A DESIGN AND MATLAB SIMULATION OF SOLAR ELECTRIC VEHICLE

A Project Report submitted in partial fulfilment of the requirements for the award of the Degree in

BACHELOR OF TECHNOLOGY

In

ELECTRICAL AND ELECTRONICS ENGINEERING

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C E R T I F I C A T E

This is to certify that the thesis entitled **"A DESIGN AND MATLAB SIMULATION OF SOLAR ELECTRIC VEHICLE**" that is being submitted by **K. AKESH, M. LIKITHA SRI, S. PRADEEP, G. VARAPRASAD** in partial fulfilment for the award of Bachelor of Technology in Electrical & Electronics Engineering to the University of Engineering Narasaraopet, Jawaharlal Nehru Technological University Kakinada is a record of bonafide work carried out by them under my guidance of supervision. The results embedded in this thesis have not been submitted to any other University/institute for the award of any degree/diploma.

Dr .M. Ravindra Babu	DR.Y.S. Kishore Babu
(Guide of the project)	(Head Of the Department)
Department of electrical engineering	Department of electrical engineering

D E C L A R A T I O N

We hereby declare that the work described in this project work, entitled **"a design and MATLAB simulation of solar electric vehicle"** which is submitted by us in partial fulfilment for the award of **Bachelor of Technology** (B.Tech.) in the Department of **Electrical & Electronics Engineering** to the University College of Engineering Narasaraopet, Jawaharlal Nehru Technological University Kakinada, Andhra Pradesh, is the result of work done by us under the guidance of **Dr. M.RAVINDRA BABU.**

The work is original and has not been submitted for any Degree/Diploma of this or any other university.

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A C K N O W L E D G E M E N T

It is a great privilege for us to convey our sincere gratitude to Dr.V. SUBBA RAO, Principal for providing us excellent lab facilities.

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We, the members of the project, heart fully thank our guide for his suggestions and co-operation in completion of the project work precisely. We shall always cherish over association with his encouragement, approachability, explanation and the freedom of thought and action.

We are thankful to our staff members who co-operated us in gathering the report. We extend our special thanks to all the esteemed faculty in Electrical and Electronics Department, who were so easily approachable, helpful and source of encouragement during this span of work.

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A DESIGN AND MATLAB SIMULATION OF SOLAR ELECTRIC VEHICLE

ABSTRACT

This study presents a model of an electric vehicle with a thin flexible photovoltaic cell installed on the roof. The electric vehicle is a key new transportation technology to reduce the pollution and to reduce the use of fossil fuels. In this study, vehicle performance is evaluated with closed loop control. According to the power requirement of electric vehicle size and other parameters of the motor are calculated. A significant reduction in battery energy consumption is noticed when vehicle is equipped with solar cells. The results presented in this study provide a practical information regarding the properties of an electric vehicle equipped with roof-mounted photovoltaic cell.

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ABBREVATIONS

PWM	:	pulse with modulation
PMDC	:	permanent magnet direct current
PS	:	physical signal
SOC	:	State of charge
Ah	:	Ampere Hour
mH	:	milli Henry
CG	:	centre of gravity

CHAPTER - 1

INTRODUCTION

1.1 INTRODUCTION

In present days Air borne pollution became a serious problem in the metropolitan cities. Even the Indian capital Delhi had faced the problem of smog which is mainly due to internal combustion engine vehicles. The ODD and EVEN car number policy which is, allowing the Even and odd car plate numbered vehicles to roam in the city on alternate days didn’t show much impact or didn’t alleviate the air borne pollution to much extent. Like this many cities in the world are facing the same problem which made the way for the Electric vehicles in the automotive market.

Tesla motors the pioneer company in the manufacturing of Electric vehicles brought a revolution in the EV market, uses Induction motor for propulsion of their vehicles as they are rugged and cheaper than Permanent Magnet machines. For an Electric vehicle design the pivotal part is estimating the parameters of various components like battery rating, motor rating, gear ratio etc. Selection of the type of motor depends on various factors like cost, efficiency, ruggedness reliability, torque capability etc. Depending on the vehicle application like whether it needs high speed or high range the battery composition should be taken (i.e) some Li-ion chemistries will have high discharge rates, some Li-ion chemistries will have fire safety like Lithium titanate.

