are required for various aircraft loads. This paper presents an induction generator-based ac/dc hybrid electric power generation system for MEA. In the proposed system architecture, a high-speed induction starter/generator and allow – speed induction generator are installed on the high pressure (HP) and low pressure (LP) spools of the engine, respectively. In generating mode of operation, all of the constant voltage variable frequency ac power is generated by the HP generator while the dc power demand is shared by both HP and LP generators. A control scheme is developed to regulate the ac load voltage and coordinate dc power generation between the two generators. The proposed induction generator based ac/dc hybrid generation system results in reduced hardware requirement compared with both ac and dc primary generation systems.

Keywords: ***Induction Motors, Generators, Distributed Power Generation, Aircraft, Power Generation Control***

1. Introduction

The EMERGING trend toward more electric architecture for airplanes is intended to replace mechanical, hydraulic, and pneumatic systems with electrical systems as much as possible. It is generally considered that the more electric aircraft (MEA) would lead to lower fuel consumption and emissions, reduced maintenance, and possibly lower costs[1]–[4].Advancements of on-board electrification have increased the electric power demand of the aircraft. A significant raise of generation capacity is required to supply the additional loads.

As is shown in Fig. 1, in present MEA systems (e.g., Boeing 787, Airbus A380), the wound-field synchronous generator (SG)-based ac primary generation system [5], [6] can feed the frequency insensitive loads directly from the SG terminals. The constant voltage variable frequency (CVVF) ac load voltage is regulated by controlling the field current of the SG through an external brushless exciter. This exciter consists of a permanent magnet (PM) machine and a diode rectifier mounted on the generator shaft. By adjusting the excitation of the field winding, the ac source voltage can be regulated with variable shaft speed. However, in the SG-based ac primary generation system, the complex rotor structure makes the torque to inertia ratio of SG lower than other type of electric machines [1]. Moreover, the rotating diode bridge structure limits the top speed of the generator shaft. If the synchronous machine is used as a starter/generator, separate field and armature voltage controls are required during its motoring operation.

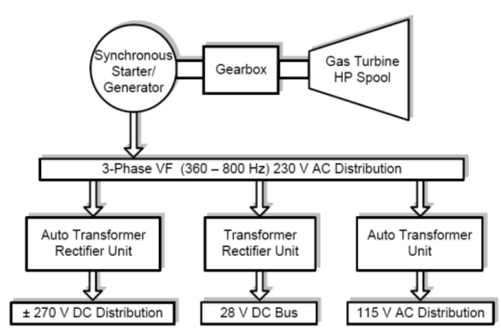

Fig. 1. System configuration of the synchronous generator based AC primary generation system [6]

In more electric aircraft systems, the effect of electrical power off take can sometimes have significant impact on the dynamics and control of the aircraft engine [7]. For instance, during the transition from cruise to descent phase, the aircraft engine power is transiently reduced while maintaining high electrical power demand. This transition creates a possibility of engine instability and may require substantial electric load shedding. This issue can be resolved by installing an extra generator on the LP spool of the engine and sharing the electrical power extraction between the HP and LP spools [4-7].

In order to parallel the two generators operated at different frequencies, a DC primary generation system with power electronic converters is preferred as an advanced more electric architecture [8-9]. PM generator is preferred in this twin-spool twin-generator architecture due to its high power density and self-excited capability [8-10]. As shown in Fig. 2, a high speed starter/generator and a low speed generator are placed directly on the HP and LP spool of the engine, respectively. In the engine starting process, the PM starter/generator on HP spool can operate as a motor to start the engine using ground power supply. During the flight mission, the power generated from the two generators are rectified and transmitted to a ±270 V DC power bus. This type of system presents high power factor and high efficiency, but suffers from excessive current flow during fault condition because of the use of PM generators [10]. Although multi-phase fault-tolerant PM generators have been investigated to limit the short-circuit fault current [11-13], using PM generator to fulfill the overload current requirement of main engine generator in aerospace application is still problematic. Furthermore, installing the PM generator close to the gas turbine engine may greatly affect the system reliability since most permanent magnet materials are vulnerable to demagnetization under very high temperature. Finally, compared to the SG based AC primary generation system architecture, the CVVF power demanded by frequency insensitive loads (e.g. wing de-icing system, galleys, etc.) in DC primary generation system is first converted to DC power by the active rectifier of the generator, and inverted back to AC power through dedicated inverters. This two-stage AC-DC-AC conversion adds extra losses and additional hardware to the system. In Boeing 787, under cursing condition, the power consumed by the frequency insensitive AC loads is close to 50% of the total electrical power consumption [8].

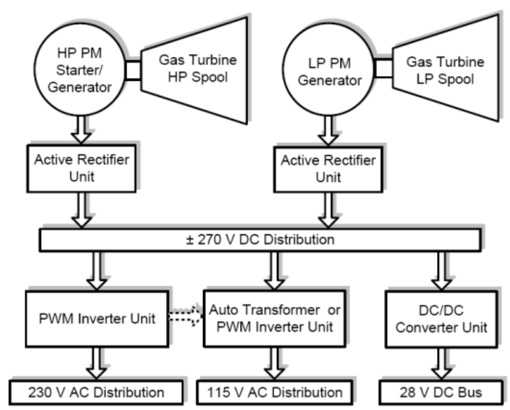

Fig. 2. System configuration of the permanent magnet generator based DC primary generation system [8]

Using induction machine as main engine generator in aircraft application is rarely reported in literature [14-16]. In medium power applications (50-150 kW), the power density of induction generator (IG) is relatively higher than wound-field synchronous generator, but lower than PM generator [17]. Nonetheless, the concern of excessive fault current due to the PM excitation for airborne applications can be easily addressed by using IGs. In addition, the internal impedance of IG is the lowest among all type of generators.

