iJRASET
International Journal For Research in Applied Science and Engineering Technology

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 9 **Issue:** VI **Month of publication:** June 2021

**DOI:** https://doi.org/10.22214/ijraset.2021.35492

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 9 Issue VI Jun 2021- Available at www.ijraset.com*

# Performance Analysis and Modelling of Electric Vehicle using MATLAB/ADVISOR

Harika Aakula[1], Sai Vamshi Patlolla[2], Sai Prasad Myanamwar[3], K. Raghavendra Reddy[4]
[1, 2, 3]*U.G. Student,* [4]*Associate professor Dept. of EEE, Sreenidhi institute of science and technology.*

***Abstract:*** ***The designing of Electric vehicles has gain higher importance in the entire world. It is important to model and design the vehicle for evaluating the prototype. The paper gives basic simulation of Electric vehicle in Type 2 configuration using MATLAB Simulink software. The analysis of different types of Electric vehicles has been done using ADVISOR. Through analysis few conclusions have been made regarding the performance of Electric vehicles.***
***Keywords: Electric vehicle, MATLAB Simulink, ADVISOR, Performance analysis, Gradeability.***

## I. INTRODUCTION

The consumption of fuel in India is very high and it ranks 3rd all over the world. According to the statistics of 2019 the consumption of gasoline is 42.41 billion liters, diesel consumption is around 100.24 billion liters and the consumption of jet fuel is around 10.19 billion liters[1]. With the usage of such fuels for urban transportation leads to emission of greenhouse gases and release of hazardous gases into environment. In order to avoid release of harmful gases into environment we need to go for alternative sources for transportation. One such an alternative is Electric vehicles. Electric vehicles run through battery they do not produce any harmful gases into environment. Electric vehicles require very little price for charging battery and leads to cost-efficient travel experience. Electric vehicle consists of power train system for propulsion. The power train system is divided into three subsystems i.e.; propulsion system, energy source and auxiliary unit. The propulsion system has an electric motor that drives the wheels and a controller that controls the flow of energy to the motor. The input to the motor is given with the help of energy source, it can be battery, fuel cell, ultra-capacitors or any other energy sources. Within auxiliary system it has temperature control unit, steering, auxiliary power unit[2]. The basic block diagram of Electric vehicle consists of a driver input, controller, motor, converter, battery, vehicle body. The working can be simplified as whenever an input is given by the driver (acceleration or deceleration) based on feedback received from the vehicle body, controller controls the flow of energy to the motor. The necessary energy to motor is provided with the help of battery. In case if motor runs on AC supply, then a converter is required. There are different types of electric vehicles available in market so, it is important to analyze each and every vehicle to determine its performance. In this paper basic simulation model of Electric vehicle using FTP75 drive cycle and analysis of different types of Electric vehicles has been done in order to determine their performance using MATLAB and ADVISOR.

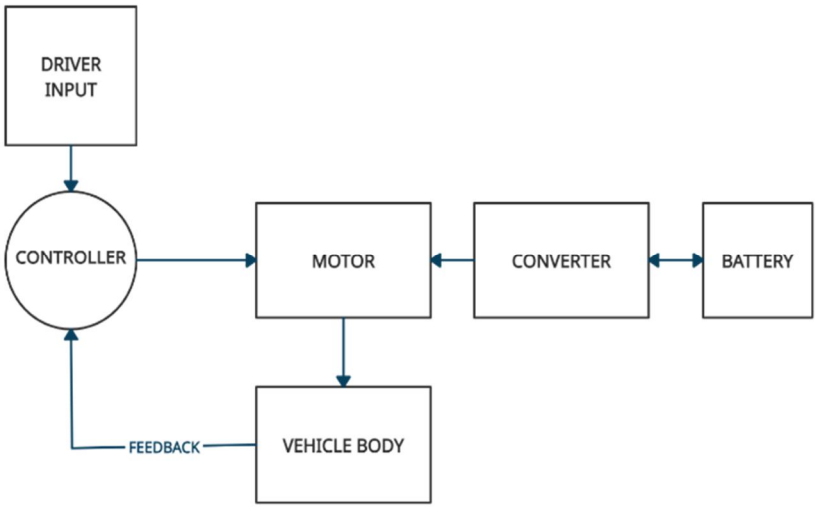



Fig.1 Block diagram of Electric vehicle

©IJRASET: All Rights are Reserved

*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 9 Issue VI Jun 2021- Available at www.ijraset.com*

### *A. Electric vehicles classification*

Electric vehicles are further divided into two categories. Each type of electric vehicles has their advantages and disadvantages. The basic classification of Electric vehicles has been divided into two as Plug-in electric vehicles and Hybrid electric vehicles. Plug-in electric vehicles are further divided into two categories as Full electric vehicles or Battery Electric vehicles and Plug-in Hybrid Electric vehicles[3].

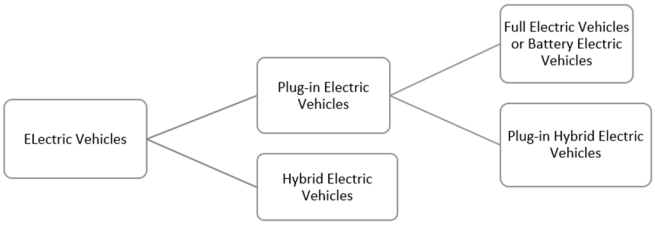



Fig.2 Classification of Electric Vehicles

BEVs or battery electric vehicles are also called as pure electric vehicles they have an onboarded batteries used to power the motor. It doesn't have Internal combustion engine. BEVs run with zero emission and no other harm to the environment. The average range of vehicles available in the market is 200 km, few performance vehicles have a range of 450 km. Battery electric vehicles have onboarded batteries that are to be charged with the help of externals charging stations or external sources with the help of chargers, the charging time will be dependent on the type of charger. Whereas Plug-in Hybrid Electric vehicles or PHEVs has batteries to power an Electric motor and also fuel such a diesel for internal combustion engine. The use of these vehicles reduces operating cost and fuel use relative to conventional vehicles. PHEVs can charge their vehicle through external charging and regenerative braking. PHEVs produce lower emission of gases and it depends on how often the vehicle used motor mode for propulsion. Though Plug-in Hybrid Electric vehicles are more expensive than conventional vehicles of same speed range, some cost can be recovered through fuel savings. The Hybrid Electric vehicles or HEVs as the name itself indicates that it is a combination of conventional vehicle and Battery electric vehicle. It has an internal combustion engine and a battery to power the motor. The major difference between PHEVs and Hybrid Electric vehicle is these vehicles cannot charge their batteries through external sources. HEVs start up using motor and petrol engine takes over as the speed raises up[2-3]. There are two configurations of HEVs are available at present, they are Series configured Hybrid Electric vehicle and Parallel configured Hybrid Electric vehicle. In Series Hybrid system the mechanical output is first converted into electricity using generator and the converted electricity can charge the battery or bypass the battery to drive the vehicle through wheels. In Parallel Hybrid system there won't be any generator and Electric motor itself acts as a generator to charge the battery by regenerative braking.

### *B. Architecture of Electric vehicle*

The modern Electric vehicles are built based on original body and frame work by satisfying the structural requirements of Electric vehicle and using electric propulsion in greater flexible way. Due to variation in electric propulsion characteristics and energy source there are variety configurations of Electric vehicle is possible. Major components present in these configurations are clutch, Fixed gearing, Electric motor, Gear box, Differential. Type 1 configuration is termed as Conventional driveline with multi-gear transmission, it consists of a Clutch, Gearbox, Differential and Electric motor. Clutch disconnects the power of electric motor from driven vehicle, gearbox is used to set the speed profile according to load applied, differential enables both sides of wheels have different speed[2]. Type 2 configuration is termed as Single gear transmission without clutch, it consists of motor, gearbox and differential. This configuration reduces the size and weight of vehicle by removing clutch. Type 3 configuration is called as Integrated fixed gearing and Differential, it has motor, fixed gearing and differential arranged on a single assembly. Type 4 configuration is Two separate motors and fixed gearing with drive shaft, in this differential is being replaced by two sperate motors for each wheel with two fixed gearbox arrangements. Type 5 configuration is Direct drive with two separate motors and fixed gearing, in this the system is further simplified by placing motor inside the wheel. Type 6 configuration is two separate in-wheel motor drive, has two separate motors for each wheel avoiding the presence of mechanical gearing system. The configuration also done based on energy source. One such a configuration includes fuel cell Electric vehicle. In this configuration vehicle is provided with batteries and fuel cell. Battery is energy storage device whereas Fuel cell is energy generating device.

