Analysis and simulation of Novel Drive Train System of Hybrid Electric Vehicle in MATLAB/Simulink

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Abstract

This paper discusses about the Simulation and analysis of novel drive train system of hybrid electrical vehicle using MATLAB/Simulink. Hybrid vehicles have two types of engines namely Internal combustion engine (ICE) and the electrical engine. Hybrid vehicles are often used to achieve various objectives like improved fuel economy, increased power, or additional auxiliary power for electronic devices and power tools. Many technologies like regenerative braking, motor drive, automatic start or shutoff are getting used in hybrid cars to form them nearly as good as conventional vehicles. In this model 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. By the regenerative braking some part of energy is feedback to the battery.

Keywords: *Electric motors, Battery, Regenerative braking, Internal Combustion Engine (ICE), Hybrid Electric Vehicle (HEV)*

I. Introduction

The automobiles play a crucial role within the transport system. With a rise in population and living standard, the transport vehicles also as car population is increasing day by day. additionally, to the present there's steep increase within the number of two wheelers during the last 20 years. of those are increasing exhaust pollution and particularly in metros as density of these vehicles in metros are very high. the most pollutants contributed by I.C. engines are CO, NOX unburned hydro-carbons (HC) and other particulate emissions. additionally, to the present, all fuel burning systems emit CO2 in large quantities and this is often more concerned with the Green House Effect which goes to make a decision the health of earth. Lot of efforts are made to scale back the pollution from petrol and diesel engines and regulations for emission limits also are imposed in USA and during a few cities of India. Hence, we will be mapped out this problem by replacing IC engine vehicles with Electric vehicles (EV) which have zero emission and really quite operational. the most critical a part of an EV is that the battery. What the interior combustion engine is to a petroleum car, the battery is to EV. Currently, all EVs use lithium-ion batteries (LIBs). the restrictions of LIBs are higher charging time and shorter discharging period of time, recharging your EV may be a far more significant time investment. While most electric engines take about four hours to succeed in a full charge.

On a full charge, most electric models are limited to a variety of 60 to 100 miles, but a little minority of models can go between 200 and 300 miles per charge. hence to recharge the battery the charging stations availability is inconsistent. one among the optimistic solutions for such problems is that the hybridization of the vehicle. HYBRID ELECTRIC VEHICLE may be a combination of a standard combustion engine and an electrical system. It implies that HEV are often driven on I.C. engine also as on electrical power. HEV produces less emission compared to a similar-sized gasoline car because the internal-combustion engine of the HEV are often geared to run at maximum efficiency. the importance of electrical gearing is that it runs with lesser power loss, hence improving the general fuel economy. Hybridization of vehicles can reduce CO2 emission and also the fuel costs.

Hybrid electric vehicle widely available in commercial vehicles, military vehicles and passenger cars. The HEV gearing systems are of either series, parallel and combination hybrid and everyone these categories are of front wheel drive.

Front-Wheel Drive advantages

- Since all the equipment is up front, they create more room and leg room within the back.
- Front-wheel drive has less components than the other drive train setup, making the vehicle lighter and improving its mileage that's why most economy-type cars are front-wheel drive.
- There is bigger tactile feedback through the wheel if the wheels are slipping.
- Front-wheel drive may be a simpler system and tends to be less costly to shop for and maintain.

Disadvantages

- Since all the load is found within the front of the vehicle, front-wheel drive cars tend to under steer.
- During sudden acceleration, front-wheel drive vehicles tend to veer to the proper or left due to something called "torque steer."
- Front-wheel drive tends to possess a lower towing capacity than rear-wheel
- Front-wheel drive has worse acceleration than rear-wheel drive, which is why most sporty and race cars use rear-wheel drive.
- With all the load up front, front-wheel drive can make handling harder.