From the generation system architecture point of view, since neither AC nor DC primary generation system is able to meet all the power requirements with optimized performance in terms of volume, weight, efficiency, reliability and cost. Hence, in this paper, an induction generator based AC/DC hybrid generation system is proposed to combine the advantages and address the shortcomings of both systems.

In this paper, the configuration of the proposed induction generator based AC/DC hybrid generation system for MEA is presented. A steady-state analysis is carried out to explain the proposed twin-spool twin-generator AC/DC hybrid generation method. A closed-loop control scheme for AC and DC voltage regulation of the proposed system is developed based on field oriented control theory. As an extension of the work in [18], the feasibility of operation of the proposed system is demonstrated by hardware-in-the-loop real time emulation.

II. SYSTEM CONFIGURATION

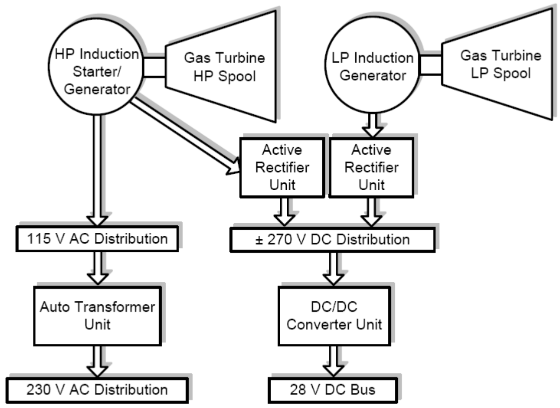

Fig. 3. System configuration of the induction generator based AC/DC hybrid generation system

The proposed induction generator based AC/DC hybrid generation system is shown in Fig. 3. In the proposed system, a high speed open-end winding squirrel-cage induction starter/generator and a low speed conventional wye-connected squirrel-cage induction generator are attached to the high pressure (HP) and low pressure (LP) spools of the engine, respectively. In generating mode of operation, the HP generator is in charge of generating all of the CVVF power, while the DC power demand is shared by both HP and LP generators. The proposed AC/DC hybrid generation architecture can supply CVVF power directly from one side of the generator winding terminals without external exciter, and generate DC power on the other side of the generator winding terminals through an inverter/rectifier unit.

From the generation system architecture point of view, compared to DC primary generation system in Fig. 3, the undesired AC-DC-AC conversion is avoided by applying AC/DC hybrid generation on HP spool in the proposed system, while the merits of the twin-spool twin-generator DC primary generation architecture have been reserved. As compared to the AC primary generation system in Fig. 1, the application of induction generator removes the external exciter, while the twin-spool twin-generator architecture improves the overall generation performance. As a result, the overall hardware requirement of the proposed system is reduced compared to both AC and DC primary generation systems.

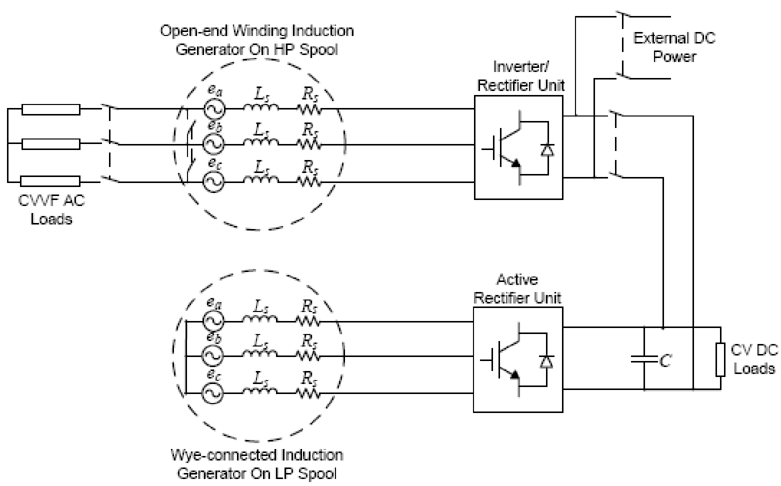

Fig. 4. Electrical system diagram of the induction generator based AC/DC hybrid generation system

A more detailed electrical system configuration is shown in Fig. 4. An inverter/rectifier unit and frequency insensitive AC loads are connected to each end of the HP spool open-end winding induction generator terminals. An active rectifier unit is connected to the LP spool wye-connected induction generator. The DC output end of the inverter/rectifier unit and the active rectifier unit are paralleled to the DC bus.

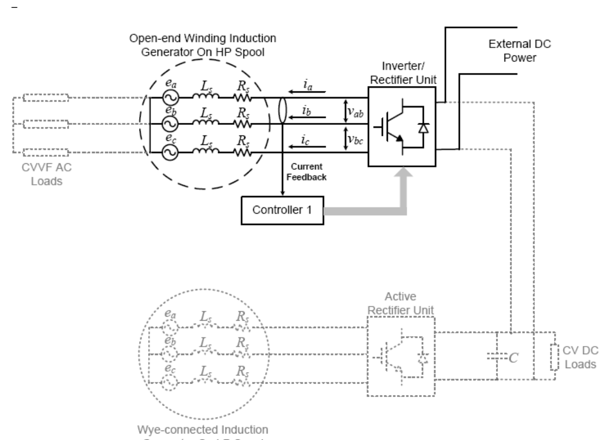

Fig. 5. Starter mode of operation of the induction generator based AC/DC hybrid generation system

In most of the MEA applications, besides generating electric power, the main engine generator is also used as a starter for starting the aircraft engine. A DC power supply from the APU generation system or ground power supply is usually available for this process. As is shown in Fig. 5, in the engine starting mode of operation, the entire LP spool generation subsystem is deactivated. The AC loads are disconnected from the HP generator, and the AC load side generator terminals are shorted to transform the open-end induction generator on HP spool into a wye-connected induction motor. Additional circuit breakers are required to implement this transformation. Using the DC power supply, the transformed induction motor can be driven by the inverter/rectifier unit to start the aircraft engine.