©IJRASET: All Rights are Reserved

*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 9 Issue VI Jun 2021- Available at www.ijraset.com*

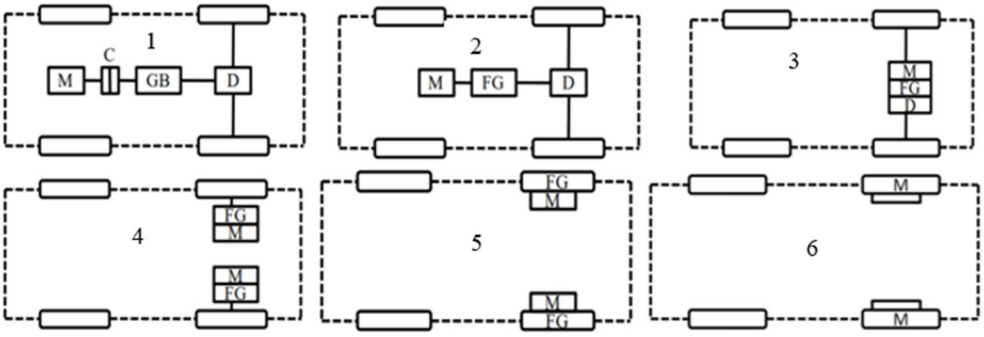


Fig.3 Configuration of Electric Vehicle from Type 1 to Type 6

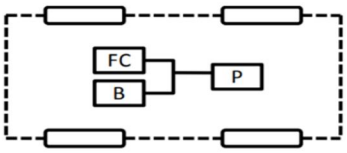


Fig.4 Electric Vehicle configuration with Battery and Fuel cell

## II. DYNAMICS OF ELECTRIC VEHICLE

The vehicle design includes basic principles of physics and Newtons second law of motion. According to Newtons second law the acceleration of an object is proportional to net force exerted on it. Therefore, an object accelerates when net force acting on it not zero. The propulsion unit of vehicles delivers required force in order to move vehicle in forward and backward direction. The force that is produced by propulsion unit helps to overcome air, tire resistance and gravitational force. For analysis of vehicle mechanics, a mathematical framework based on Newtons second law of motion has been provided. When vehicle is in motion it experiences various forces from outside[3]. The total resistance force required to drive the vehicle can be mathematically expressed as the summation of Rolling resistance force, Aerodynamic drag force, Gradient resistance force or Hill climbing force and Acceleration force.

$$F_t = F_r + F_a + F_g + F_l \quad (1)$$

Where $F_t$ represents Total Resistance force, $F_r$ represents Rolling resistance force, $F_a$ represents Aerodynamic drag force, $F_g$ represents Gradient resistance force, $F_l$ represents Acceleration resistance force.

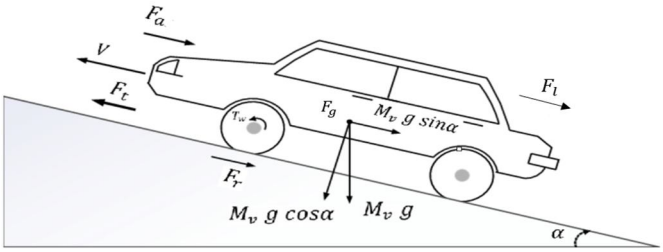


Fig 5. Forces acting on an Electric Vehicle

### *A. Rolling Resistance Force*

The energy required by the vehicle tiers in order to maintain consistent speed over a surface is Rolling resistance. It can also be termed as efforts that are to be made to keep tier rolling. It happens whenever vehicle tier makes contact with the surface of the road. The rolling resistance of tiers on hard surface is mainly caused by hysteresis in the tier material that causes asymmetric distribution of ground reaction forces. Whereas on soft surfaces rolling resistance is mainly caused by deformation of ground surface. From the principles of physics an expression can be developed for rolling resistance force as

$$F_r = \mu_r M_v g \cos\alpha \quad (2)$$

Where $M_v$ represents mass of vehicle in kilograms, $g$ represents gravitational constant, $\mu_r$ rolling resistance coefficient, $\alpha$ is gradient angle of the road. The coefficient of rolling resistance varies based on condition of road and it depends on factors like tier material, tier structure, tier inflation pressure, road roughness and road material.

©IJRASET: All Rights are Reserved

*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 9 Issue VI Jun 2021- Available at www.ijraset.com*

*B. Aerodynamic Drag force*

Aerodynamic force is the oncoming air force that is applied on moving vehicle. It can also be termed as resistance offered by air to the movement of the vehicle body. Aerodynamic drag force effects the car performance and speed. There are also few ways through which aerodynamic drag force can be reduced such as streamlining the exterior body of the vehicle. The mathematical expression for aerodynamic drag force is expressed as

$$F_a = C_D \frac{1}{2} \rho A_f V^2 \quad (3)$$

Where $C_D$ represents drag coefficient

$\rho$ represents density of air $[kg/m^3]$

$A_f$ represents vehicle frontal area $[m^2]$

$V$ represents speed of the vehicle $[m/s]$

The vehicle frontal area can be generally obtained by using below formula

$A_f = 0.82 \times b \times h$, where $b$, $h$ represents width and height of the vehicle.

Drag coefficient is generally calculated from wind tunnel test. Air density is very sensitive to atmospheric pressure and temperature so, it is a function of pressure, temperature and expressed as

$$\rho(P,T) = \frac{348.7 \times P(bar)}{273.15 + t(℃)} [kg/m^3] \quad (4)$$

*C. Gradient Resistance Force Or Hill Climbing Force*

When a vehicle moves up or down a hill, its weight produces a component of force that is always directed downwards. This force component opposes the forward motion and can be termed as gradient climbing. The mathematical expression for gradient resistance is

$$F_g = \pm M_v g \times \sin\alpha \quad (5)$$

Where, $\alpha$ is gradient angle of road

The gradient resistance is negative when the vehicles go down the hill. In this case the resistive power required is reduced and instead the inertial energy can be restored with an energy recovery system.

*D. Acceleration Resistance Force*

Whenever vehicle accelerates or decelerates it experiences positive or negative inertial force. The inertial force consists of two parts i.e.; angular resistance of power train system and linear resistance of running vehicle. The mathematical expression for inertial resistance is

$$F_l = (M_v + m_f)\frac{dv}{dt} \quad (6)$$

Where $M_v(kg)$ represents mass of vehicle, $m_f\ (kg)$ is fictive mass of all rolling inertia, $\frac{dv}{dt}$ represents acceleration.

While knowing about vehicle dynamics there is an important term included with it i.e.; Gradeability. It is usually defined as the grade or grade angle that the vehicle can overcome at a certain constant speed.

*E. Variation Of Total Resistance Force By Speed And Gradient*

There by understanding the dynamics of vehicle we considered the input parameters of vehicle and obtained the variation between Total resistance force at various speeds and gradients.

Table I. Input parameters of vehicle for analysis

| Input Parameters | Values |
|---|---|
| Mass of the Vehicle | 600 $kg$ |
| Drag coefficient | 0.335 |
| Frontal area | 2 $m^2$ |
| Air density | 1.2 $kg/m^3$ |
| Coefficient of rolling resistance | 0.02 |

After considering the parameters mentioned in Table I and calculating the total force at various speeds and gradient. The following bar graphs obtained. They represent the Total Resistance force(Newton) at various speed(Miles per hour or mph) which have been calculated and represented.