Hence to overcome these draw backs we changed the planning of gearing system in such how that the IC engine is coupled to front wheel and motor is coupled to Rear-wheel drive where we will run the vehicle in two modes and that we can gain both the drive system benefits as per desired way generally rear wheel drive offers better initial acceleration than front-wheel drive because weight is transferred to the rear of the car upon accelerating, which boosts traction. Rear-wheel drive also permits expert drivers to use various techniques to slip the buttocks around corners, which may be a skill most useful in racing. It also gives the good acceleration and gradeability.

II. Coupling of Novel Drive Train System:

In this novel drive train HEV system, the engine is coupled to front wheel shaft and the electric motor is coupled to the rear axle shown in fig.1, whenever the vehicle runs with IC engine the vehicle runs through front wheel where back wheels acts as dummy by this we can get the benefits of front wheel drive and to get the benefits of rear wheel drive we can switch over the vehicle mode from IC engine to electrical engine which is coupled to rear wheels now front wheels acts as dummy, in this way we are optimizing the benefits of both front and rear wheel drive and at the same time the battery can be charged by the IC engine via the electric motor when the vehicle is at light load condition which reduces the battery charging time period.

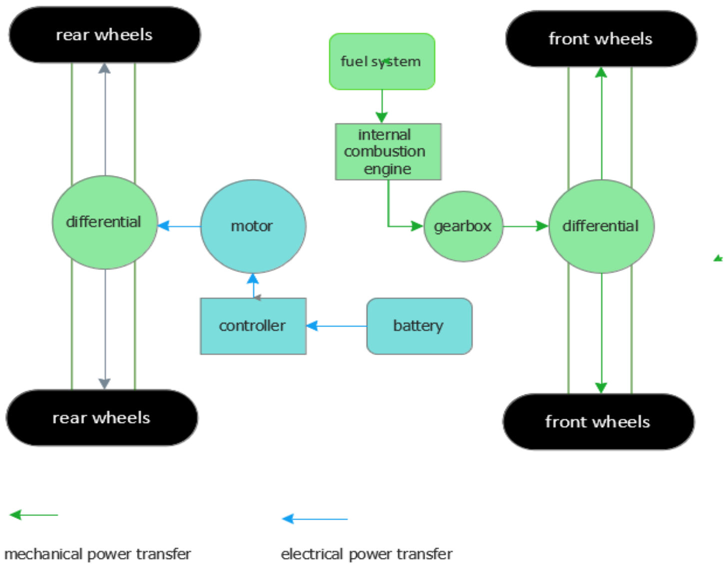

Figure 1. Coupling of Novel Drive Train System

III. Simulink Model of Proposed HEV:

This model shows the basic architecture of a novel drive train system of HEV. Electrical power is applied to the motor through batteries which rotates the rear wheels. The electrical torque is applied at the rear wheel axle. In this test, the vehicle accelerates, maintains the faster speed, and then decelerates back to the original speed. The power management strategy uses just electrical power to affect the maneuver, the combustion engine only delivering the power required to maintain the original speed.

Output power of the combustion engine and battery, battery electrical losses, battery charge, shaft speeds of both the engines, fuel consumption of the Internal Combustion Engine (ICE) are modeled and simulated in MATLAB/Simulink. This model is simulated for 20 seconds, solver used is ode 15s and type of solver is variable step.