Once the engine shaft reaches its idle speed, the proposed system begins to operate in generator mode. As is shown in Fig. 6, in this mode of operation, the AC load side terminals of the HP generator are connected to the CVVF loads, and the wye-connected induction generator on LP spool is activated. All the CVVF power is generated by the HP generator only, while the power demand of the DC loads is shared between both the HP and LP generators. The DC bus capacitor will be fully charged at the beginning of the generator mode of operation.

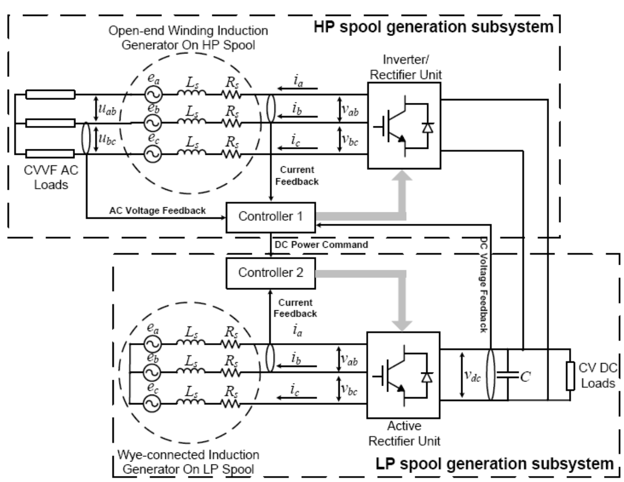

Fig. 6. Generator mode of operation of the induction generator based AC/DC hybrid generation system

In the proposed AC/DC hybrid generation system, instead of using a conventional wye-connected induction generator and connecting the CVVF loads in parallel with the inverter/rectifier unit [19], the CVVF loads, the HP shaft open-end winding induction generator, and the inverter/rectifier unit are connected in series. Compared to the conventional shunt connected configuration [19], the series connected inverter/rectifier unit requires higher current ratings. However, the open-end winding generator configuration can increase the output voltage of the generator [20-21], from which the current rating of the generator can be reduced for the same amount of power generation demand. As a result, the size and weight of the generator can be greatly reduced compared to the shunt connected configuration.

III. SYSTEM MODELING AND OPERATION PRINCIPLE

A. Mathematical Model of the PMSM

The electrical equations of the PMSM in the rotor (dq) reference frame are as follows:

$$v_d = R_s i_d + L_d \frac{d}{dt} i_d - \omega_r L_q i_q$$
$$v_q = R_s i_q + L_q \frac{d}{dt} i_q - \omega_r (L_d i_d + \emptyset_f)$$
$$\emptyset_d = L_d i_d + \emptyset_f$$
$$\emptyset_q = L_q i_q$$

The mechanical equation can be written as:

$$\frac{d\omega}{dt} = (C_e - T_L - f_r \omega_r)/J$$
$$C_e = \frac{3}{2} p\left[\emptyset_f i_q - (L_q - L_d) i_d i_q\right]$$

where Rs is the stator resistance, Ld, Lq are stator inductances in (d,q) frame, r ω is the rotor speed, (φd, φq)are stator flux, φf rotor flux, ((id,iq) and (vd ,vq) are respectively stator currents and stator voltages in the (d,q)frame , Ce is the electromagnetic torque, TL is the load torque. J and fr are the rotor moment inertia and the friction coefficient.

B. Current Controller and Decoupling Compensation

When a voltage source PWM inverter is used, the stator currents need to be controlled to track the reference currents. The dynamics of the stator currents with stator voltages as input are coupled and nonlinear. However, if the stator voltages commands are given in the form

$$v_d = u_d - u_{d\_comp}$$
$$v_q = u_q - u_{q\_comp}$$

Where

$$u_{d\_comp} = \omega_r L_q i_q$$
$$u_{q\_comp} = -\omega_r (L_d i_d + \emptyset_f)$$

Then the stator currents dynamics reduce to

$$v_d = R_s i_d + L_d \frac{d}{dt} i_d$$
$$v_q = R_s i_q + L_q \frac{d}{dt} i_q$$

Since the current dynamics are linear and decoupled, PI controllers can be used for current tracking

$$v_d = k_{pi_d}(i_{d\_ref} - i_d) + k_{Ii_d} \int (i_{d\_ref} - i_d) dt$$
$$v_q = k_{pi_q}(i_{q\_ref} - i_q) + k_{Ii_q} \int (i_{q\_ref} - i_q) dt$$

Figure shows the block diagram of the de coupling system

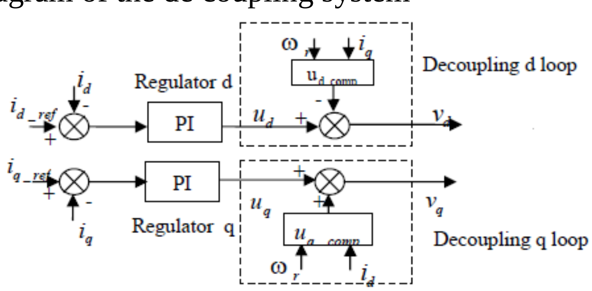

Fig7. Decoupling system with compensation

C. Vector Control of the PMSM

The objective of the vector control of PMSM is to allow the motor to be controlled just like a separately excited DC motor. So, the direct'd' axis is aligned with permanent magnet flux linkage phase and the direct current ' id' is forced to be zero. Then can be written as follows

$$\emptyset_d = \emptyset_f$$
$$\emptyset_q = L_q i_q$$

And the electromagnetic torque is

$$C_e = k_t i_q$$
$$k_t = \frac{3}{2} p \emptyset_f$$

Note that the electromagnetic torque equation is similar to that of DC motor

D. PWM Inverter

Pulse width modulation (PWM) technique is used to generate the required voltage or current to feed the motor or phase signals. This method is increasingly used for AC drives with the condition that the harmonic current is as small as possible. Generally, the PWM schemes generate the switching position patterns by comparing the three-phase sinusoidal wave forms with a triangular carrier. The inverter model is represented by the relationship between output phase voltages (va,vbb, vc) and the control logic signals(s1, s2, s3) as follows:

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \frac{V_{dc}}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} S_1 \\ S_2 \\ S_3 \end{bmatrix}$$

Where Vdc is the rectified voltage, Si (i = 1,2,3) ∈[0 1] are logic signals.