In 1834, the first non-rechargeable battery-operated EV was built by Thomas davenport. After invention of lead acid batteries, rechargeable battery based EV was built by David salmons in 1874. By 1912, nearly 34000 EVs were registered in us but unfortunately EVs disappeared by 1930s.The reasons were,

1.First development is that Henry ford mass produced ford model t in 1925, and reduced its price by over 1/3rd to its price in 1909.

2.The second development was invention of automobile starter motor by Charles metering, That helped remove manual cranking required in ICEV, and enabled electric ignition and start.

1.2 ORGANISATION OF THESIS

Chapter 1 deals with introduction to the project, literature survey and overview of organization of thesis

Chapter 2 gives brief description of each and every block used in designing the simulation model

Chapter 3 depicts the block diagram of the solar electric vehicle

Chapter 4 shows the complete simulation model and subsystems in this analysis

Chapter 5 deals with complete analysis of this simulation and analysis of results

Chapter 6 deals with future scope of this project, conclusion and references taken.

CHAPTER 2

BLOCKS DESCRIPTION

2.1 Blocks used

1. Drive cycle
2. Motor controller
3. Vehicle body
4. Tire
5. Longitudinal driver
6. Battery
7. Solar cell
8. Controlled switch
9. Switch block
10. Terminator, constants and signal converters
11. Power gui

2.2DRIVE CYCLE:

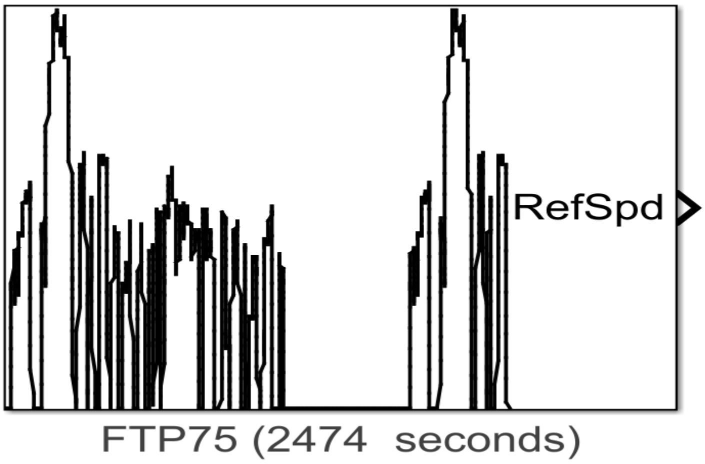


Fig 2.1 FTP75 drive cycle

The Drive Cycle Source block generates a standard or user-specified longitudinal drive cycle. The block output is the specified vehicle longitudinal speed, which you can use to:

- Predict the engine torque and fuel consumption that a vehicle requires to achieve desired speed and acceleration for a given gear shift reference.
- Produce realistic velocity and shift references for closed loop acceleration and braking commands for vehicle control and plant models.
- Study, tune, and optimize vehicle control, system performance, and system robustness over multiple drive cycles.

