MODELLING OF MULTI-SOURCE BASED PERFORMANCE OF HYBRID ELECTRIC VEHICLE

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***Abstract*—** An electric system powers an electric vehicle (EV) instead of a gas-powered motor, which generates power besides consuming a mixture of fuel as well as gases. An electric vehicles utilization, expands the interest of power which understudy causes over-burden on creating plants and furthermore increment the toxins in the nature (since most extreme measure of power creation is finished by utilizing petroleum derivatives) and these are non-sustainable assets. To decrease the creation of poisons and to fulfill the rising need we want to use the sustainable power assets. The topping off time for electric vehicle is more, causes issues like time waste and traffic at charging station. In this task an electrical framework for the powertrain of Half and half Electric Vehicle (EHV) which is controlled by Energy component, Proton Trade Film type, (is an energy-transformation gadget which changes over a Fuel's (hydrogen and oxygen) compound energy into power straight by delivering water and intensity as a biproduct), Battery and PV board (utilized as an other power supply gadget) which are not influence the nature, is broke down. Hydrogen can be effectively movable and can be rapidly refillable. A Simulink model will be ready and mimicked. The recreation results like Energy unit proficiency, DC to DC converter current, voltages, photovoltaic board execution are talked about.

Keywords—PV cell, Hybrid Electric Vehicle (EHV), Fuel cell, Proton Exchange Membrane (PEM).

I INTRODUCTION

An energy source that is considered to be environmentally friendly must be practical, meaning it must be perpetual, like the sun [1] [2]. When you hear the term "renewable energy" at this point, it usually also refers to environmentally friendly power sources [3] [4]. It alludes to energy sources that are an alternative to the most widely used non-maintainable sources, like coal. One of the most important steps you can take to lessen your impact on the environment is to use clean, sustainable energy [5] [6]. Clean energy also reduces harmful brown haze, poisonous developments in our air and water, and the effects caused by coal mining and burning. Power production is our main source of ozone depleting substances, more than all of our driving and flying combined [7].

However, replacing our reliance on petroleum products will require time. There are areas of strength for and, support from both state and government commands to fabricate environmentally friendly power age and interest for clean energy from consumers and organizations [8] [9]. Wind energy is a plentiful source of clean energy. With wind power's consistently growing commitment to the Public Framework, wind ranches are an undeniably recognizable sight in the UK. In order to deal with wind energy, turbines are used to power generators, which in turn supply power to the Public Framework [10] [11]. Even though there are available "off-framework" or homegrown age frameworks, only one out of every odd property is appropriate for a homegrown breeze turbine. Hydro Plant—Hydro power is one of the most lucrative forms of energy because it is environmentally friendly. An enormous supply can be used to create a controlled flow of water that will turn a turbine and generate power by building a dam or boundary. This is especially true for certain types of properties [12] [13]. Tidal energy is another form of hydropower that uses the two daily tidal flows to power turbine generators. Although a flowing stream, unlike some other hydro energy sources, isn't always predictable, it is remarkably predictable and can, therefore, make up for times when the tide momentum is weak. Visit our marine energy page to learn more [14] [15].

II.DESIGN OF HYBRID ELECTRIC VEHICLE BY USING MATLAB

In this chapter we are going to discuss about the design of hybrid electric vehicle by multiple sources like Fuel cell, PV cell and Battery in simulation software. In matlab simulation software which consists of different types of libraries like Simulink, simscape, simscape power systems library etc,. The matlab inbuilt blocks to make user easy to do their works.

According to the type of work we can choose the blocks from different libraries. So we need to have a basic knowledge about the components which are going to use in this simulation model of hybrid electric vehicle.

Components of Model:

$$E_{oc} = K_c E_n \qquad \text{…….. 1}$$

$$i_0 = \frac{zFk\left(P_{H_2} + P_{O_2}\right)\Delta v}{Rh} e^{\frac{-\Delta G}{RT}} \qquad \text{…… 2}$$

$$A = \frac{RT}{z\alpha F}, \qquad \text{……………….3}$$

<u>*PV Array*</u>- A number of photovoltaic (PV) modules are used in the PV cell block. The array is made up of parallel strings of modules, each string consisting of a series of connected modules. With the help of this block, you can simulate both custom PV modules and pre-defined PV modules from the 2018 System Advisor Model from the National Renewable Energy Laboratory (NREL).

Simscape / Electrical / Specialized Power Systems / Sources

<u>Input parameters:</u>

`Ir` — Control signal

`T` — Control signal defining temperature of cells, degrees Celsius.scalar

Mathematical Modelling:

$$I_d = I_0\left[\exp\left(\frac{V_d}{V_T}\right) - 1\right] \qquad \text{………… 4}$$

$$V_T = \frac{kT}{q} \times nI \times Ncell \qquad \text{………… 5}$$

<u>*Battery*</u>-

Library:

Simscape / Electrical / Specialized Power Systems Sources

Mathematical modelling:

- Discharge Model (i* > 0)

$$f_1(it, i*, i) = E_0 - K \cdot \frac{Q}{Q - it} \cdot i* - K \cdot \frac{Q}{Q - it} \cdot it + A \cdot \exp(-B \cdot it)$$

- Charge Model (i* < 0)

$$f_2(it, i*, i) = E_0 - K \cdot \frac{Q}{it + 0.1 \cdot Q} \cdot i* - K \cdot \frac{Q}{Q - it} \cdot it + A \cdot \exp(-B \cdot it)$$

Permanent magnet DC motor

Library**:**

Simscape / Electrical / Electromechanical / Brushed

$$m\dot{V}_x = F_x - F_d - mg \cdot \sin\beta$$

$$F_x = n(F_{xf} + F_{xr})$$

$$F_d = \frac{1}{2} C_d \rho A (V_x + V_w)^2 \cdot \text{sgn}(V_x + V_w)$$

Zero normal acceleration and zero pitch torque determine the normal force on each front and rear wheel.

$$F_{zf} = \frac{-h(F_d + mg\sin\beta + m\dot{V}_x) + b \cdot mg\cos\beta}{n(a+b)}$$

$$F_{zr} = \frac{+h(F_d + mg\sin\beta + m\dot{V}_x) + a \cdot mg\cos\beta}{n(a+b)}$$

The wheel normal forces satisfy $F_{zf} + F_{zr} = mg\frac{\cos\beta}{n}$.