PRINCIPLE OF FLC

The design of FLC does not require mathematical modeling. The formulation of the control rules is based on the knowledge of the PMSM drive and the experience of the control engineer.

A. Fuzzy logic controller structure

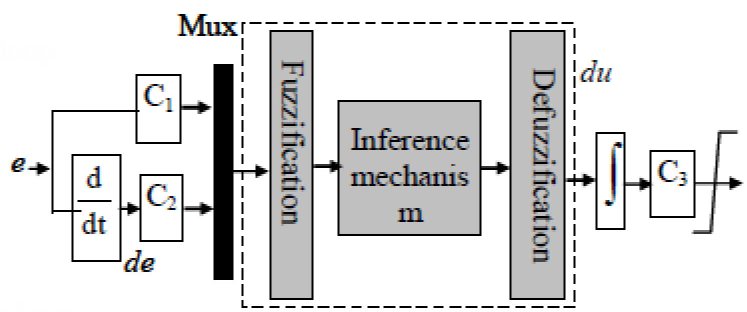

Fig8. FLC internal structure

The FLC has three functional blocks as shown in figure. In the fuzzification block, the inputs and output crisp variables are converted into fuzzy variables 'e', 'de' and 'du' using the triangular and the trapezoidal membership functions shown in figure. (a)

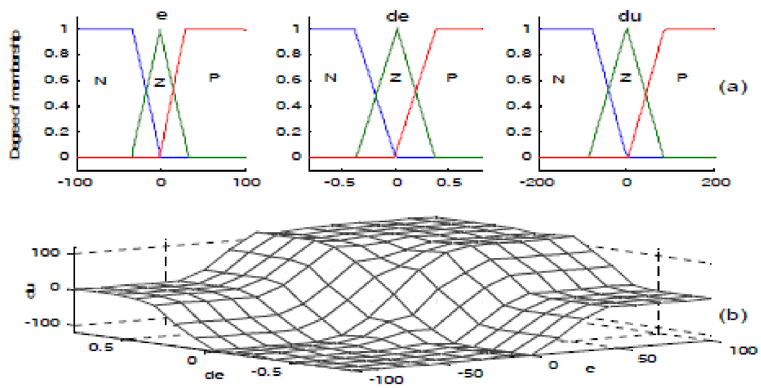

Fig9. (a) Membership functions (b) Control surface

Each universe of discourse is divided into three fuzzy sets: Negative (N), Zero (Z) and Positive (P). The fuzzy variables 'e' and 'de' produced by the fuzzification block are then processed by an inference mechanism that executes a set of control rules contained in a (3x3) table as shown in table 1.

Table 1 Fuzzy control rules for 'du'

du		E		
		N	Z	P
de	N	N	N	Z
	Z	N	Z	P
	P	Z	P	P

The fuzzy rules are expressed under the IF-THEN form. The crisp output of the FLC is obtained by using Max-Mininference algorithm and the center of gravity de fuzzification approach

B. FLC DESIGN

The fuzzy controller behavior depends on the membership functions, their distribution and the rules that influence the fuzzy variable in the system. There is no formal method to determine accurately the parameters of the controller.

Tuning the FLC is an iterative process requiring trial several combinations of membership functions and control rules. The adjustment can be done by observing the response of the system regulator and modifying the fuzzy sets in the universes of discourse of the input variables (e and de)and output variable (du) until satisfactory response is obtained. The control surface 3 (b) is a three dimensional graphic showing the output variable corresponding to all combinations of values of the inputs. This surface can be used to facilitate the FLC tuning. The number of rules can be reduced in order to optimize the inference engine execution speed. In this paper, a trial and error approach issued to determine and adjust the weighting factors Ci(i=1,2,3).

C. MODEL REFERENCE ADAPTIVE FUZZY LOGIC CONTROLLER

The reference model is used to specify the desired performance that satisfies design specifications. A fuzzy logic adaptation loop is added in parallel to the fuzzy control feedback loop. In the nominal case, the model following is perfect and the fuzzy controller adaptation loop is idle. When parameters change, an adaptation signal produced by adaptation mechanism will be added to the output signal of the direct speed fuzzy logic controller to preserve the desired model following control performance.

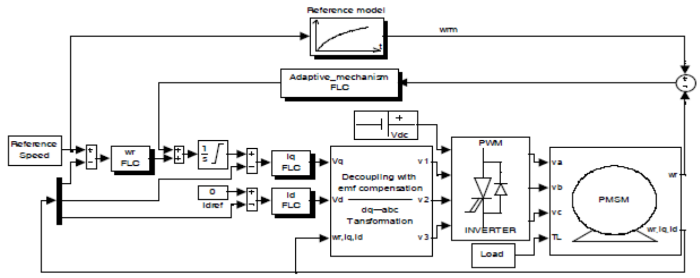

Fig10. Simulink block of MRAFLC for PMSM

Figure. shows a Simulink block diagram of the proposed hybrid controller for vector control PMSM. The chosen reference model is a first order transfer function with time constant set at 50ms.