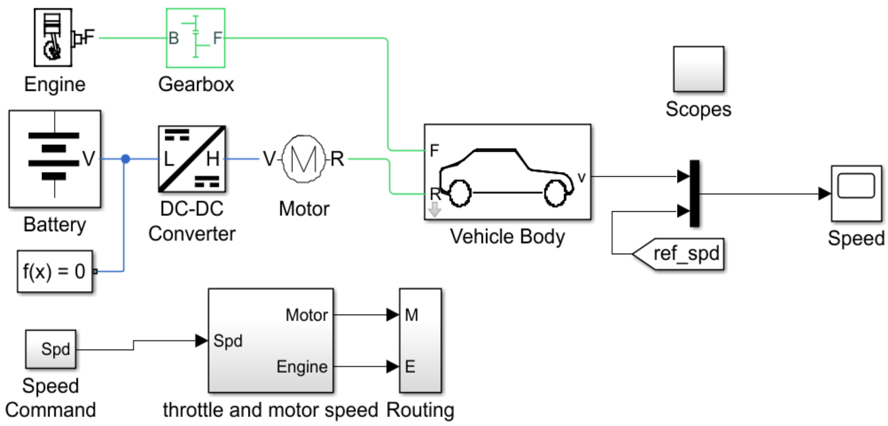

Figure 2. Simulink model of proposed HEV

The vehicle body subsystem is shown below:

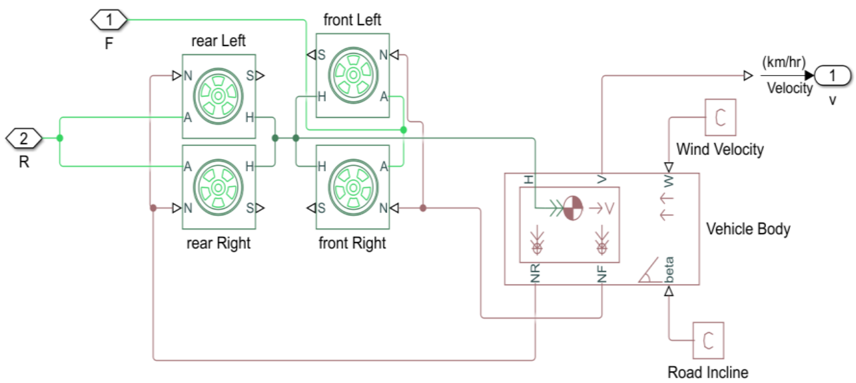

Figure 3. Vehicle body subsystem

From the above figure it is shown that front wheels are connected to the Internal combustion engine (ICE) and rear wheels are connected to the motor.

The speed command of the proposed HEV is shown below. The throttle command for the engine is 0.35 i.e., 35% of the full power and for the motor the speed command is as follows:

- At time t=2s, the vehicle accelerated from initial value 0 to final value 1.
- At time t=5s, the acceleration is stopped and continued till time t=10s.
- At time t=10s, the vehicle is decelerated from 0 to -1 and continued till t=15s.
- At time t= 15s, deceleration is stopped.

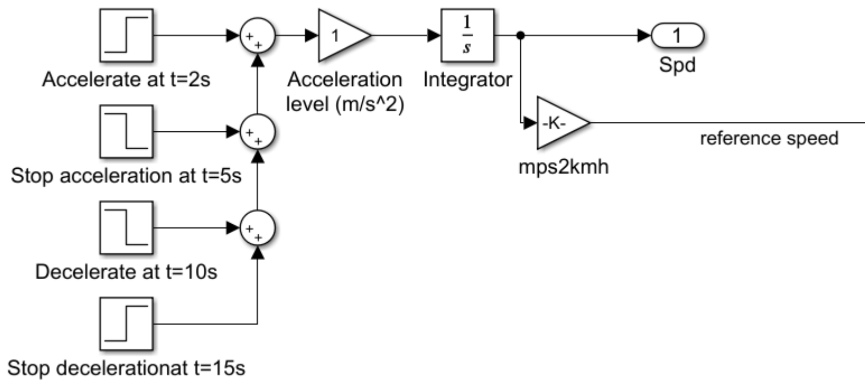

Figure 4. Speed command for the vehicle

The vehicle parameters are shown below.