Motors

Mathematical modelling

Eb = V – Ia .Ra

P = T . W

Vehicle Body

Library:

Simscape / Driveline / Tires & Vehicles

Decription:

A two-hub vehicle body is addressed by the vehicle body block as it moves longitudinally. The vehicle may have an equivalent number of wheels on each pivot or a different number. two wheels on the front pivot and one wheel on the back hub, for instance. It is anticipated that the size of the vehicle wheels will be identical. The vehicle may also have a centre of gravity (CG) that is on, near, or below the plane of motion.

Due to speed increase and street profile, the block represents weight, streamlined drag, street slope, and weight distribution between axles. Alternately, add elements of pitch and suspension. Comparatively speaking to the ground, the vehicle does not ascend. The block has the option to include both a remotely characterised mass and an inactivity. Due to structural changes, the vehicle body's mass, motion, and centre of gravity may change over the course of reproduction.

Vehicle Model Variables:

Symbol	Description
g	Gravitational acceleration
β	Incline angle
m	Mass of the vehicle
h	Height of vehicle center of gravity (CG)
a, ***b***	Distance of front and rear axles

Symbol	Description
V_x	Velocity of the vehicle
V_w	Wind speed. When $V_w > 0$.

Table .1 .vehicle Model Variables

Vehicle Dynamics

The vehicle's centre of gravity acts as a conduit for the weight mg (CG). The weight pulls the vehicle to the ground and pushes it in one of two directions, depending on the angle of the incline. The vehicle slows down due to aerodynamic drag whether it is moving forward or backward. To keep things simple, it is assumed that the drag operates via the CG.

H-Bridge

Library:

Simscape / Electrical / Semiconductors & Converters / Converters

The H-Bridge block represents an H-bridge motor driver. The block has the following two Simulation mode options:

The block maintains the load circuit using one of the following three Freewheeling mode choices if its value is less than the Enable threshold voltage parameter value:

- Via two freewheeling diodes
- Via one semiconductor switch and one freewheeling diode
- Via two semiconductor switches and one freewheeling diode

Synchronous procedure is a term that is also used to describe the first and third choices.

Mathematical modelling:

$$\frac{V_O V_{PWM}}{A_{PWM}} - I_{OUT} R_{ON} \qquad \ldots\ldots\ 12$$

To calculate the speed control output, the block uses these equations.

Setting	Equation
PI	$y = \frac{K_{ff}}{v_{nom}} v_{ref} + \frac{K_p e_{ref}}{v_{nom}} + \int \left(\frac{K_i e_{ref}}{v_{nom}} + K_{aw} e_{out} \right) dt + K_g \theta$
Scheduled PI	$y = \frac{K_{ff}(v)}{v_{nom}} v_{ref} + \frac{K_p(v) e_{ref}}{v_{nom}} + \int \left(\frac{K_i(v) e_{ref}}{v_{nom}} + K_{aw} e_{out} \right) e_{ref} dt + K_g(v) \theta$

-

Longitudinal Drive:

Library:

Powertrain Blockset / Vehicle Scenario Builder Vehicle Dynamics Blockset / Vehicle Scenarios / Driver

The equations use these variables.

v_{nom}	Nominal vehicle speed
K_p	Proportional gain

K_i	Integral gain
K_{aw}	Anti-windup gain
K_{ff}	Velocity feed-forward gain
K_g	Grade angle feed-forward gain
θ	Grade angle
τ_{err}	Error filter time constant
y	Nominal control output magnitude
y_{sat}	Saturated control output magnitude
e_{ref}	Velocity error
e_{out}	Difference between saturated and nominal control outputs
y_{acc}	Acceleration signal
y_{dec}	Braking signal
v	Velocity feedback signal
v_{ref}	Reference velocity signal

Table.2. abbrivations

III DEVICE SPECIFICATION

In the design process it is very important to select the ratings of the device which we are going to use in this model. The rating of the each device is mentioned below.

Parameters	Ratings
Type	Lithium ion
Power rating	50 kwh
Voltage rating	200 V
Current Rating	250 Ah
Volume	0.72 m3
Weight	190

Table 3 Battery

Parameters	Ratings
Type	PEMFC
Power rating	25 kw
Voltage rating	240 V
Efficiency	50 %
No. of cells	350
Each cell Voltage	0.7 V
H2 composition	99.95 %
O2 composition	21 %
Fuel flow rate	1460 lpm
Air flow rate	7350 lpm
Temperature	50 C
Fuel pressure	355 b
Air pressure	137 b
Weight	50 kg

Table 4 Fuel Cell

Parameters	Ratings
Type	DC Permanent Magnet
Power rating	50 kw
Voltage rating	200 V
Current Rating	250 A
Efficiency	70 %
No load speed	13000 rpm
Rated speed	9000 rpm
Type of Breaking	Regenerative
Weight	300 kg

Table 5 DC motor

Parameters	Ratings
Type	Monocrystalline
Power rating	2138 W
Voltage rating	237.6 V
Current Rating	9 A
No. of series cell	360
Each cell voltage	0.66
Irradiance	1000 W/m2
Efficiency	22 %
Volume	5 m2
Weight	100 kg

Table 6 Solar cell

Table 7Miscellaneous Specification

Parameters	Ratings
Vehicle Body Weight	700 kg
H Bridge Converter O/P Voltage	200 V

When Battery is in Fully Charged Condition (Mode 1)

In this situation battery (Assume initially battery in fully charged condition) is connected to the EV which is showed in the figure. In simulation model we can see longitudinal driver, H- bridge, DC motor, Friction, Vehicle body blocks and some measurement

Working:

The EV shows to the stock which comes from the battery, above all else the stockpile is given to the H-span circuit, which is having 4 changes to control the engine speed, force and power by utilizing PWM (Heartbeat With Regulation) strategy. It will likewise go about as a stater for the engine it will control the beginning flows of the engine by PWM. This supply is given to the engine, it will progressively speed up the engine relying on the reference signal. We realize that longitudinal drive will have the reference signal with that signal we will differ the velocities it could be speed increase, deacceleration and slowing down.