IV. MATLAB DESIGN OF CASE STUDY AND RESULTS:

MODEL I: study with PI controller:

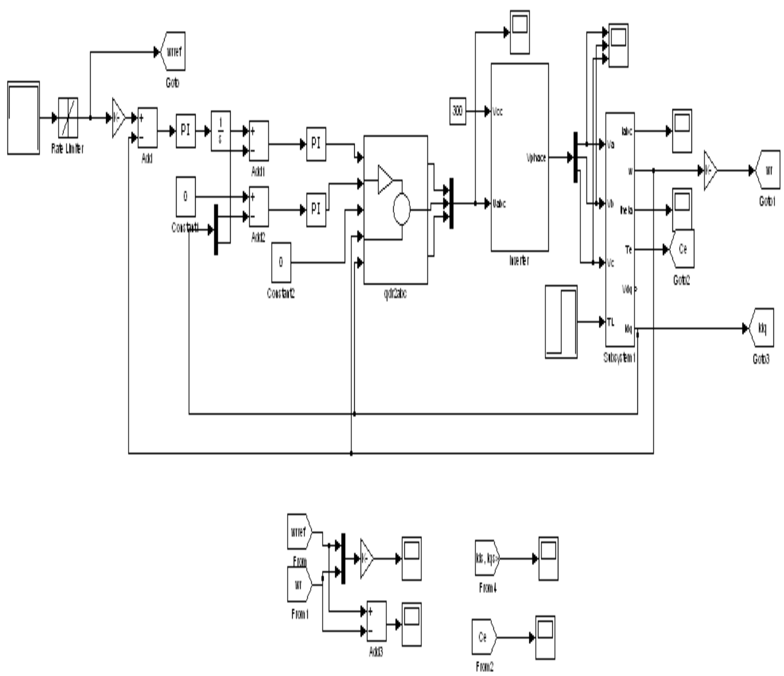

Fig11. Simulink model of PMSM with PI controller

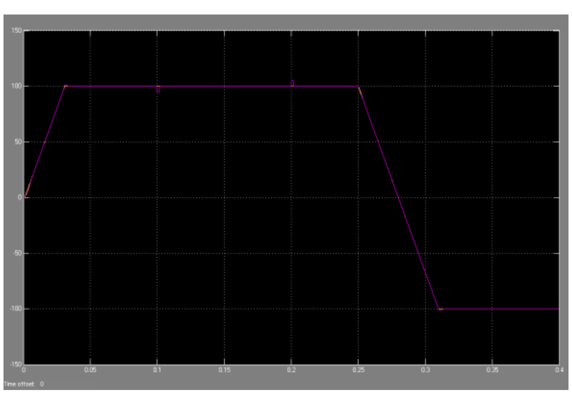

Fig12. speed

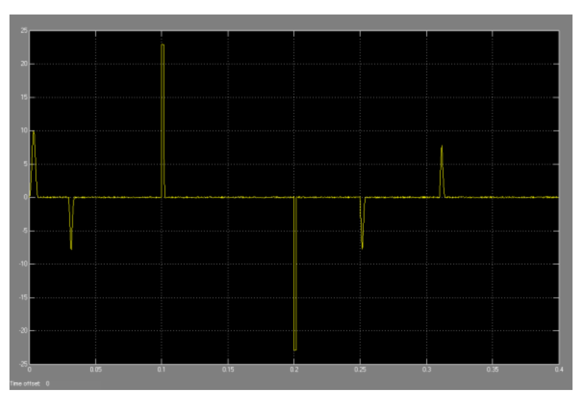

Fig13. speed error

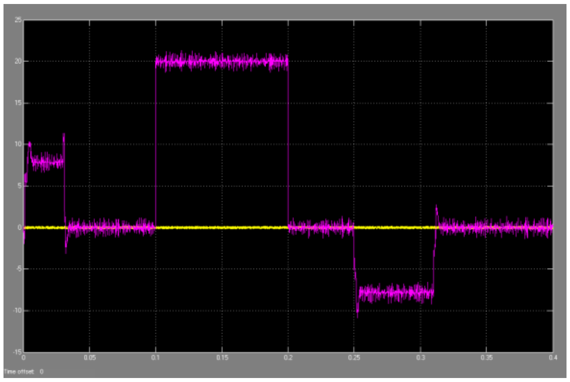
Fig14. stator current components (d, q)

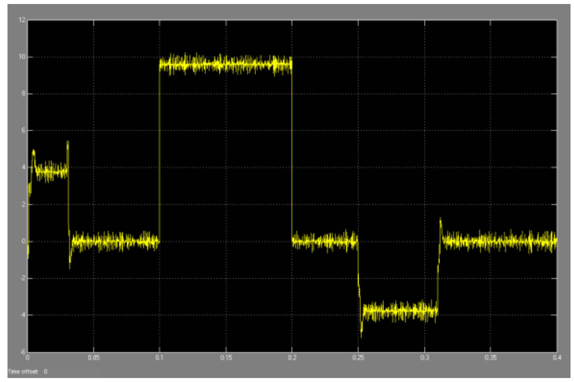
Fig15. Electromagnetic torque

MODEL II: STUDY WITH FUZZY LOGIC CONTROLLER (FLC):

CASE I: PMSM FLC

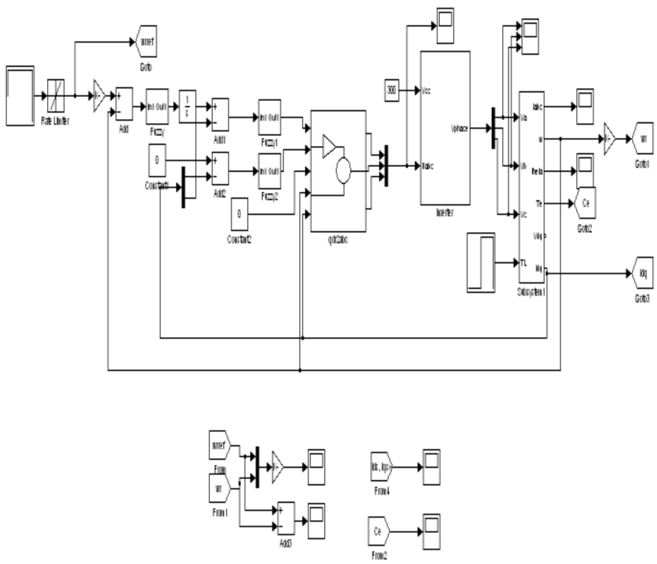
Fig16. Simulink model of MRAFLC for PMSM