2.3 MOTOR CONTROLLER:

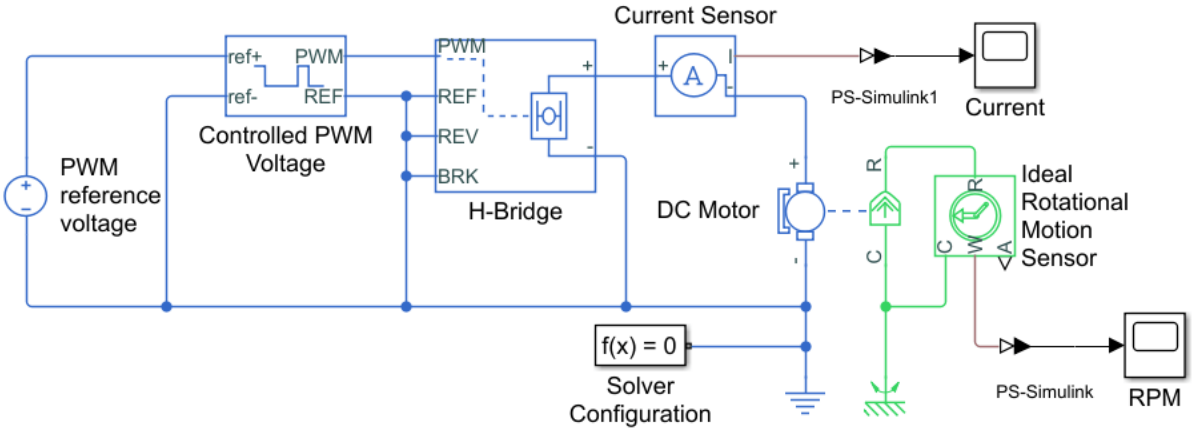


Fig 2.2 motor controller

Block	Description
Solver Configuration	Defines solver settings that apply to all physical modeling blocks
Controlled PWM Voltage	Generates the signal that approximates a pulse-width modulated motor input signal
H-Bridge	Drives the DC motor
DC Motor	Converts input electrical energy into mechanical motion
Current Sensor	Converts the electrical current that drives the motor into a measurable physical signal proportional to the current
DC Voltage Source	Generates a DC voltage
Electrical Reference	Provides the electrical ground
Mechanical Rotational Reference	Provides the mechanical ground
Ideal Rotational Motion Sensor	Converts the rotational motion of the motor into a measurable physical signal proportional to the motion

Table 2.1 description of motor controller blocks

2.3.1 Motor Input Signal Parameters

You generate the motor input signal using these blocks:

The DC Voltage Source block (PWM reference voltage) generates a constant signal.

- The Controlled PWM Voltage block generates a pulse-width modulated signal.
- The H-Bridge block drives the motor.

In this example, all input ports of the H-Bridge block except the PWM port are connected to ground. As a result, the H-Bridge block behaves as follows:

- When the motor is on, the H-Bridge block connects the motor terminals to the power supply.
- When the motor is off, the H-Bridge block acts as a freewheeling diode to maintain the motor current.

In this example, you simulate the motor with a constant current whose value is the average value of the PWM signal. By using this type of signal, you set up a fast simulation that estimates the motor behaviour.

1. Set the DC Voltage Source block parameters as follows:
    - **Constant voltage** to 2.5
2. Set the Controlled PWM Voltage block parameters as follows:
    - **PWM frequency** to 4000
    - **Simulation mode** to Averaged

      This value tells the block to generate an output signal whose value is the average value of the PWM signal. Simulating the motor with an averaged signal estimates the motor behaviour in the presence of a PWM signal. To validate this approximation, use value of PWM for this parameter.
3. Set the H-Bridge block parameters as follows:

- **Simulation mode** to Averaged

This value tells the block to generate an output signal whose value is the average value of the PWM signal. Simulating the motor with an averaged signal estimates the motor behaviour in the presence of a PWM signal. To validate this approximation, use value of PWM for this parameter.

2.4 VEHICLE BODY:

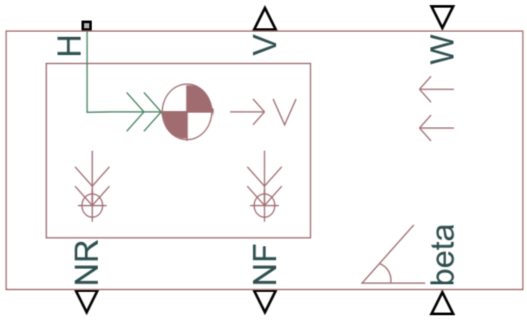


Fig 2.3 vehicle body block

The Vehicle Body block represents a two-axle vehicle body in longitudinal motion. The vehicle can have the same or a different number of wheels on each axle. For example, two wheels on the front axle and one wheel on the rear axle. The vehicle wheels are assumed identical in size. The vehicle can also have a centre of gravity (CG) that is at or below the plane of travel.