The engine is precisely coupled to the shaft of the gearbox through some rubbing block. The vehicle body is associated with the tires which will convey the mechanical capacity to tires. We will have a few sensors like force, current, speed, and voltage blocks to work out the effectiveness, yield power and so forth,. To see the wave structures we will have the extensions at every estimation blocks.

When EV driven by Fuel Cell (Mode 2)

In this situation Fuel Cell is connected to the EV In simulation model we can see longitudinal driver, H- bridge, DC motor, Friction, Vehicle body blocks and some measurement blocks.

Working:

The EV runs by the supply which comes from the Fuel cell, first of all the supply is given to the H-bridge circuit, which is having 4 switches in order to control the motor speed, torque and power by using PWM (Pulse With Modulation) technique. It will also

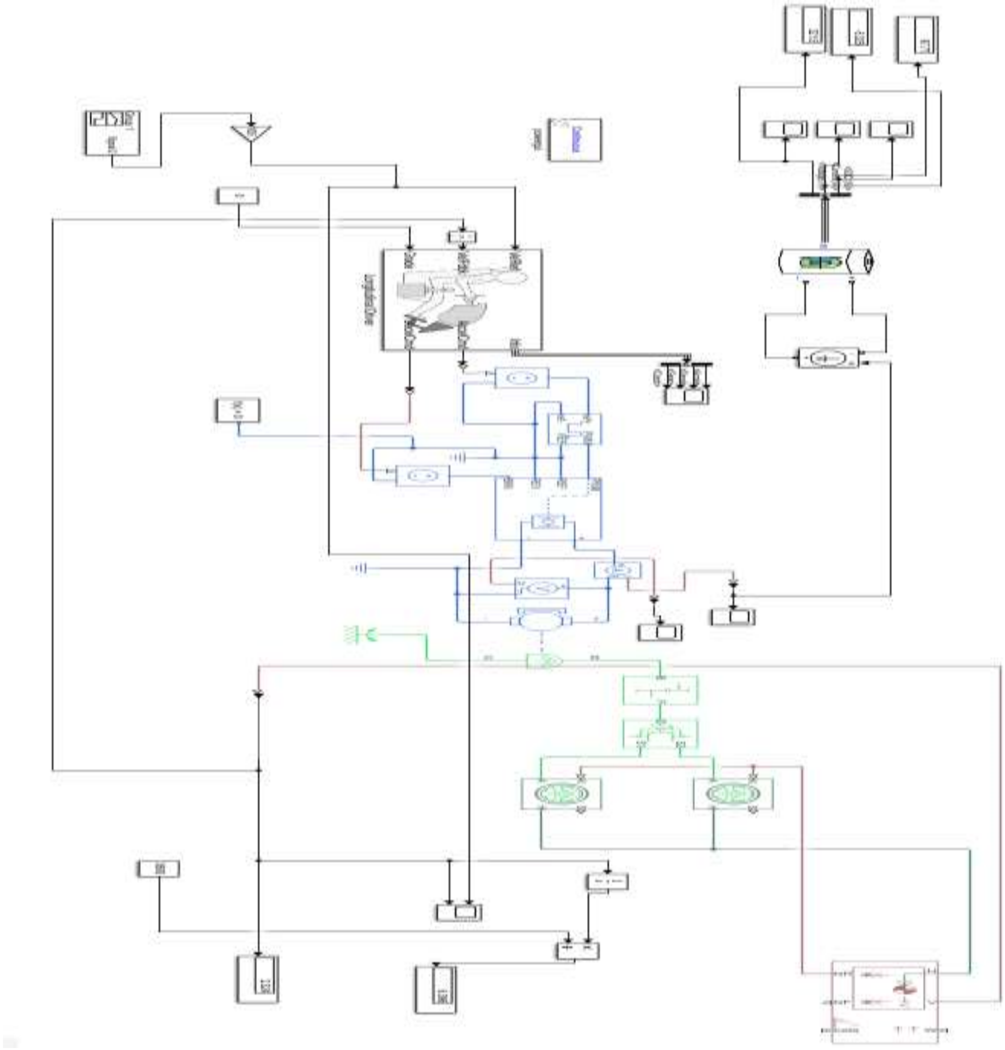

Fig.1. Simulation Diagram of EV driven byBattery

act as a stater for the motor it will control the starting currents of the motor by PWM. This supply is given to the motor, it will gradually increase the speed of the motor depending upon the reference signal. We know that longitudinal drive will have the reference signal with that signal we are going to vary the speeds it may be acceleration, deacceleration and braking.

Battery charging by solar cell (Mode 3)

In this case battery initially is in discharged mode we are going to charge the battery with the help of solar cell, which is possible only in day time, because of low efficiency of solar cell it will take more time to charge the battery The charging rate, time for full charge, and efficiency of solar cell varies with respective to climate, timings, and seasons.

Working:

In this model we are given the amount irradiance and temperature which is in degree Celsius to the solar cell, the solar cell will produce the energy with respective to that input parameters. The solar cell is predefined with number of cells and their combination, voltages, currents etc.,

The power produced by the solar cells is given to the battery which is already in discharged mode will get charging from the solar cell. The voltage of the solar cell is maintained more than that of fully charged battery to maintain the flow of energy from solar cells to the battery. In order to maintain the appropriate voltage with the solar cells we need to select the series and parallel combination of cells in such a way that it should produce the desired voltage and currents.