Table 1: vehicle parameters

s.no	parameters	value	units
1	Vehicle mass	900	kg
2	Number of wheels per axle	2	-
3	Horizontal distance from CG to front axle	0.8	m
4	Horizontal distance from CG to rear axle	1.3	m
5	CG height above ground	0.4	m
6	Frontal area	4	m^2
7	Drag coefficient	0.26	-
8	Air density	1.18	Kg/m^3

The engine parameters are shown below:

Table 2: Engine parameters

s.no	parameters	value	units
1	Maximum power	50e3	W
2	Speed at maximum power	5500	rpm
3	Maximum speed	7000	rpm
4	Stall speed	500	rpm
5	Engine inertia	0.2	Kg*m^2
6	Initial velocity of engine	19.6	Rad/s
7	Engine time constant	0.2	s
8	Speed threshold	20	rpm

The tire parameters are shown below:

Table 3: Tire Parameters

s.no	parameters	value	units
1	Rolling radius	0.204	m
2	Tire inertia	1e^-2	Kg*m^2
3	Initial velocity	98.03	Rad/s
4	Velocity threshold	0.1	m/s

Battery parameters are shown below:

Table 4: Battery parameters

s.no	parameters	value	units
1	voltage	60	volts
2	capacity	150	Ahr
3	Internal resistance	0.05	ohm
4	Fully charge voltage	65	volts
5	Discharge current	60	A

IV. Results

From the above Simulink model, the following results are noted,

- Vehicle speed vs reference speed
- Engine Speed
- Engine and battery power
- Battery electrical losses
- Battery charge (Ah)
- Fuel consumption of the Internal combustion engine (ICE)

The graphs of the above results are shown below:

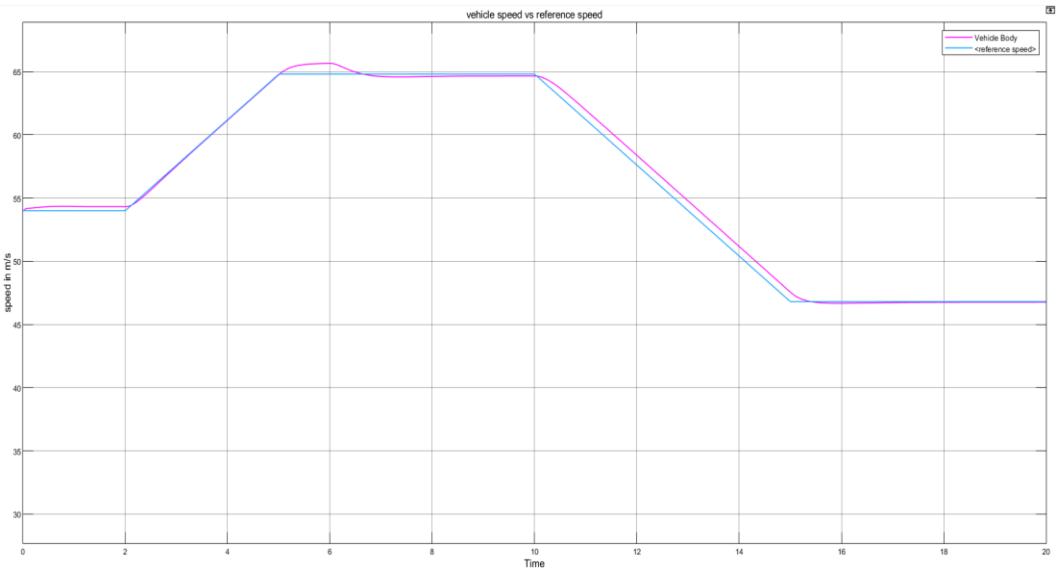

Figure 5. Vehicle speed vs Reference speed

From the fig 5, pink line represents the speed of the vehicle and the blue line represents the reference speed. The vehicle speed almost follows the reference speed. It is noted that the vehicle speed is 65 kmph at t=5s considering the initial velocity to be 49 kmph. The engine speed is shown in the fig 6.