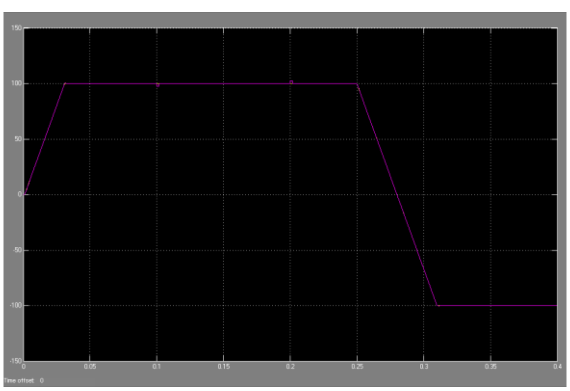
Fig17. speed

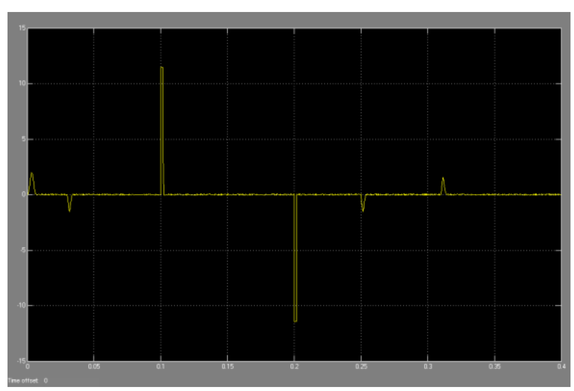
Fig18. speed error

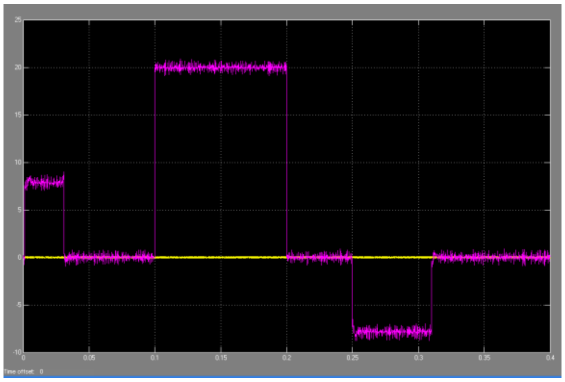

Fig19. stator current components (d, q)