©IJRASET: All Rights are Reserved

*1) At 0% gradient*

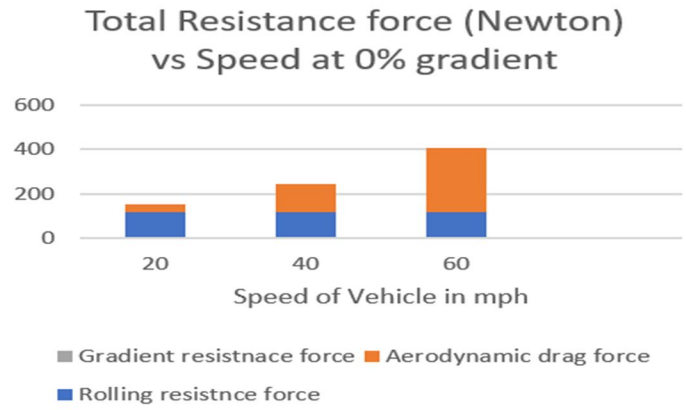



Fig 6. Variation of Resistance force at 0%gradient

*2) At 2% gradient*

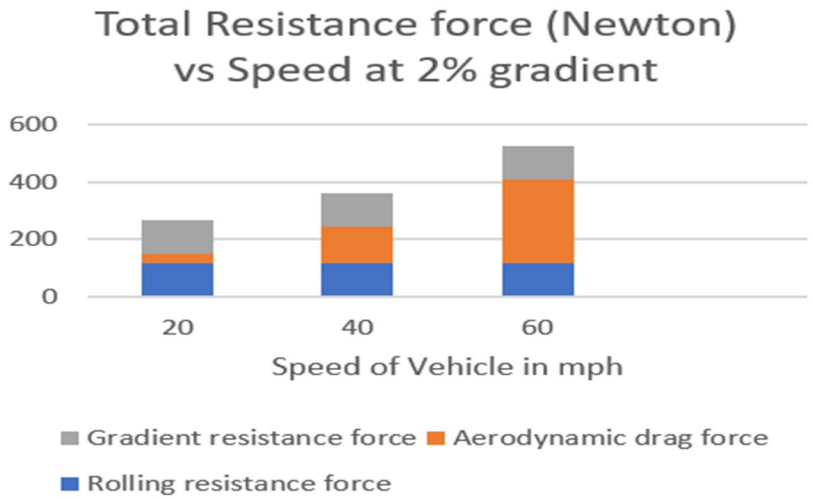



Fig 7. Variation of Resistance force at 2% gradient

*3) At 4% gradient*

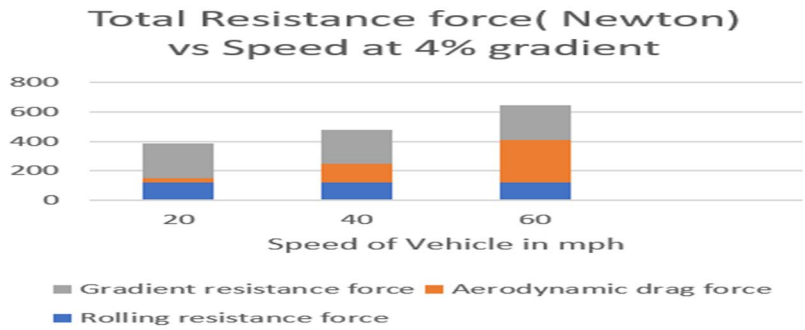



Fig 8. Variation of Resistance force at 4% gradient

The above bar graphs are obtained by considering that the vehicle is at steady state and as per the specifications of vehicle mentioned in Table I. As, the vehicle is under steady state there won't be any effect of acceleration resistance, because under steady state the derivative of velocity becomes zero. It is evident from the graph that, the gradient resistance force is increased as gradient increases and gradient of road has a prominent effect on Rolling resistance force and Gradient resistance force but it doesn't have any effect on Aerodynamic drag force.

©IJRASET: All Rights are Reserved

## III. SIMULATION MODEL OF ELECTRIC VEHICLE

The software which has been used in order to model the vehicle is MATLAB Simulink. When we compare conventional vehicle with Electric vehicle there are more electrical components present in Electric vehicle. So, it is very important to a designer to choose the parameters of vehicle initially before modeling. Each of the design parameters must be chosen carefully for best energy saving, safety, drivability in typical times without losing consumers taste view that includes design and price. The design of modern cars passes by the environmental aspects and EVs gain plenty of room in this discussion for the advantage they bring in this regard[4]. Thus, it is very important to model and simulate the vehicle for evaluating the prototype. The simulated model consists of vehicle body, motor and controller, battery pack and power converter, drive cycle source. Battery is the power house of electric vehicle model which supplies power to motor and other equipment necessary for efficient operation of the vehicle. Power converter converts energy from battery to an optimal level as required by motor. Controller is bidirectional in nature which helps in taking regenerative energy back to the battery there by providing charging while vehicle is decelerating. Vehicle body represents the body of the vehicle with wheels which are connected to the motor through a transmission system. As per load requirement motor takes necessary power from battery and it has been controlled with the help of controller which reviews load requirement and produces required signal with the help of feed-back from the vehicle so as to obtain a smooth and efficient operation of vehicle.

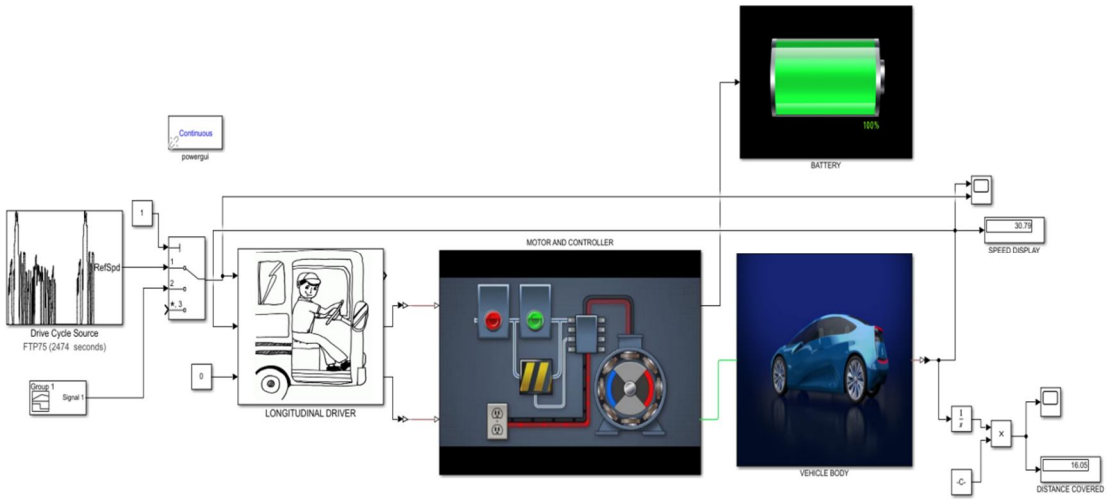



Fig 9. Simulation Model of Electric Vehicle

### A. *Vehicle body Subsystem*

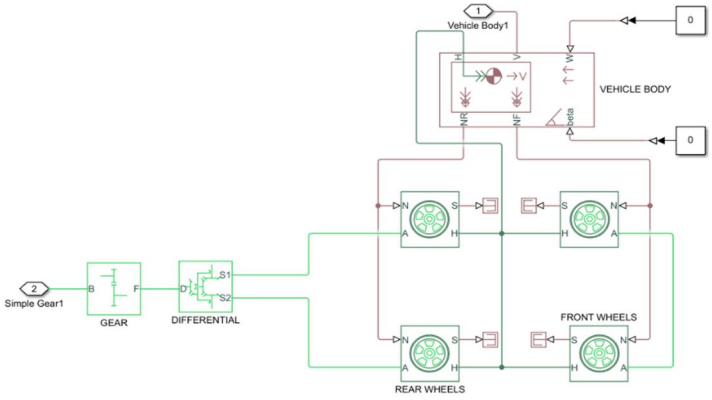



Fig 10. Vehicle body subsystem of Electric Vehicle

The vehicle body subsystem consists of front and rear wheels, here in this simulation we have chosen rear wheel drive i.e.; motor has been connected to the rear wheels of vehicle. The EV configuration which we have chosen is type 2 configuration. The specifications of vehicle chosen for simulation are mentioned in Table I.

©IJRASET: All Rights are Reserved

*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 9 Issue VI Jun 2021- Available at www.ijraset.com*

*B. Motor and Controller Subsystem*

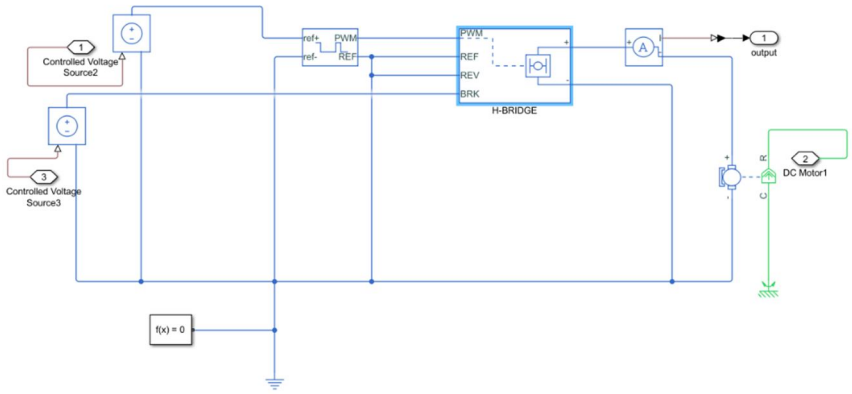



Fig 11. Motor and Controller subsystem

The motor that has been chosen for simulation is a DC motor and the controller which has been chosen is a H-bridge drive which controls the power input to the motor based on the load requirement. The input to the H-bridge drive is controlled pulse width voltage, which produces PWM signals to control voltage fed to H-bridge as per the requirement. The motor parameters for vehicle have been represented in Table II.