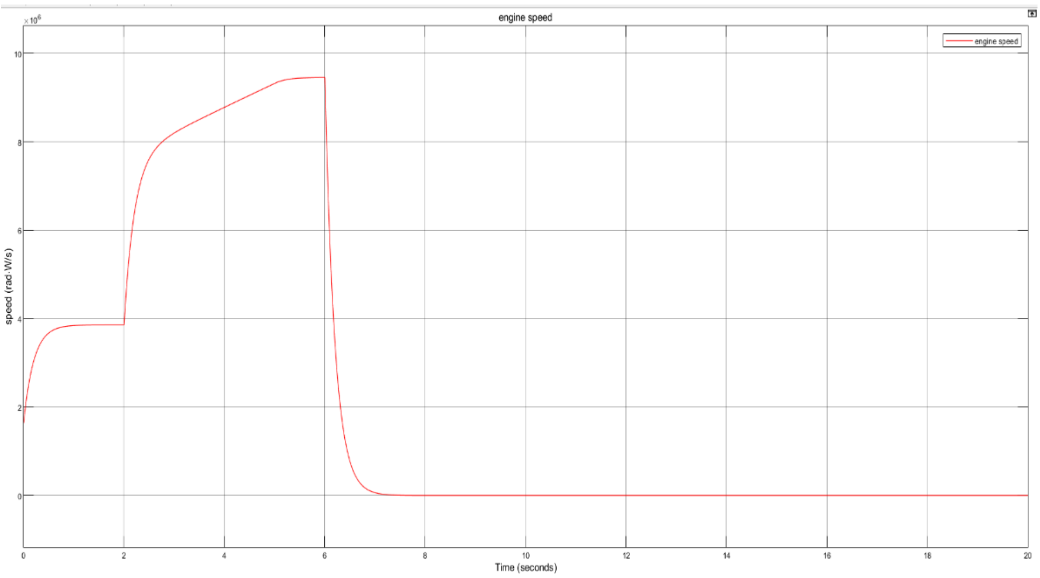

Figure 6. Engine speed

From the fig 6, we note that after 6 seconds the ICE gets turn off so the speed reduces to zero.