Battery charging by Fuel cell (Mode 4)

For this situation battery at first is in released mode we will accuse the battery of the assistance of Energy component, which is conceivable just when fuel present, due to low effectiveness of sun powered cell it will require greater investment to charge the battery. The charging rate, time for full charge, and proficiency of sun powered cell differs with individual to fuel stream rate, fuel organization and wind current rate.

The power created by the energy components is given to the battery which is as of now in released mode will get charging from the energy unit. The voltage of the power device is kept up with more than that of completely energized battery to keep up with the *progression of energy from energy units to the battery. To keep up with the fitting voltage with the energy units we want to choose the series and equal blend of cells so that it ought to create the ideal voltage and flows.*

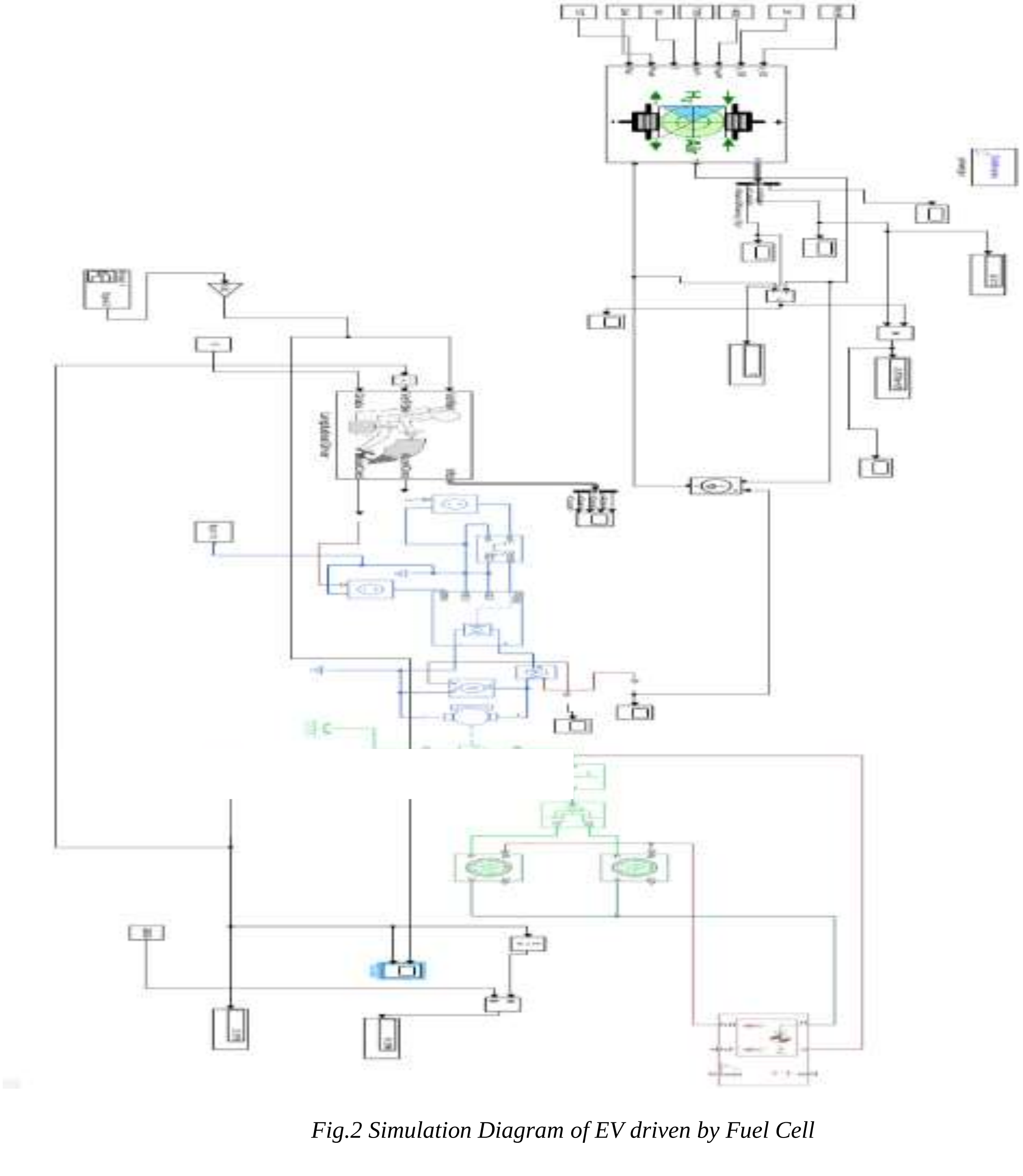

Fig.2 Simulation Diagram of EV driven by Fuel Cell

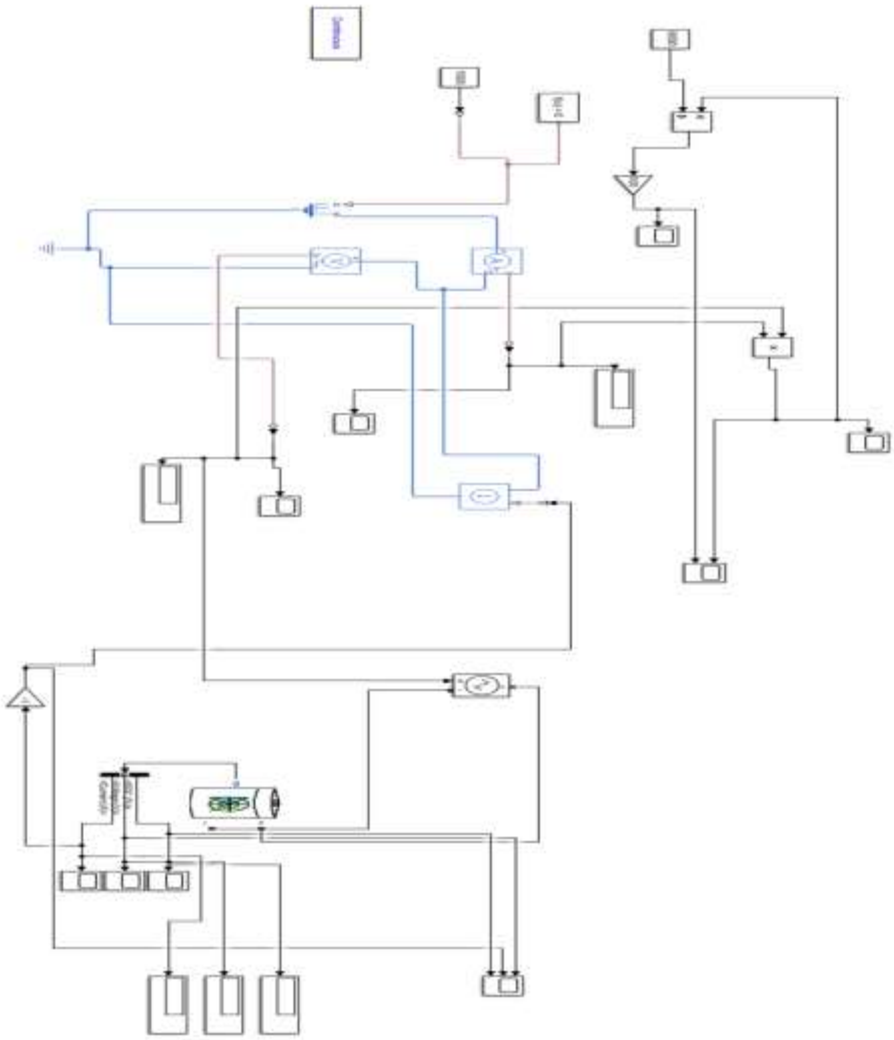

Fig.3.Simulation diagram of Battery charging by

IV. INTEGRATION OF ENERGY SOURCES LIKE BATTERY, PV CELL, AND FUEL CELL WITH ELECTRIC VEHICLE

In previous pages we seen individual sources connected to the battery or electric vehicle but not all together. If we want to connect all sources together In order to change or connect the sources to battery or electric vehicle or battery

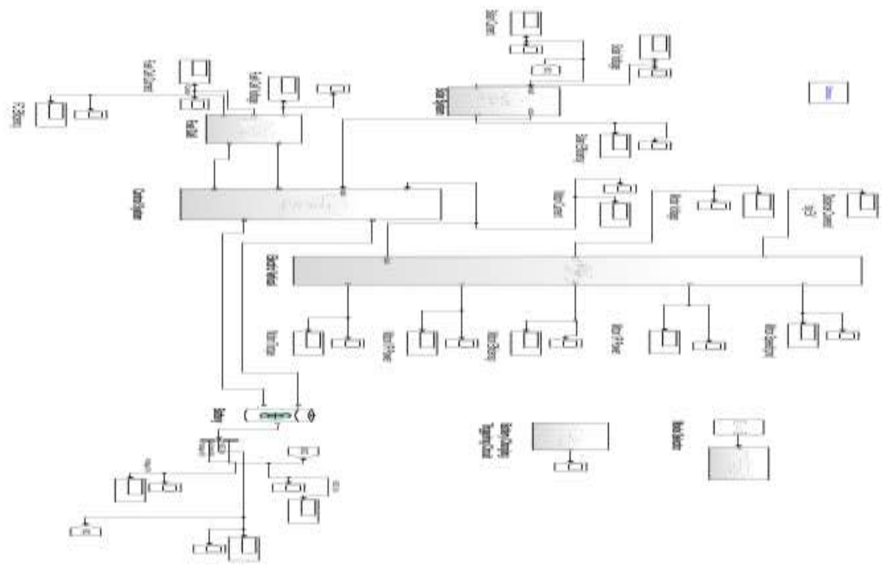

Fig.5. Simulation Diagram of the HEV

to electric vehicle we need to have a control system by which we can make connections between devices according to our need and requirements. In order to make the battery charging and discharging automatically we are going to use trigging circuit and to make connections between devises we are going to use binary codes to select the mode of operation called mode selector. See the below graph which is having different types of subsystems like fuel cell, solar system, battery, control system, triggering circuit, mode selector and electric vehicle. The control system, trigging circuit and mode selector are plays important role in controlling process.

Control System

The control system which is used to connect the devices in the model is shown below normally we are going to use the switches, AND gates, NOT gates and pulse signals to control the ON and OFF of the switches makes the proper connection between the devices. In this control system we are using 4 switches for each source in total 12 switches. The four switches which are responsible for the respective source will have one AND gate, NOT gate, Pulse signal and Binary code receiver.

The pulse signal which will comes from the battery triggering circuit depending upon the state of charge of the battery and another signal which comes from the mode selector to select the type of mode. These signals are connected to the AND gate which will produce the signal according to the input combination which will intern give the signal to the switches for turn ON and OFF actions, input high makes switch ON and input low makes turn OFF the switch.