Table II
Motor parameters for EV simulation

| Motor parameters | Values |
|---|---|
| No-load speed | 13000 $rpm$ |
| Rated speed (at rated load) | 12000 $rpm$ |
| Rated load (mechanical power) | 5 $kw$ |
| Rated DC supply | 48 $V$ |

*C. Battery system*

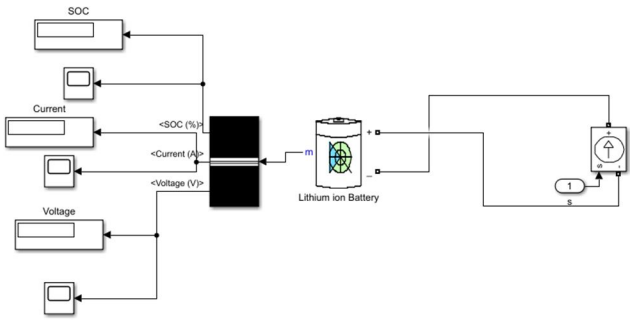



Fig 12. Battery system in simulated EV model

In battery system of EV simulation, we have chosen lithium-ion battery because of its merits. The nominal voltage of battery is 48 $V$ and rated capacity is 50 $AH$.

Other than these blocks we have used a longitudinal driver which represents a longitudinal speed controller which produces acceleration and deceleration based on feedback provided and command signal is generated using PI controller. In order to provide reference to the longitudinal driver, here we are using drive cycle source. It generates drive cycles for particular time. It is basically time vs speed data which resembles similar to that of a real-time driving conditions with acceleration and deceleration in an irregular pattern.

©IJRASET: All Rights are Reserved

*D. Simulation Results*

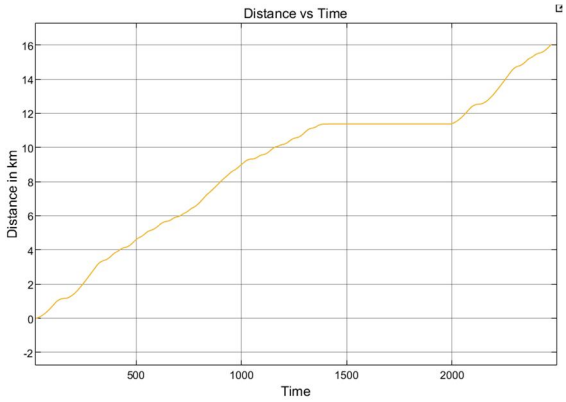



Fig 13. Distance covered by modelled vehicle in km vs Time in seconds

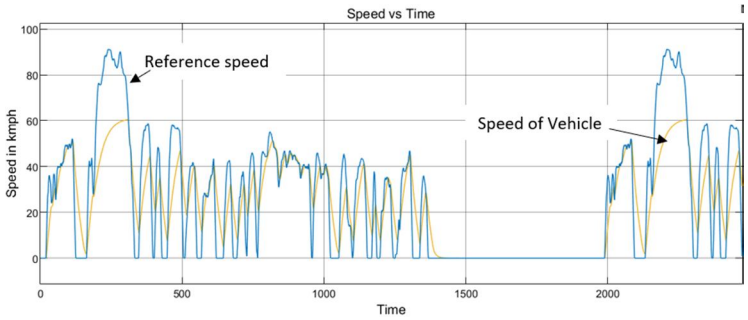



Fig 14. Speed covered by vehicle in kmph vs Time in seconds

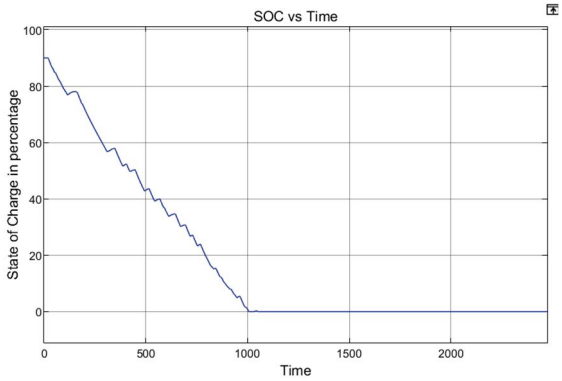



Fig 15. Variation of State of charge in percentage vs Time in seconds

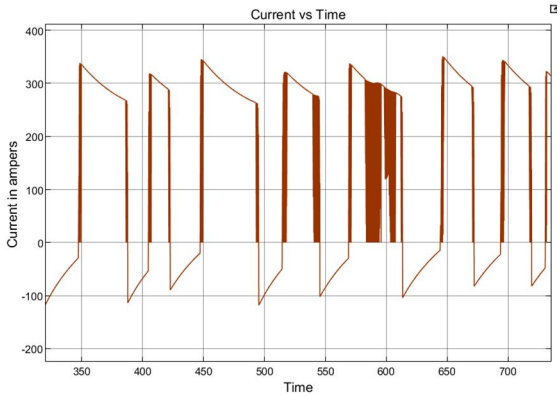



Fig 16. Variation of battery current in amperes vs Time in seconds

©IJRASET: All Rights are Reserved

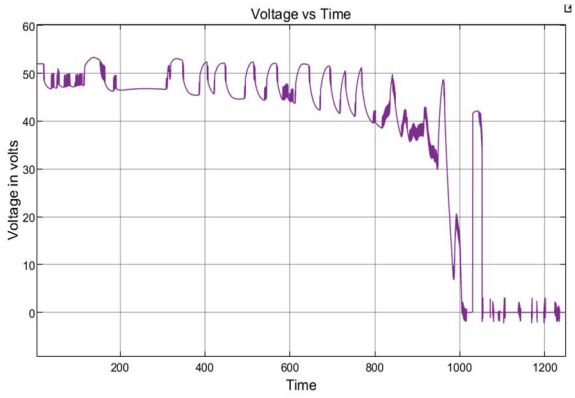



Fig 17. Variation of battery voltage in volts vs Time in seconds

After simulation graphs such as distance covered by vehicle, speed of vehicle, SOC of battery used, Voltage and current discharge during vehicle propulsion has been obtained. With the given parameters' the modelled electric vehicle can covered a distance of 16.06 *km* and maximum speed of the vehicle is 30.79 *kmph*. We can also run the simulation for various drive cycles and can obtain the variation in distance covered and speed of the vehicle. The State of Charge denotes the capacity that is currently available as a function of rated capacity. In this case as we can see initial SOC percentage of the battery is full and when the vehicle is in motion battery capacity is getting decreased as it is giving input to the motor which drives the vehicle. The SOC has fallen to 0% at 1000 seconds.

## IV. ADVISOR FOR ANALYSIS OF ELECTRIC VEHICLE

ADVISOR, NRELD's ADvanced VehIcle SimulatOR is a set of model, data, and script text files for use with MATLAB and Simulink. It is a platform provided for rapid analysis of performance and fuel economy of Conventional, Electric and Hybrid Electric vehicle. It also enables the user for detailed simulation analysis of drive train components specified by the user. It benefits the user in many ways such as estimating the fuel economy of the vehicle that has not yet been built, evaluate an energy management strategy for hybrid vehicle fuel converter. ADVISOR real power lies in prediction of performance of vehicle that has not yet been built[5-6]. The process flow in ADVISOR is usually divided into two as, define a vehicle using measured or estimated components, overall vehicle data, prescribe a speed vs time trace which is nothing but drive cycle. ADVISOR has advantages of predicting the performance and analyzing the vehicle, it also has certain limitations such as it is developed as an analytical tool but not as a detailed design tool, physical vibrations, electric field oscillations and other dynamics cannot be captured using ADVISOR. Advisor software is used to analyze the performance of Electric vehicle, Fuel cell vehicle, Hybrid vehicle in series, parallel configuration[8]. For analysis of all these vehicle parameters of motor, battery, vehicle and weight of each component of vehicle are considered to be the same. The analysis has been done by varying the speed and conducting the gradeability test.