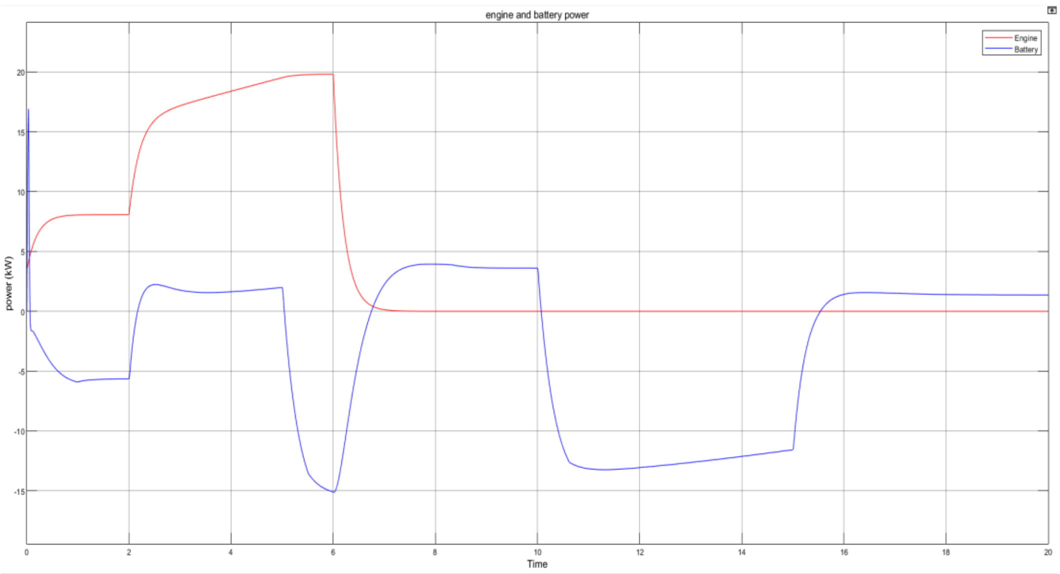

Figure 7. Engine and battery power

From the fig 7, the red line represents the engine power in KW which is high till t=6s due to the throttle command is of 0.35. After 6s the ICE gets decelerated. The blue line represents battery output power. At t=2s the motor is accelerated till t=5s, from t=5s to 6s the curve gets negative because the acceleration is stopped at t=5s but the ICE is still running. At t=6s, ICE is decelerated. Again, motor takes the power from the battery. At t=10s, the motor is decelerated and from the fig 7 we can observe that some amount is feedback to the battery. The battery electrical losses are shown in fig 8.