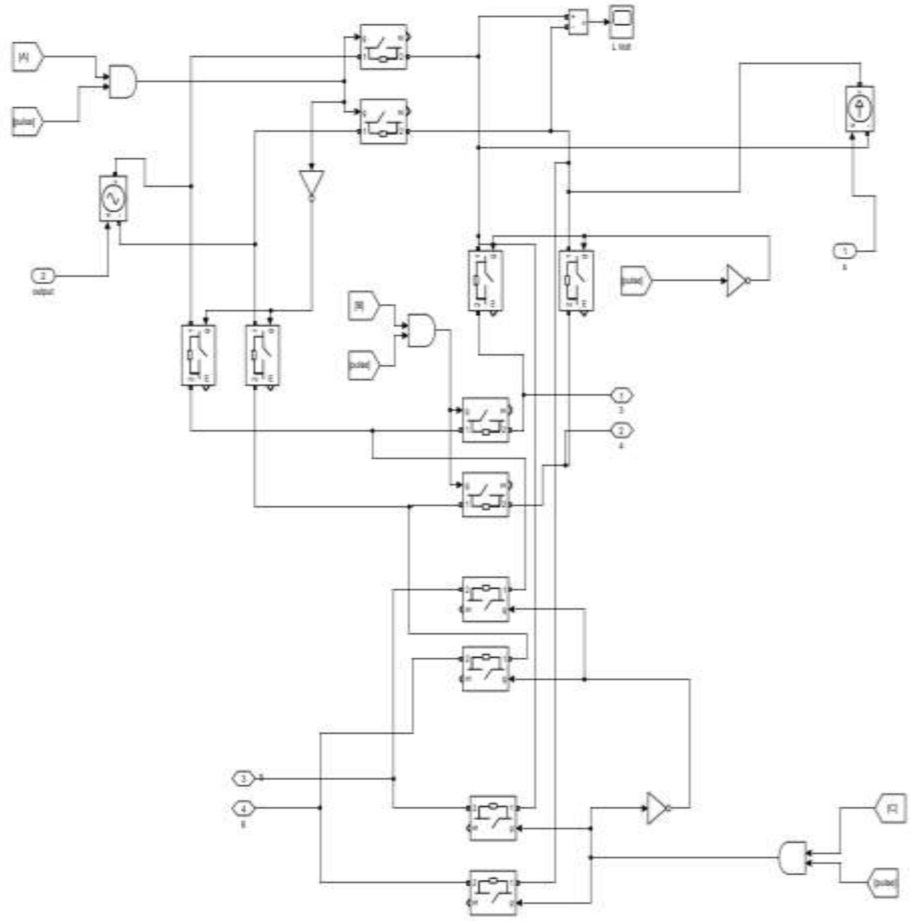

Fig.6. Simulation diagram of the Control System

Battery Triggering Circuit:

The battery triggering circuit is a simple circuit which produce the pulse signal either one or zero it pending upon the state of charge of the battery. See the below figure pulse will be one when battery is in charging mode and zero when battery in discharging mode. When battery charging percentage is more than 95% makes the pulse to zero and less than 5% makes the pulse to one.

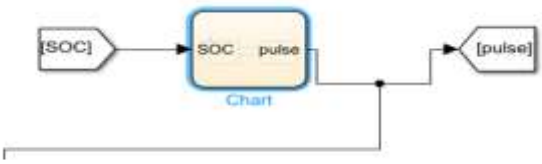

Fig.7. Battery triggering circuit

Mode selector:

The mode selector is a circuit which will pass the signals to the respective binary signal blocks which are connected to AND gates in control system block, We can see in the below figure in this circuit we are using constant block where we can give binary numbers to it and demux which will pass the given input to respective binary signal blocks.

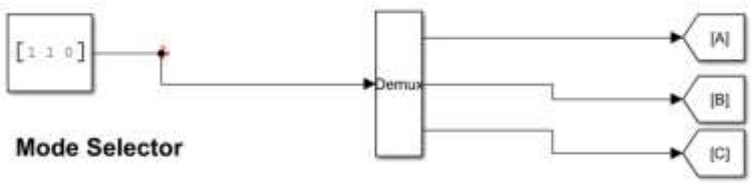

Fig 8 Simulation diagram of Mode Selector

V.RESULTS

When Battery is in Fully Charged Condition (Mode 1)

See the below graphs like battery current, voltage, state of charge and motor speed, output power and efficiency. We can observe at 0 to 200 seconds we will have positive slope at output power of the motor because of the increasing speed (acceleration mode) from 200 to 300 seconds we will have flat line because of the constant speed, at 300 seconds we can observe immediate drop in the motor output power because of the braking action from 300 to 500 seconds we can see the power is decreasing (deacceleration mode).

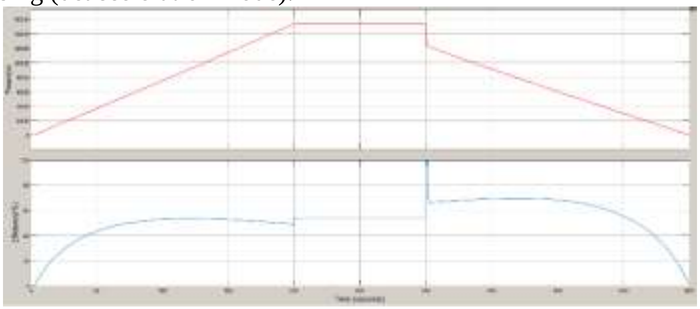

Fig.9. Output power and efficiency graphs of the motor

In any motor drive we know that torque speed characteristics are important aspect to analyze the performance of the motor in particular loads. See the below torque speed characteristics of the motor, we are going have a constant torque through out operation because of constant load(we assume 700kg as a total vehicle weight on the motor shaft) speed and power is directly proportional to each other.

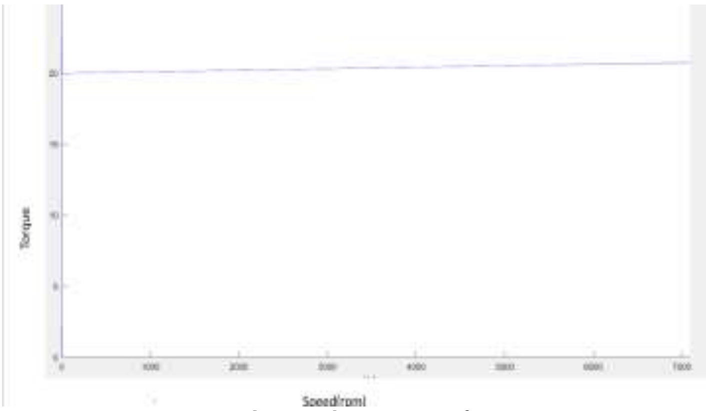

Fig.9. Speed torque characteristics of DC motor

Battery which is giving supply to the vehicle will have some parameter changes in it see the graphs below where we can observe the voltage drop, current variation and decrement in the percentage of charge in the battery because of energy consumed by the vehicle. We can see the changes at 300 seconds in battery parameters graphs because of regenerative braking action.