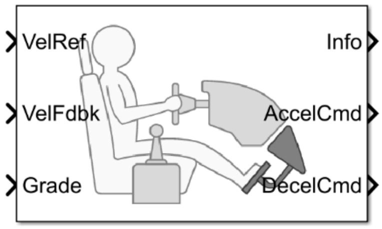
The block accounts for body mass, aerodynamic drag, road incline, and weight distribution between axles due to acceleration and road profile. Optionally include pitch and suspension dynamics. The vehicle does not move vertically relative to the ground.

The block has an option to include an externally-defined mass and an externally-defined inertia. The mass, inertia, and centre of gravity of the vehicle body can vary over the course of simulation in response to system changes.

2.5 TIRE:

The Tire-Road Interaction (Magic Formula) block models the interaction between the tire tread and road pavement. The longitudinal force arising from this interaction is given by the magic formula, an empirical equation based on four fitting coefficients. Tire properties such as compliance and inertia are ignored.

2.6 LONGITUDINAL DRIVER:

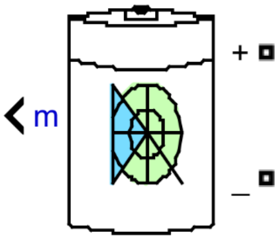


Longitudinal Driver

The Longitudinal Driver block implements a longitudinal speed-tracking controller. Based on reference and feedback velocities, the block generates normalized acceleration and braking commands that can vary from 0 through 1. You can use the block to model the dynamic response of a driver or to generate the commands necessary to track a longitudinal drive cycle.

2.7 BATTERY:

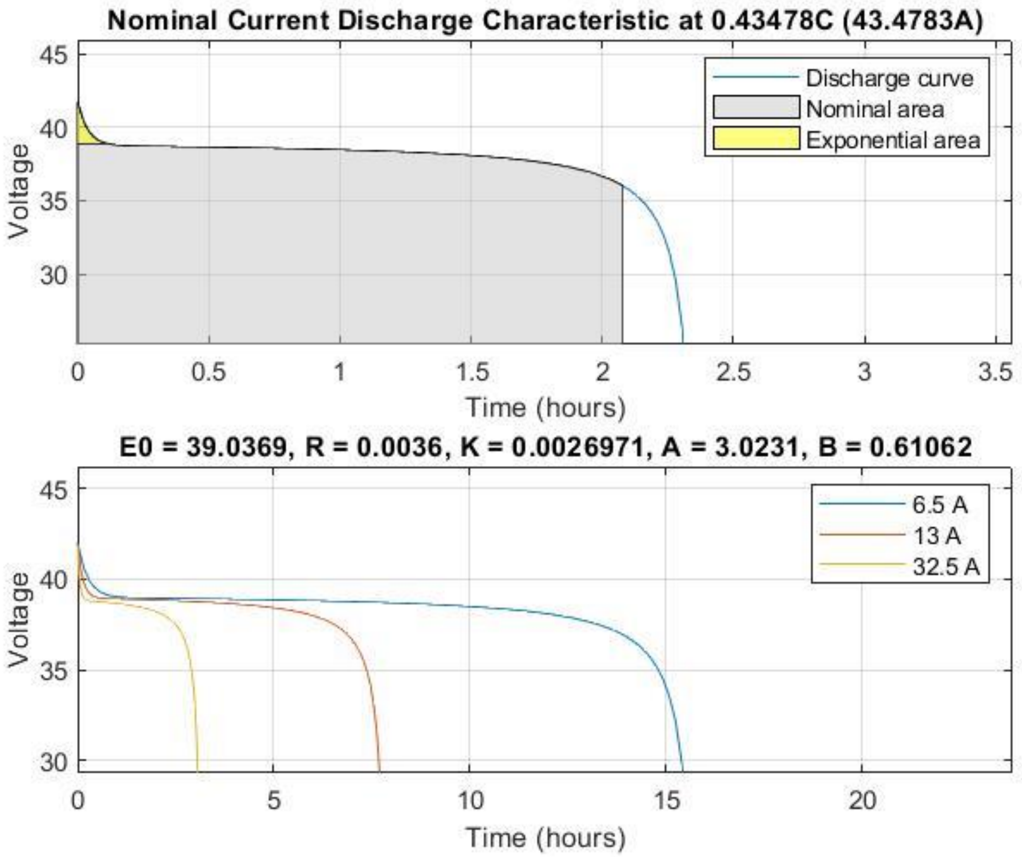
The Battery block implements a generic dynamic model that represents most popular types of rechargeable batteries.