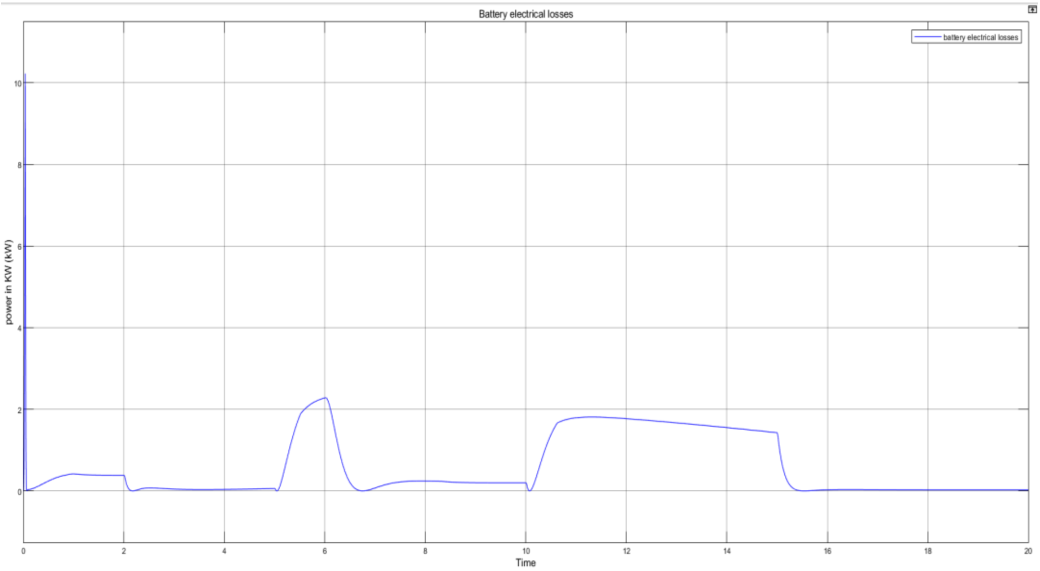

Figure 8. Battery electrical losses

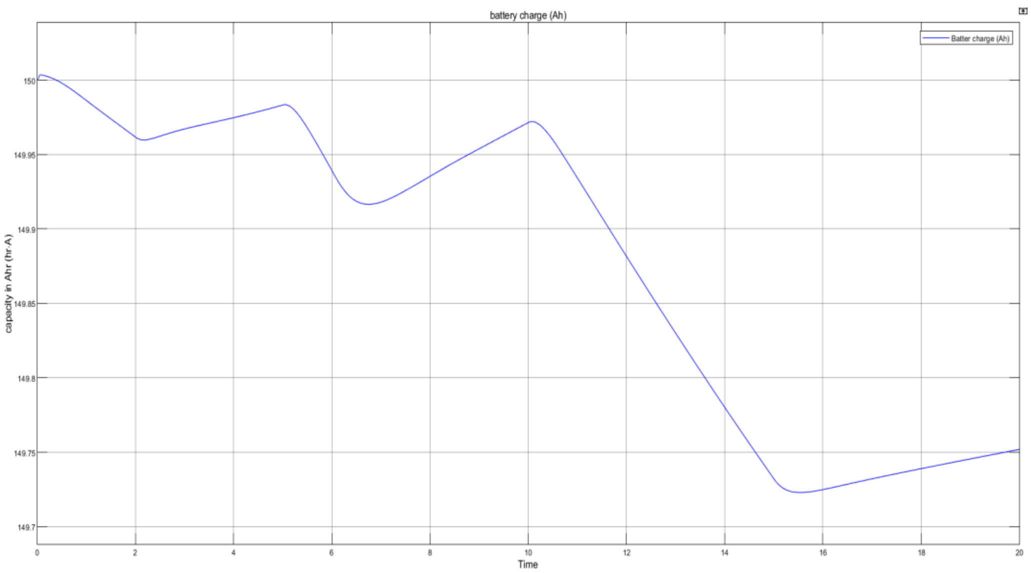

Figure 9. Battery Charge

In this model, lead-acid battery is considered, the battery capacity is 150 Ah and the vehicle gives 76 km distance when run at a speed of 40kmph.

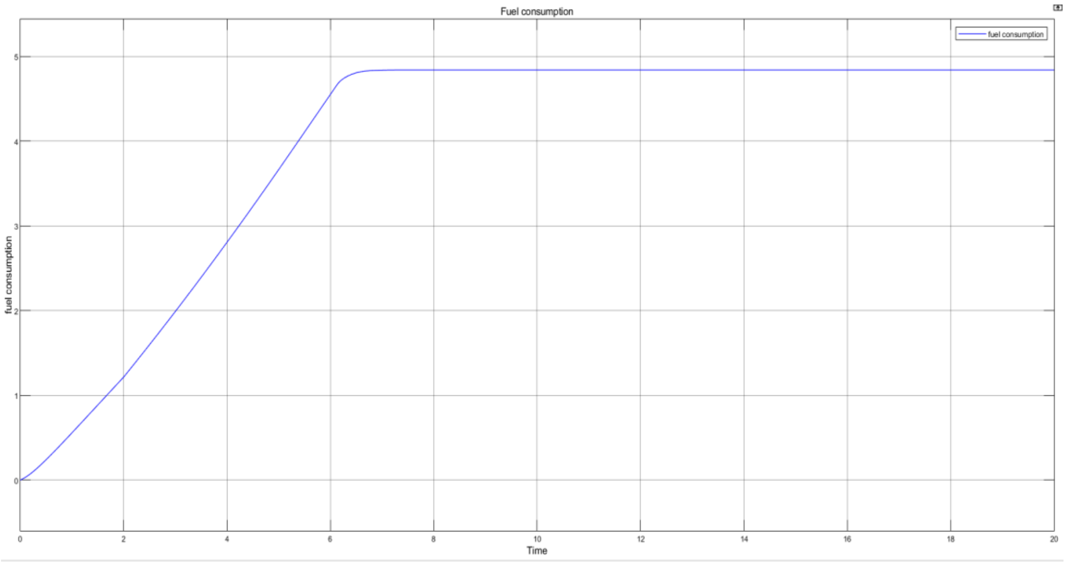

Figure 10. Fuel consumption

The ICE throttle command is 0.35 and at t=6s ICE is switched off, so the fuel consumption is only from 0 to 6 seconds.

V. Conclusion

Hybrid-electric vehicles (HEVs) have the combine advantages of IC engines and electric motors and may be configured to get different objectives, like improved fuel economy, increased power, or additional auxiliary power for electronic devices and power tools

The transmission of power using front wheels drive and rear wheel drive is straightforward and reliable. One disadvantage is that driving on electrical power isn't an honest option for an extended distance travel. Though this proposed gearing system can become much useful in additional stop and go traffic situations. With the utilization of this gearing system, the general fuel consumption and fuel economy is improved and battery charging time is reduced. Such vehicle would run on fuel but would use its motor to spice up the facility when needed. the prices of HEVs are a touch quite the traditional cars but they more efficient and therefore the exhaust emissions are less.

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