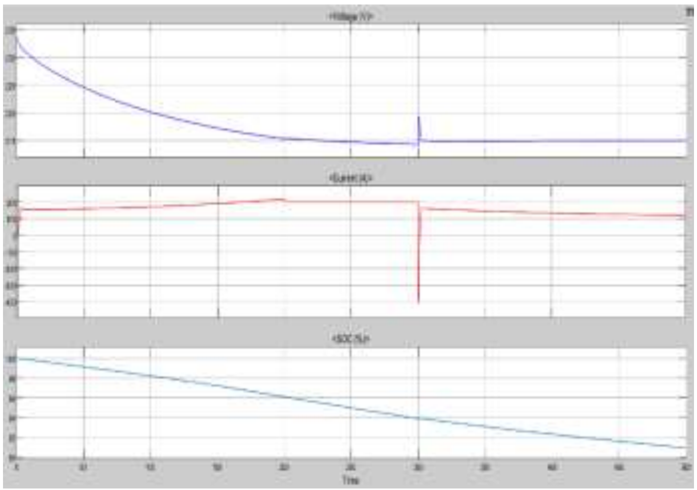

Fig 9 V, I and SOC characteristics of Battery

When EV driven by Fuel Cell (Mode 2)

Observation:

See the below graphs like fuel cell current, voltage, and motor speed, output power and efficiency. We can observe at 0 to 200 seconds we will have positive slope at output power of the motor because of the increasing speed (acceleration mode) from 200 to 300 seconds we will have flat line because of the constant speed, at 300 seconds we can observe immediate drop in the motor output power because of the braking action from 300 to 500 seconds we can see the power is decreasing (deacceleration mode).

Now observe the efficiency graph from 0 to 200 seconds we are having the efficiency which is increasing manner and 200 to 300 seconds we can observe the constant efficiency because of the constant output power from the motor at 300 seconds we can observe the very high efficiency the graph increases rapidly because of regenerative braking action which gives the power back to the supply mains. From 300 to 500 seconds we will have the efficiency which is more than that of previous time because deacceleration mode involves regenerative braking action.

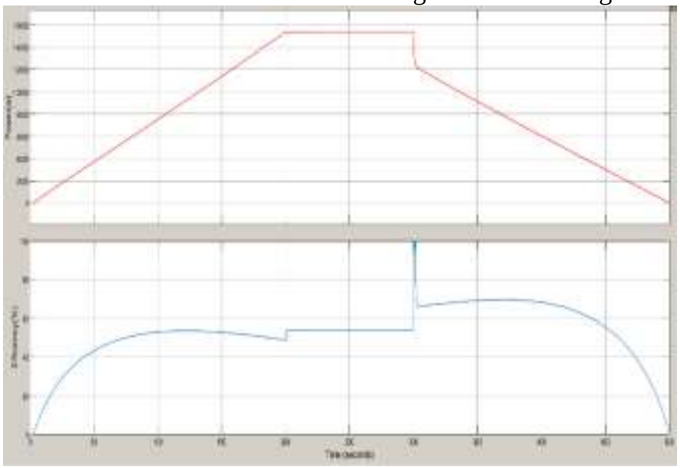

Fig10Output power and efficiency graphs of the motor

In any motor drive we know that torque speed characteristics are important aspect to analyze the performance of the motor in particular loads. See the below torque speed characteristics of the motor we are going have a constant torque through out operation because of constant load(we assume 700kg as a total vehicle weight on the motor shaft) speed and power is directly proportional to each other.

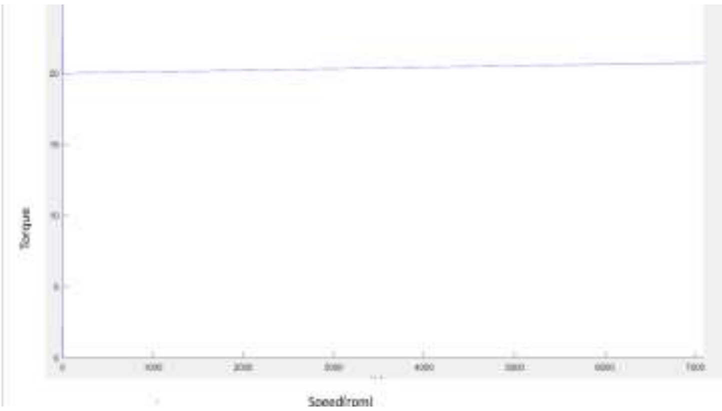

Fig 11 Speed torque characteristics of DC motor

Fuel cell which is giving supply to the vehicle will have some parameter changes in it see the graphswhere we can observe the voltage drop, current variation, power and efficiency parameters because of energy consumed by the vehicle respective to the time. We can see the changes at 300 seconds in Fuel cell parameters graphs because of regenerative braking action.

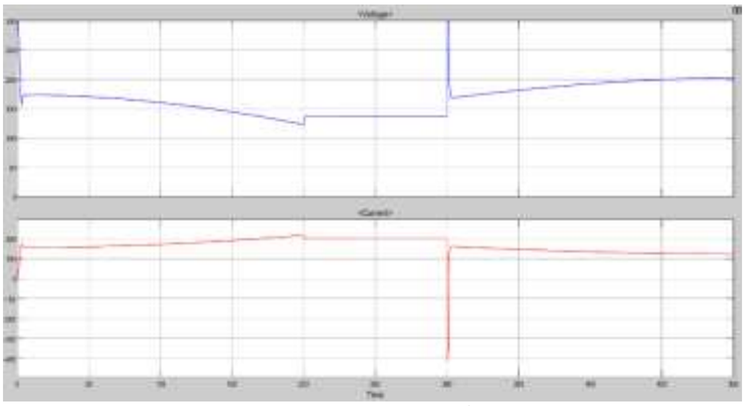

Fig 12. V and I characteristics of Fuel Cell

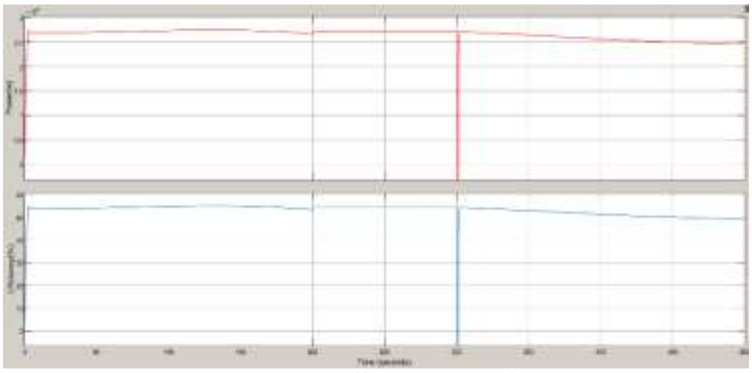

Fig 13.Output power and efficiency graphs of the Fuel Cell

Battery charging by solar cell (Mode 3)