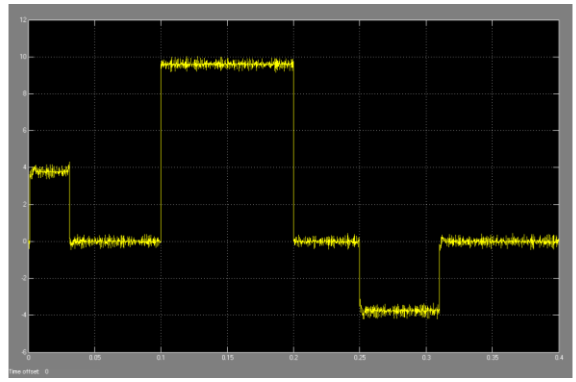

Fig20. Electromagnetic torque

CASE II: PMSM MRAFLC

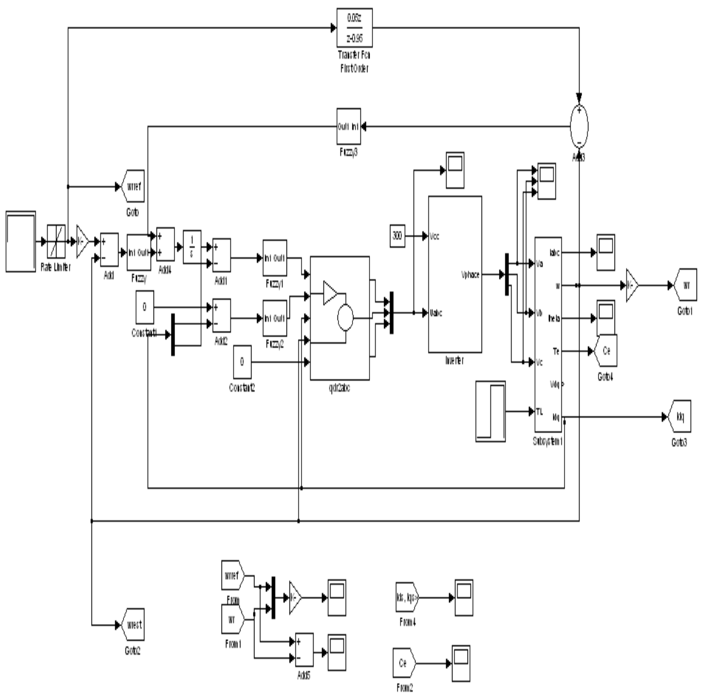

Fig21. Simulink model of MRAFLC for PMSM

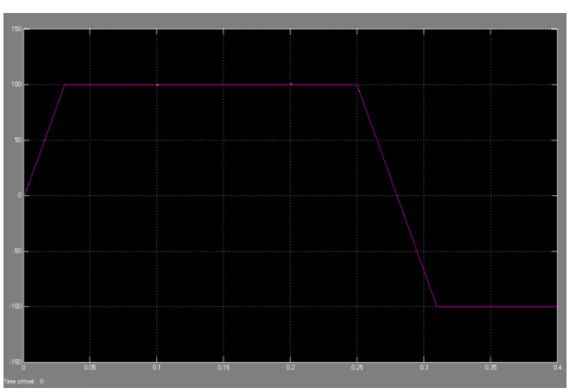

Fig21. speed

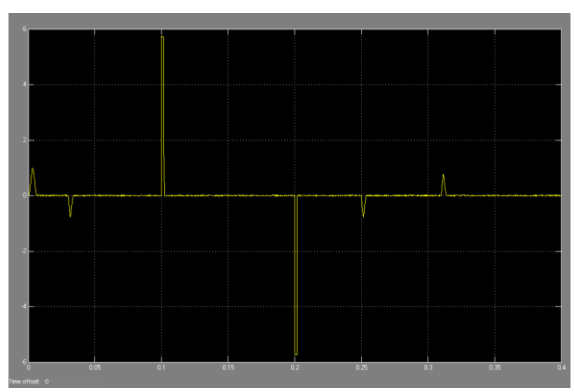

Fig22. speed error

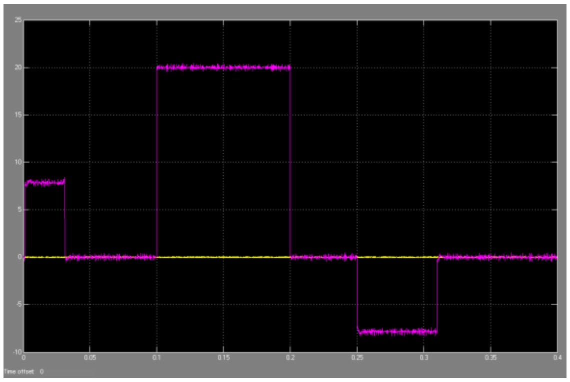

Fig23. stator current components (d, q)

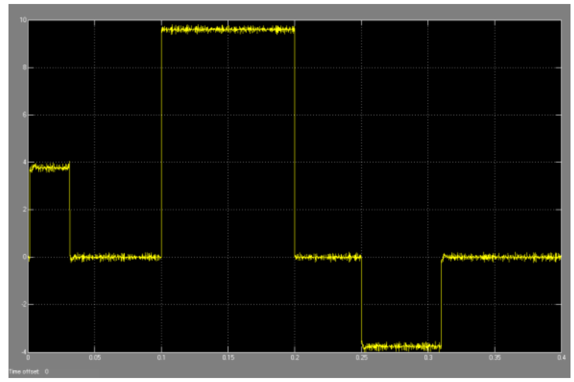

Fig24. Electromagnetic torque

V. CONCLUSION

In this paper, an IG-based ac/dc hybrid generation system for MEA is presented. The application of IG addresses the problem of excessive fault current due to the PM excitation in PM generator-based generation system. The proposed ac/dc hybrid generation architecture supplies CVVF power directly from generator terminals without external exciter. As a result, the hardware requirement is reduced compared to both ac and dc primary generation systems. Both ac and dc output voltages of the system can be well regulated with generator speed, ac and dc side load, and dc power output command variation. The feasibility of operation of the proposed system is demonstrated by HIL real-time emulation.

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A COMPARATIVE STUDY ON DIFFERENT CONTROL TECHNIQUES OF SAPF FOR POWER QUALITY IMPROVEMENT

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Abstract:

The intense of the paper is to present different control strategies applied for Active Power Filter. Conventional techniques have been identified and they have compared with Soft Computing techniques. Basically three soft computing techniques have been identified Fuzzy logic (FL), Artificial Neural Network (ANN), and PI controller (PI). The review has been done for recognizing the components, which can control APF, and three components have been identified Harmonic Detection, Current Control and DC bus voltage. The objective of most papers to use soft computing techniques in Active Power Filter is to increase the efficiency, stability, accuracy, and robustness, tracking ability of the systems. Moreover, minimizing unneeded signal and to reduce total harmonic distortion is the ultimate goal in applying these techniques to the APF. Hysteresis control is used to control the current in PWM inverter. The simulation results reveals that comparative study of all this results shows the advantage and disadvantages of 3 control strategies.

FORM - 2

THE PATENTS ACT, 1970

(39 OF 1970)

THE PATENTS RULES, 2003

COMPLETE SPECIFICATION

(Section 10; rule 13)

Hybrid Electric Vehicle

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Preamble:

The following specification particularly describes the invention and the manner in which it is to be performed:

Field of Invention:

The Invention related in the field of Automobiles and more Particularly relates to Hybrid Electric Vehicle.

Background of the invention

In today's world, we face the problem of dwindling fuel resources for vehicles. The usage of Conventional petrol and diesel vehicle increased pollution and other environmental hazards i.e., it emits more CO2 and decrease in fossil fuels with respect to time. This problem causes a serious affect; at a particular time in future there will be unavailability of fuel resources (fossil fuels). The emission of increased levels of carbon-dioxide from an automobile exhaust is a concern for the increasing rate of global warming. The pollution can be reduce to a certain amount by using Electric vehicle. But the problem arises with the electrical vehicle is increase in charging time period i.e., battery takes more time to charge say 8-10 hours for full charge and charging stations are less in India. Switching from conventional vehicle (IC engine) to electrical vehicle is not possible in the present scenario due to the unavailability of charging stations. One of the optimistic solutions for such problems is the hybridization of the vehicle. HYBRID ELECTRIC VEHICLE is a combination of a conventional internal combustion engine and an electric propulsion system. Possible combinations include diesel/electric, gasoline/fly wheel, and fuel cell (FC)/battery. It implies that HEV can be driven on I.C. engine as well as on electric power. The combination of two power sources may support two separate propulsion systems. Thus, to be a True hybrid, the vehicle must have at least two modes of propulsion. These two power sources may be paired in series, meaning that the gas engine charges the batteries of an electric motor that powers the car, or in parallel, with both mechanisms driving the car directly.