### *A. Analysis of Battery Electric Vehicle*

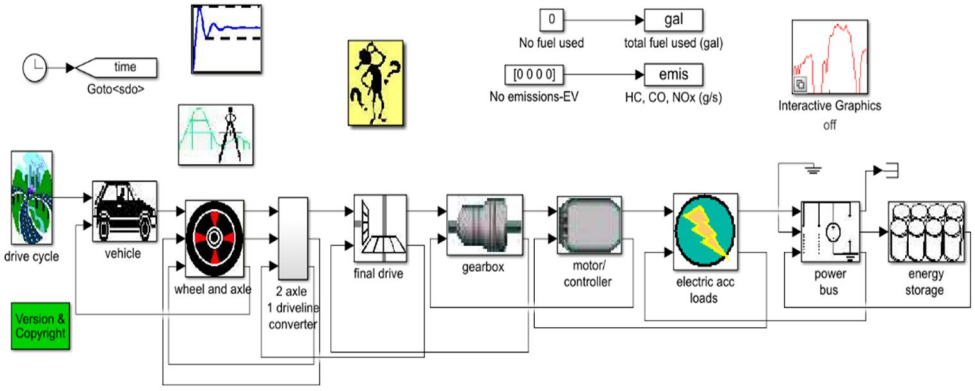



Fig 18. Simulation diagram of Battery Electric Vehicle in ADVISOR

©IJRASET: All Rights are Reserved

ADVISOR as mentioned earlier, provides the user to analyze different vehicles by varying parameters. We can analyze the vehicle performance for various drive cycles, motors, batteries and input parameters of vehicle such as air density, weight of vehicle, drag coefficient, wheel or tier radius etc. The Simulation diagram of Battery Electric vehicle in ADVISOR is shown in Figure 18. As we can see in the figure for each part of the vehicle a subsystem has been created. The parameters and other things like drive cycles for the vehicle can be chosen for analysis of vehicle. Here for analysis, we have chosen rear wheel drive. The propulsion unit the motor used is a $75\,kw$ AC induction motor, with $0.92$ efficiency, Motor torque is $12.6\,Nm$, Battery type used is Lithium-ion with Nominal voltage $427\,V$ with 40 units**,** Drive-cycle for analysis is FTP ( Federal test procedure). The vehicle parameters chosen for analysis are mentioned in Table I. The remaining components and parameters are mentioned in Table III.

Table III
Weight of each component of vehicle chosen for analysis

| Components | Mass $(kg)$ |
|---|---|
| Motor | 91 |
| Vehicle mass | 592 |
| Battery mass | 91 |
| Transmission | 50 |
| Cargo mass | 400 |
| Gross weight =1175 | |

After selecting all the necessary input values the following graphs have been obtained

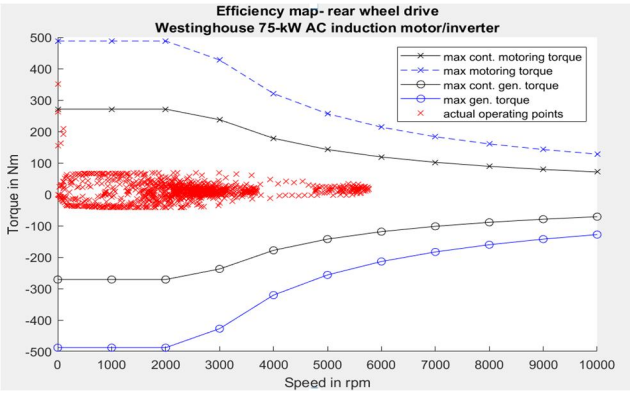



Fig 19. Variation of Torque w.r.t Speed

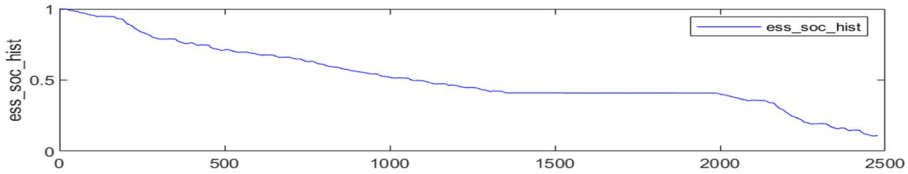



Fig 20. Variation of State of charge w.r.t Time

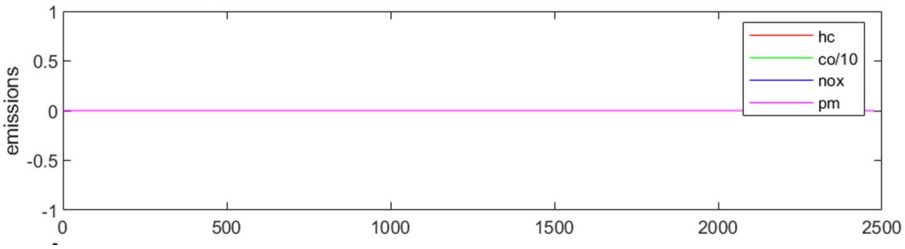



Fig 21. Emission of gases w.r.t Time

©IJRASET: All Rights are Reserved

After simulating Battery Electric vehicle, the Torque vs speed profile has been achieved. From figure 19 it is clear that for rear wheel drive of Battery Electric vehicle the operating region starts at 0 $rpm$ and operates at various torque regions. We can say that, the vehicle can operate up to 6000 $rpm$. From figure 20 it is clear that the state of charge isn't completely get discharged for 1 drive cycle of FTP. As it is an electric vehicle it doesn't emit any kind of gases so the emission level remains zero. As, the drive cycle used is FTP the distance covered by vehicle in one cycle is 11 $mph$. The remaining other observations are mentioned in Table IV.

Table IV
Observed Parameters during analysis of Battery Electric Vehicle

| Observed Parameters | Values |
|---|---|
| Fuel Economy | 0 mpg (miles per gallon) |
| Maximum Speed | 162.7 $kmph$ |
| Maximum Acceleration | 23.77 $m/s^2$ |

The vehicle has also undergone gradeability test in order to analyze the relation between speed and gradient angle of the road. Gradeability test has been done by considering various speed intervals at constant duration of 10s. The results obtained during gradeability test on Battery vehicle are tabulated.

Table V
Variation of gradeability w.r.t speed at constant duration of 10s

| Speed in mph | Speed in kmph | Gradeability |
|---|---|---|
| 20 | 32 | 39.7% |
| 40 | 64 | 25.1% |
| 60 | 97 | 13.7% |

From gradeability test it is evident that at constant duration of 10s the gradeability value decreases with increase in speed. So, we can say that at constant duration gradeability is inversely proportional to speed.

*B. Analysis of Fuel cell Electric Vehicle*

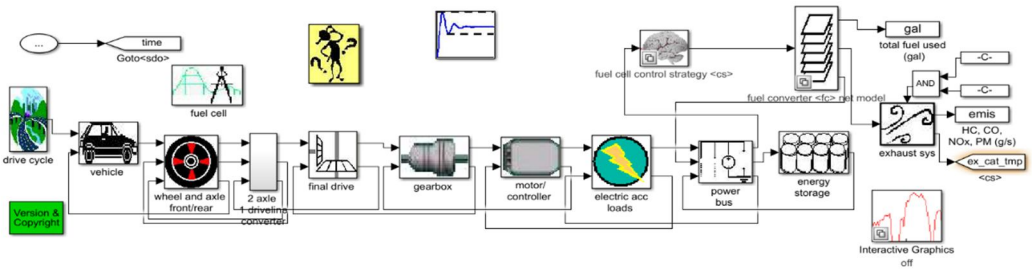



Fig 22. Simulation diagram of Fuel cell Electric Vehicle in ADVISOR

The configuration of Electric vehicle can also be done on basis of power source used; Fuel cell Electric vehicle is example for such a configuration. The block diagram of Fuel cell Electric vehicle is shown in figure 22, from block diagram it is evident that the vehicle consists of energy source i.e.; a battery for energy storage purpose and a fuel cell energy generation purpose. The rear wheel type of vehicle is chosen for analysis. For analyzing Fuel cell electric vehicle, the same parameters used for Battery Electric Vehicle has been considered only the difference is presence of fuel converter. In this case Fuel converter chosen is ANL model- 50 $kw$.Due to the addition of fuel converter and exhaust aftertreat the gross weight is changed to 1414$kg$. By considering all the parameters we have simulated the fuel cell electric vehicle and obtained the results.