Observation:

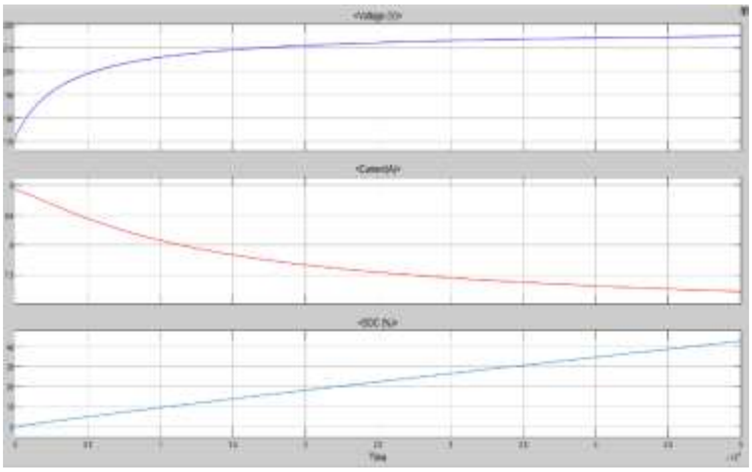

Fig 14. V, I and SOC characteristics of Battery

See the below graphs which gives the power and efficiency of the solar cell, we know that solar cell or solar panel are having very low efficiency it is varies between 20 to 25%. The power output of the solar cells which we are employed is varies between 1kw to 1.5kw

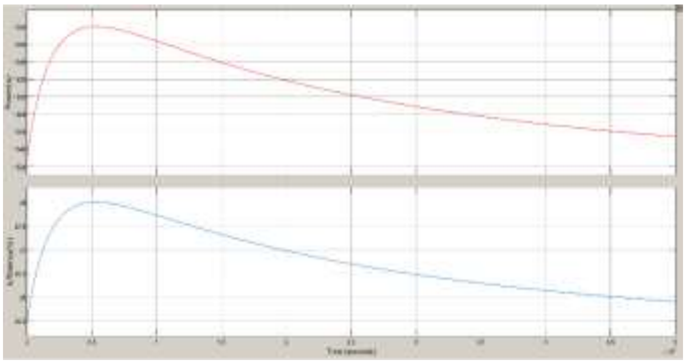

Fig 15. Output power and efficiency of the Solar cell

Battery charging by Fuel cell (Mode 4)

Observation:

We know that battery has to be charge with fuel cell and it is initially at zero percentage, see the below wave forms the voltage and state of charge is increasing rapidly.

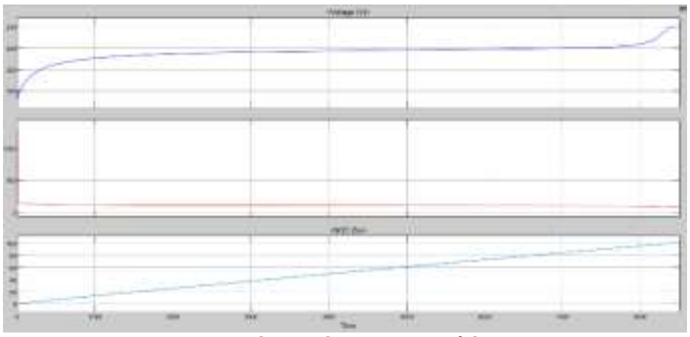

Fig 16. V, I and SOC characteristics of the Battery

See the graphs which gives the power and efficiency of the fuel cell, we know that fuel cell are having very low efficiency it is varies between 50 to 60%. The power output of the fuel cells which we are employed is varies between 25 to 26kw.

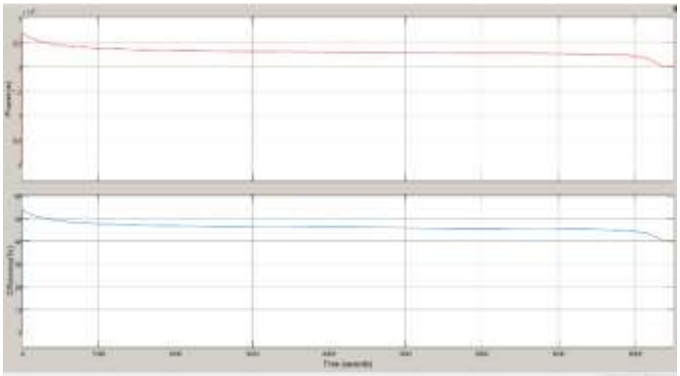

Fig 17. Output power and efficiency of the Fuel cell

VI .CONCLUSION

Electric vehicles are introduced to reduce, emission of toxic gases and pollution in the environment.Even though it reduces environment effect, batteries used in electric vehicles doesn't give satisfactory performance, i.e., it doesn't give efficient energy to drive a vehicle continuously.The distribution generation (by using renewable resources) concept is used in our project to reduce the burden on existing power plants. Normally, battery charging can be done only in charging stations but in our project charging will be done by using solar and hydrogen energy within the car automatically when it drains it's energy, which can be explained in further reviews.To prevent all the drawbacks, we introduce multi-source based vehicle, which drive vehicle continuously and decreases the toxic gases which reduces pollution in the environment.

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