Consistent with the definition of hybrid above, the hybrid electric vehicle combines generally a gasoline engine with an electric motor. An alternate arrangement is a diesel engine and an electric motor. The Electric Vehicle (EV) has an M/G which allows regenerative braking for an EV; the M/G installed in the HEV enables regenerative braking. For the HEV, the M/G is tucked directly behind the engine. The transmission appears next in line. This 3 arrangement has two torque producers; the M/G in motor mode, M-mode, and the gasoline engine. The battery and M/G are connected electrically. HEVs are a combination of electrical and mechanical components. Three main sources of electricity for hybrids are batteries, FCs, and capacitors. Each device has a low cell voltage, and, hence, requires many cells in series to obtain the voltage demanded by an HEV.

In the proposed model shown in Fig.1 the Internal combustion engine is placed on front wheels and the electric motor is placed on rear wheels. Front wheel has worse acceleration than rear wheel drive and rear-wheel drive improves handling due to “load transfer” in acceleration and more even weight distribution. Coupling of axle is shown in Fig.2.By the regenerative braking some part of energy is feedback to the battery. By using the toggling switch, various modes of driving the vehicle can be done i.e., ICE, Electric or Both.HEV produces less emission compared to a similar-sized gasoline car as the gasoline engine of the HEV can be geared to run at maximum efficiency. .

Summary of the invention

The major purpose of our hybrid vehicle is to save the fuel, to reduce pollution and decrease the charging time of batteries in case of EV. The future scope is going to be hybrid or electric rather than engine operated vehicle. Even the coming pollution norms is forcing the automobile industries to shift to hybrid electric vehicles and increased funding is being provided to electrically operated vehicles as they cause less pollution and have an equal output as an engine operated vehicle. Due to the increased pollution and extinction of fuel coming nearby it can be concluded that hybrid electric vehicle will replace the conventional type of vehicles

Hybrid electric vehicles are energy efficient cars or trucks that run on an internal combustion engine of a gas vehicle with the battery and electric motor of an electric vehicle. This results in twice the fuel economy of gas vehicles. These hybrid electric vehicles consume fewer natural resources than gas vehicles and produce almost no emission. The HEV introduced a system with two energy sources. In system the electric machine which is coupled to rear axle acts as motor when it gets the supply through battery and it acts as dynamo when it gets mechanical energy through front wheels when vehicle runs on IC engine.

OBJECT OF INVENTION:

The main object of the Invention is proposed system utilized a new power transmission technology to accomplish regenerative breaking.

The Other object of Invention is reducing charging time of battery by Coupling of electric machine to rear axle acting as dynamo.

The Other object of Invention is to make the vehicle light weight and more reliable.

The Other object of Invention is to reduce pollution.

Brief description of the system

The innovation of this project is its new power transmission technology and usage of BLDC motor as both motor and generator .Brushless is an important type of motor used in this type of vehicle. A rechargeable battery is also used to make this vehicle more functional. This vehicle used lighter weight batteries. Batteries used in this vehicle are lead acid battery. The battery charging time period is reduced by charging the batteries through electric machine coupled to rear axle which acts as dynamo, by taking the mechanical energy through the front wheel when the vehicle is running with IC engine. In this way we can reduce the usage of dynamo separately and the vehicle can run on both the axles. The energy is transmitted through front wheels when vehicle runs with IC engine and transmitted through rear axle when vehicle runs with electric motor. In this novel technique the electric machine which is coupled to rear axle acts as motor when it gets the supply through battery and it acts as dynamo when it gets mechanical energy through front wheels when vehicle runs on IC engine. The parameters of the batteries vary according to the voltage and capacity required for the vehicles. Motor controller is an important device that improves the performance of an electric motor in a pre-arranged manner. In this vehicle we used only one controller. The controller takes power from the batteries and delivers it to the motor. The accelerator pedal hooks to a pair of potentiometers (variable resistors), and these potentiometers provide the signal that tells the controller how much power it is supposed to deliver. The controller can deliver zero power (when the car is stopped), full power (when the driver floors the accelerator pedal), or any power level in between. In this car, the controller takes in 48/60 volts DC from the battery pack. It converts it into a maximum of 240 volts AC, three-phase, to send to the motor. It does these using very large transistors that rapidly turn the batteries' voltage on and off to create a sine wave. When you push on the gas pedal, a cable from the pedal connects to these two potentiometers: The signal from the potentiometers tells the controller how much power to deliver to the electric car's motor. There are two potentiometers for safety's sake. The controller reads both potentiometers and makes sure that their signals are equal. If they are not, then the controller does not operate. This arrangement guards against a situation where a potentiometer fails in the full-on position.

I/We Claim:

1.The Hybrid Electric Vehicle, Comprising:

a. IC engine;
b. Rechargble Battery; and
c. Controller.

2. The Hybrid Electric Vehicle has both fuel and battery mode with same axial. Since the fuel combustion is reduced in battery mode, the vehicle runs economically.

3. The Hybrid Electric Vehicle has reduced charging time because the batteries through electric machine coupled to rear axle which acts as dynamo. The mechanical energy through the front wheel is utilized for charging when the vehicle is running with IC engine

4. The Hybrid Electric Vehicle has a unique controller which takes power from the batteries and delivers it to the motor. The accelerator pedal hooks to a pair of potentiometers (variable resistors), and these potentiometers provide the signal that tells the controller how much power it is supposed to deliver.

5. The uniqueness of the Hybrid Electric Vehicle is the vehicle runs with a single motor which is used for both running the vehicle and generator for charging batteries in the dual mode operation.

6. The Hybrid Electric Vehicle is a straightforward and reliable Power transmission using front wheels and rear wheel.