©IJRASET: All Rights are Reserved

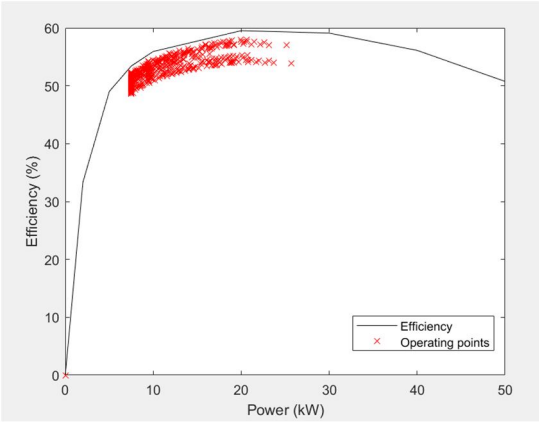



Fig 23. Efficiency vs Power variation profile

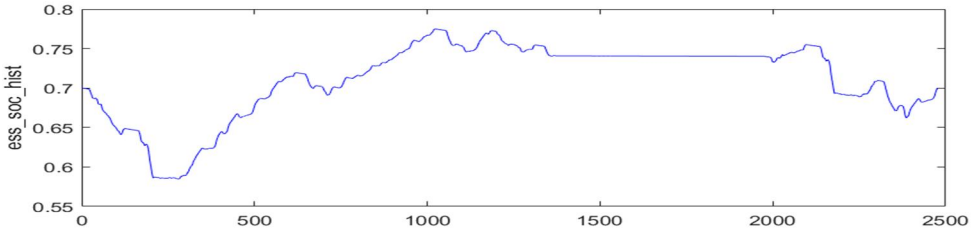



Fig 24. Variation of State of Charge w.r.t Time

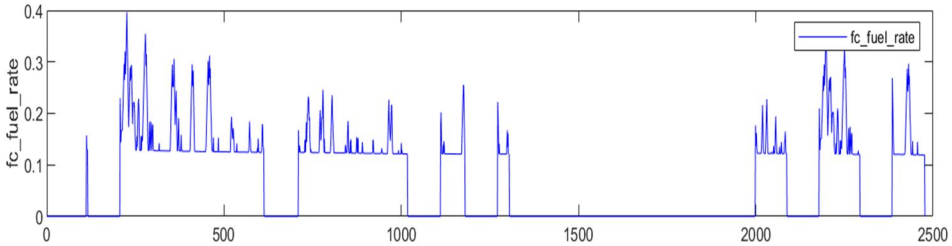



Fig 25. Fuel used by fuel converter in grams/second

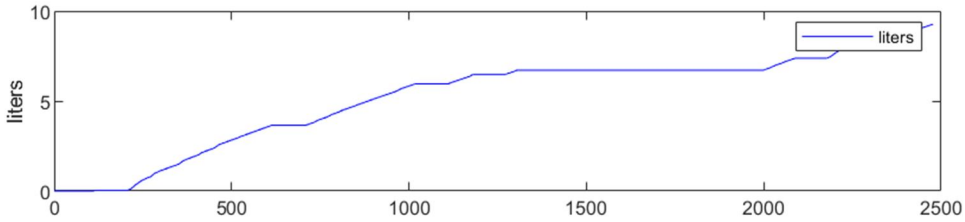



Fig 26. Cumulative Liters of Fuel consumed w.r.t Time

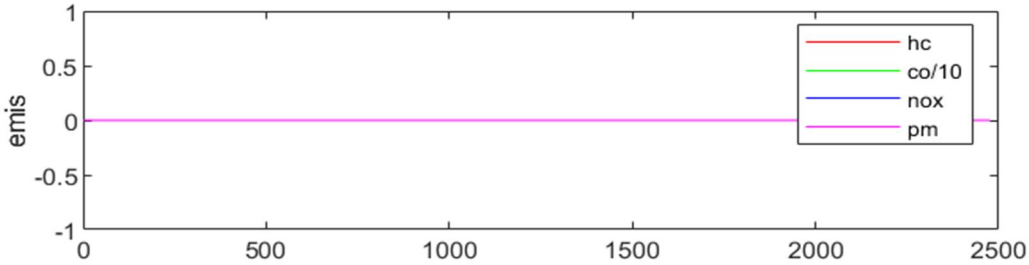



Fig 27. Emission of gases w.r.t Time

©IJRASET: All Rights are Reserved

From graphs it is evident that initially battery getting discharged as its SOC level reduces and as time varies fuel converter comes into picture. The efficiency vs power plot gives the operating region of the Fuel cell electric vehicle the maximum efficiency that the vehicle can operate is around 60%. The fuel consumed by fuel converter is gradually increases with time as shown in figure 26. As same drive cycle has been used for analysis Fuel cell electric vehicle has covered a distance of 11 mph for one drive cycle. The remaining other observations are mentioned in Table VI.

Table VI
Observed parameters during analysis of Fuel cell Electric Vehicle

| Observed parameters | Values |
|---|---|
| Fuel Economy | 4.5 mpg (miles per gallon) |
| Maximum speed | 159.32 $kph$ |
| Maximum Acceleration | 4.8768 $m/s^2$ |

There are no graces of Hydro carbon, carbon monoxide, Nitrogen oxide gases during propulsion of vehicle. For fuel cell vehicle with rear wheel drive the operating point can go up to 30 $kW$ for chosen motor. The vehicle has also undergone gradeability test in order to analyze the relation between speed and gradient angle of the road. Gradeability test has been done by considering various speed intervals at constant duration of 10s. The results obtained during gradeability test on Battery vehicle are tabulated.

Table VII
Variation of Gradeability w.r.t Speed at constant duration of 10s

| Speed in mph | Speed in kmph | Gradeability |
|---|---|---|
| 20 | 32 | 31.7% |
| 40 | 64 | 15.1% |
| 60 | 97 | 8% |

Similar to that of Battery Electric Vehicle the gradeability in case of fuel cell electric vehicle has been decreased with increase in speed at constant duration.

*C. Analysis of Hybrid Electric Vehicle*

Hybrid electric vehicles also have different configurations[8], here we have obtained the analysis of two configurations of Hybrid Electric vehicle i.e.; Series configuration and Parallel configuration.

*1) Analysis of Series configured Hybrid Electric Vehicle*

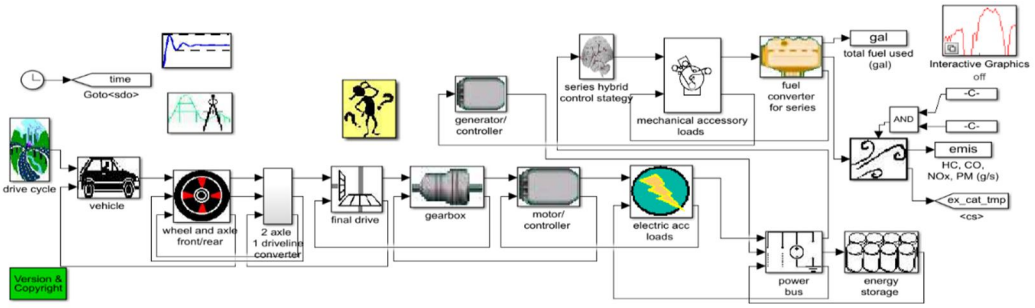



Fig 28. Simulation diagram of series configured Hybrid Electric Vehicle in ADVISOR

In series configuration an extra machine has been added i.e.; a generator/converter. In this analysis same parameters of Battery Electric Vehicle have been chosen, as it is a series configured hybrid electric vehicle it includes a generator and we have considered generator( ETA_95) of peak power 75 kw and 0.95 efficiency. Due to the addition of weight the Gross weight now comes to 1407 kg. There are various graphs have been obtained after simulation.

©IJRASET: All Rights are Reserved

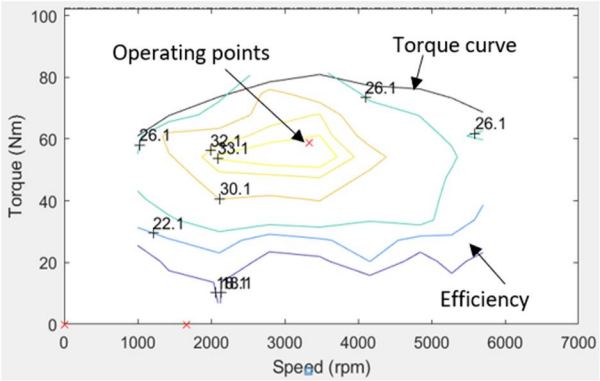


Fig 29. Torque vs Speed profile of Series configured Hybrid Electric Vehicle

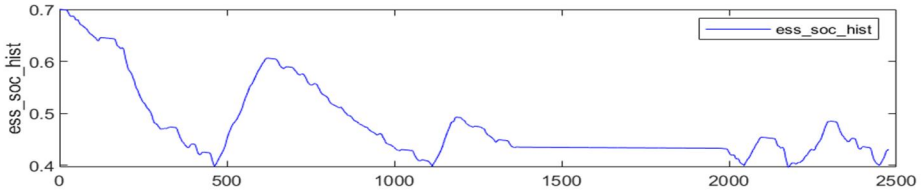


Fig 30. Variation of State of Charge w.r.t Time

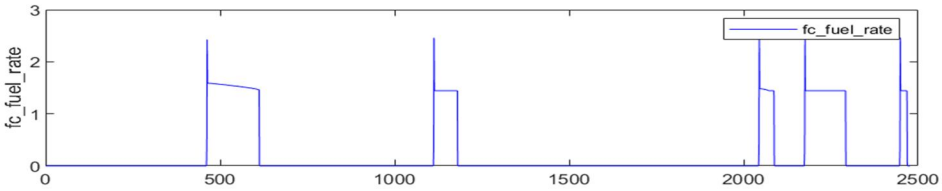


Fig 31. Fuel consumed by fuel converter in grams/second

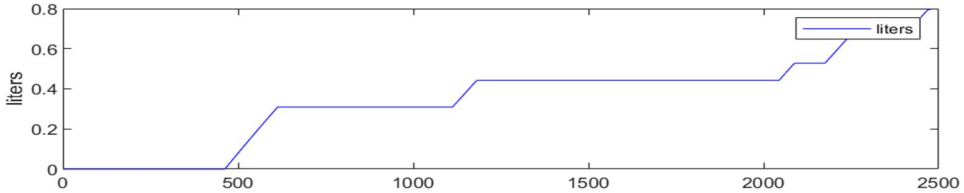


Fig 32. Cumulative liters of fuel consumed vs Time

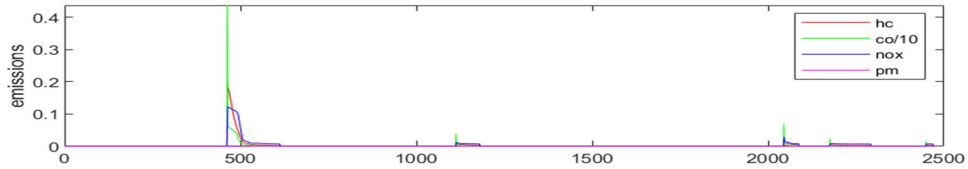


Fig 33. Emission of gases w.r.t Time

The conclusions that are to be drawn after analyzing series hybrid electric vehicle are, as it is a vehicle which consists of engine as well as battery for propulsion from the soc history graph it has been evident that the soc has initially decreased to 0.4 value and at that instant of time fuel converter has come into picture and it started providing the input to the motor. When we look towards the gaseous emission carbon monoxide traces has been found in higher rate than hydrocarbons and nitrogen oxides. As, the content of CO is heavy it leads to the damage of all living beings and adds to the greenhouse effect. The torque vs speed profiles give the operating points of the vehicle. As same drive cycle has been used for analysis Series configured Hybrid Electric vehicle has covered a distance of 11 mph for one drive cycle. The remaining other observations are mentioned in Table VIII.

©IJRASET: All Rights are Reserved

Table VIII
Observed parameters during analysis of Series configured Hybrid Electric Vehicle

| Observed Parameters | Values |
|---|---|
| Fuel Economy | 52.4 $mpg$ |
| Maximum Speed | 159.32 $kmph$ |
| Maximum Acceleration | 4.876 $m/s^2$ |
| Hydrocarbons | 0.518 $grams/mile$ |
| Carbon monoxide | 2.591 $grams/mile$ |
| Nitrogen oxide | 0.674 $grams/mile$ |

The vehicle has also undergone gradeability test in order to analyze the relation between speed and gradient angle of the road. Gradeability test has been done by considering various speed intervals at constant duration of 10s. The results obtained during gradeability test on Battery vehicle are tabulated.

Table IX
Variation of Gradeability w.r.t Speed at constant duration of 10s

| Speed in mph | Speed in kmph | Gradeability |
|---|---|---|
| 20 | 32 | 24.4% |
| 40 | 64 | 11.2% |
| 60 | 97 | 5.5% |

The take away from gradeability test on series Hybrid electric vehicle is the gradeability decreases by increase in speed at constant duration. We can also make a note that by varying the duration gradeability will also changes.

*2) Analysis of Parallel configured Hybrid Electric Vehicle*

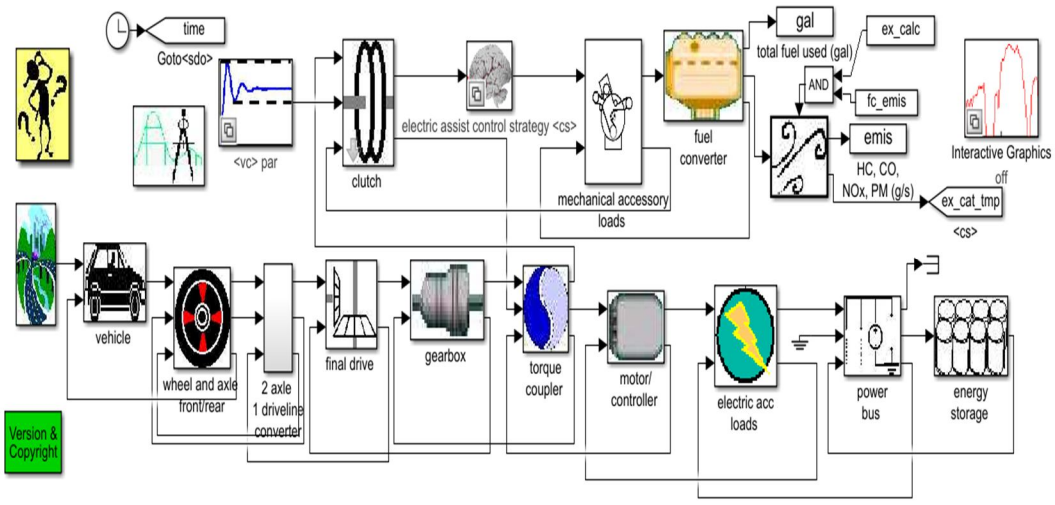



Fig 34. Simulation diagram of parallel configured Hybrid Electric Vehicle

The gross weight obtained in this configuration is 1384 kg, as generator is absent in this configuration. Simulation has been done by considering the same parameters as in the case of Battery Electric Vehicle. After simulating the following graphs have been obtained.

©IJRASET: All Rights are Reserved

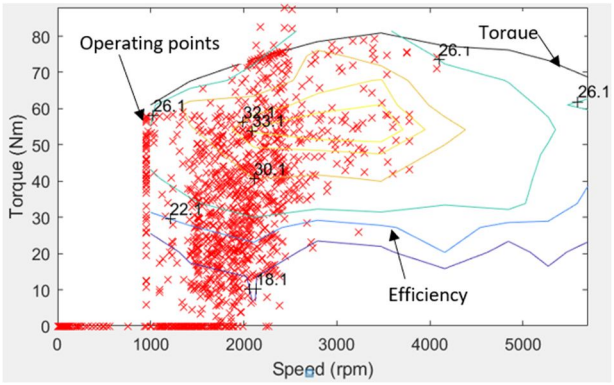



Fig 35. Torque vs Speed profile of parallel configured Hybrid Electric Vehicle

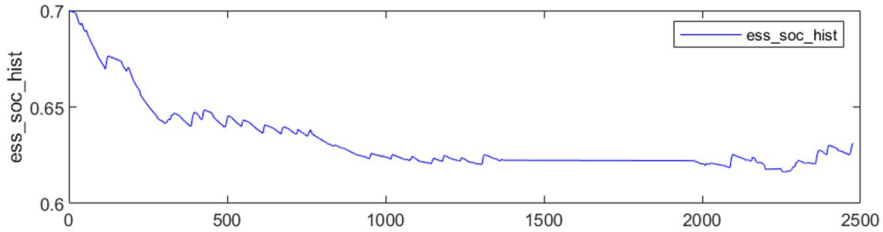



Fig 36. Variation of State of Charge w.r.t Time

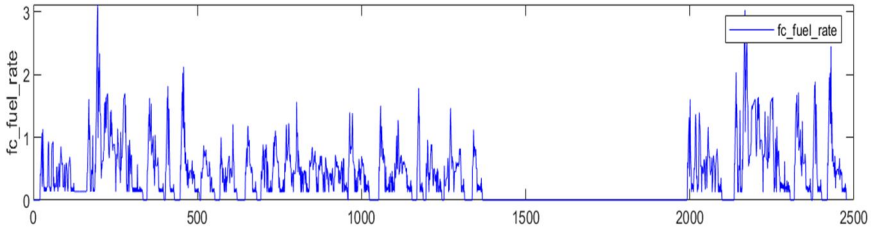



Fig 37. Fuel used by fuel converter in grams/second

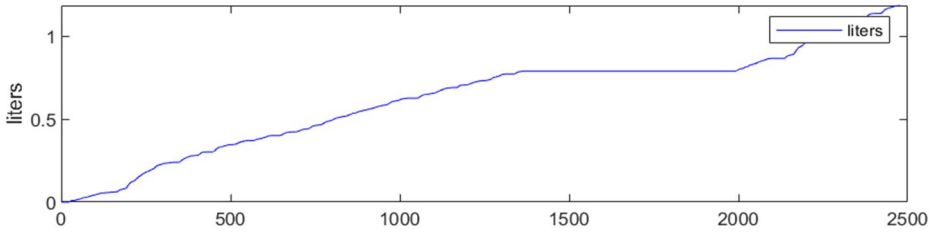



Fig 38. Cumulative liters of fuel consumed vs Time

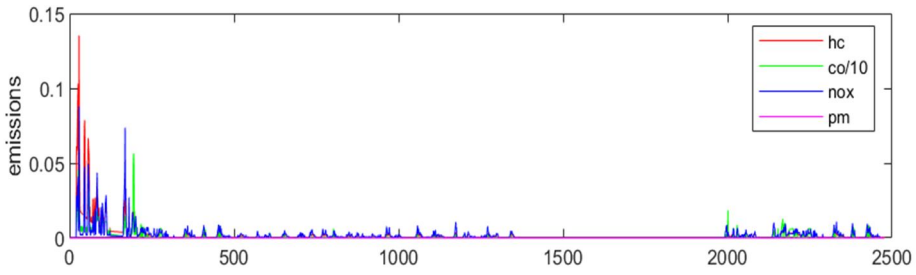



Fig 39. Emission of gases w.r.t Time

©IJRASET: All Rights are Reserved

From obtained graphs, we can say that the parallel configured hybrid electric vehicle will emit larger amount of carbon monoxide when compared to series configured vehicle it has less fuel economy and also emission of effluents is less. From torque vs speed profile, the operating points of parallel configured electric vehicle has been obtained and we can say that beyond 4000 rpm the vehicle can't be operated. The remaining other observations are mentioned in Table X.

Table X
Observed parameters during analysis of Parallel configured Hybrid Electric Vehicle

| Observed Parameters | Values |
|---|---|
| Fuel Economy | 32.5 $mpg$ |
| Maximum Speed | 05.8 $kmph$ |
| Maximum Acceleration | 4.8768 $m/s^2$ |
| Hydrocarbons | 0.436 $grams/mile$ |
| Carbon monoxide | 2.26 $grams/mile$ |
| Nitrogen oxide | 0.393 $grams/mile$ |

The vehicle has also undergone gradeability test in order to analyze the relation between speed and gradient angle of the road. Gradeability test has been done by considering various speed intervals at constant duration of 10s. The results obtained during gradeability test on Battery vehicle are tabulated.

Table XI
Variation of Gradeability w.r.t Speed at constant duration of 10s

| Speed in mph | Speed in kmph | Gradeability |
|---|---|---|
| 20 | 32 | 24.8% |
| 40 | 64 | 12.3% |
| 60 | 97 | 6.2% |

From the above table it is evident that the gradeability decreases with increase in speed at constant duration

## V. CONCLUSIONS

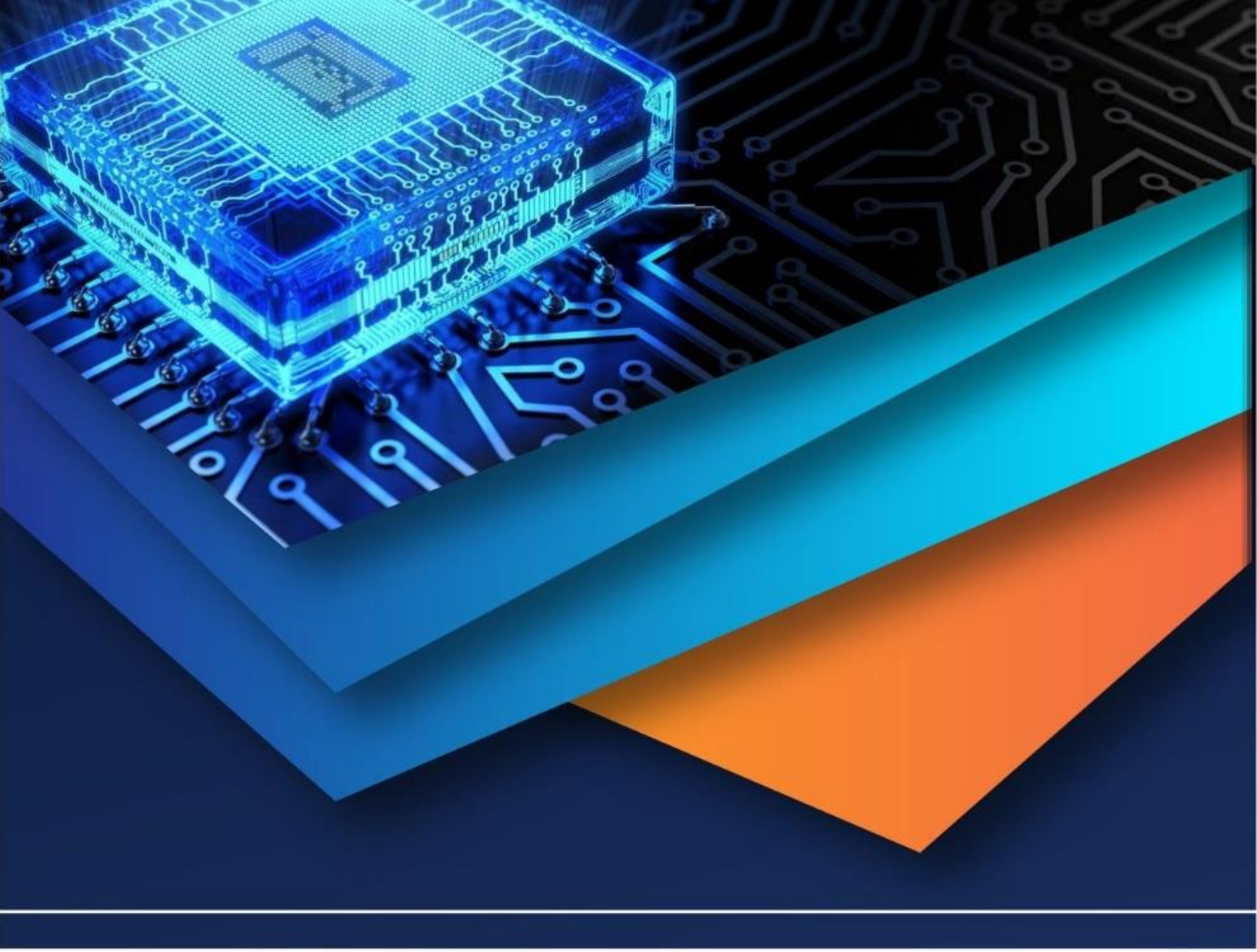
This study presents a brief idea about various architectures and types of Electric vehicles and dynamics of vehicles. Initially we have considered a basic vehicle specification, driving conditions and plotted bar graphs representing total resistance forces at different speeds and gradients. Gradient highly effects hill climbing force and as the gradient value get increases the force required for tractions also increases. Electric vehicle simulation results show, speed and distance covered by vehicle. In our analysis of vehicles using ADVISOR, it has been found that the operating range is more in case of Battery electric vehicle. The analysis shows Parallel configured Hybrid electric vehicle has obtained highest maximum speed than remaining vehicles but it includes the emission of gases that adds to greenhouse effect. The gradeability test in all the 3 vehicles says that, for the same speed the gradeability value has been higher in case of Battery electric vehicle and Fuel cell electric vehicle than Hybrid vehicle. Hence Hybrid electric vehicles are suitable for Hilly areas and areas with large gradient. The maximum speed obtained by the Hybrid electric vehicle is high compared to others so, they also suitable in case of travelling long distances. Whereas Battery electric vehicles are more suitable to travel in urban areas and within city premises. Since Battery electric vehicles has been referred as Green-transportation it is highly recommended for private transport or for shorter distance travel. Finally, we can say that there are certain pros and cons are associated with each type of vehicle but considering environment and global warming issue it is highly recommended for people to turn toward Electric vehicles.

©IJRASET: All Rights are Reserved

## REFERENCES

[1] Seith Leitman and Bob brant, “Build your own Electric vehicle”, second edition, McGraw Hill, 2009
[2] M. Ehsani, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2005
[3] Husain, I., 2003, Electric and Hybrid Vehicles Design Fundamentals, Pertama, CRC Press, United Stated.
[4] Bambang Sri Kaloko, Soebagio, Mauridhi Hery Purnomo, “Design and Development of Small Electric Vehicle using MATLAB/Simulink”, International Journal of Computer Applications (0975 – 8887) Volume 24– No.6, June 2011
[5] T. Markel A. Brooker T. Hendricks V. Johnson K. Kelly B. Kramer et al. "ADVISOR: A systems analysis tool for advanced vehicle modeling" Journal of Power Sources vol. 110 no. 2 pp. 255-266 2002
[6] ADVISOR Documentation, National renewable energy laboratory, version 2003, Modified October 2003
[7] Benedito A. Arruda, Max M. Santos, Ritesh Kumar Keshri, “A Comparative Study of Performance for Electric Vehicles for Wheel Traction Configurations”, Conference Paper · June 2016 DOI: 10.1109/ISIE.2016.7744990
[8] Maddumage, W.; Perera, M.; Attalage, R.; Kelly, P. Power Management Strategy of a Parallel Hybrid Three-Wheeler for Fuel and Emission Reduction. *Energies* **2021**, *14*, 1833. https://doi.org/10.3390/en14071833

©IJRASET: All Rights are Reserved



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)