2.7.1 Charge and Discharge Characteristics

circuit parameters can be modified to represent a specific battery type and its discharge characteristics. A typical discharge curve consists of three sections.

The first section represents the exponential voltage drop when the battery is charged. The width of the drop depends on the battery type. The second section represents the charge that can be extracted from the battery until the voltage drops below the battery nominal voltage. Finally, the third section represents the total discharge of the battery, when the voltage drop rapidly.



. Fig 2.4 discharge characteristics

The state of charge (SOC) for a battery is a measure of battery's charge, expressed as a percent of the full charge. The depth of discharge (DOD) is the numerical compliment of the SOC, such that *DOD* = 100% - *SOC*.

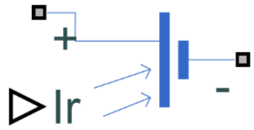
For example, if the SOC is:

- 100% — The battery is fully charged and the DOD is 0%.
- 75% — The battery is 3/4 charged and the DOD is 25%.
- 50% — The battery is 1/2 charged and the DOD is 50%.
- 0% — The battery is has 0 charge and the DOD is 100%.

Parameter	Value
Rated Capacity	100 Ah
Internal Resistance	36 mΩ
Rated Capacity	6.5 Ah
Maximum Capacity (b)	7 Ah (5.38 h * 1.3 A)
Fully Charged Voltage (c)	41.9035 V
Capacity @ Nominal Voltage (a)	90.4348 Ah
Exponential Voltage (e)	38.8939 V
Exponential Capacity (e)	4.91 Ah

Table 2.2 Battery specifications

2.8 SOLAR CELL:

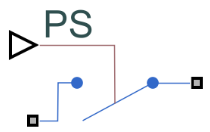


The Solar Cell block represents a solar cell current source.

The solar cell model includes the following components:

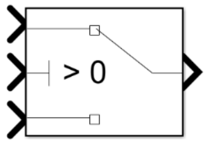
- Solar-Induced Current
- Thermal Port

2.9 CONTROLLED SWITCH:



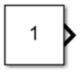
The Switch block models a switch controlled by an external physical signal. If the external physical signal PS is greater than the value specified in the **Threshold** parameter, then the switch is closed, otherwise the switch is open.

2.10 SWITCH BLOCK:

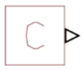


The Switch block passes through the first input or the third input signal based on the value of the second input. The first and third inputs are data input. The second input is a control input. Specify the condition under which the block passes the first input by using the Criteria for passing first input and Threshold parameters.

2.11 TERMINATORS, CONSTANTS AND SIGNAL CONVERTERS:

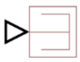


The Constant block generates a real or complex constant value

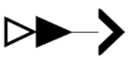


The PS Constant block generates a physical signal of a constant value. You specify the value and unit of the signal as the **Constant** parameter.

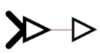
The Terminator block to cap blocks whose output ports do not connect to other blocks



The PS Terminator block to cap physical signal output ports that do not connect to other blocks.



The PS-Simulink Converter block converts a physical signal into a Simulink® output signal.



The Simulink-PS Converter block converts the input Simulink® signal into a physical sig1nal.

2.12 POWER GUI:

You need the powergui block to simulate any Simulink model containing Simscape™ Electrical™ Specialized Power Systems blocks. It stores the equivalent Simulink circuit that represents the state-space equations of the model.

When using one powergui block in a model:

- Place the powergui block in the top-level diagram for optimal performance.
- Make sure that the block is named powergui.

CHAPTER 3

SOLAR ELECTRIC VEHICLE

3.1 BLOCK DIAGRAM OF ELECTRIC VEHICLE

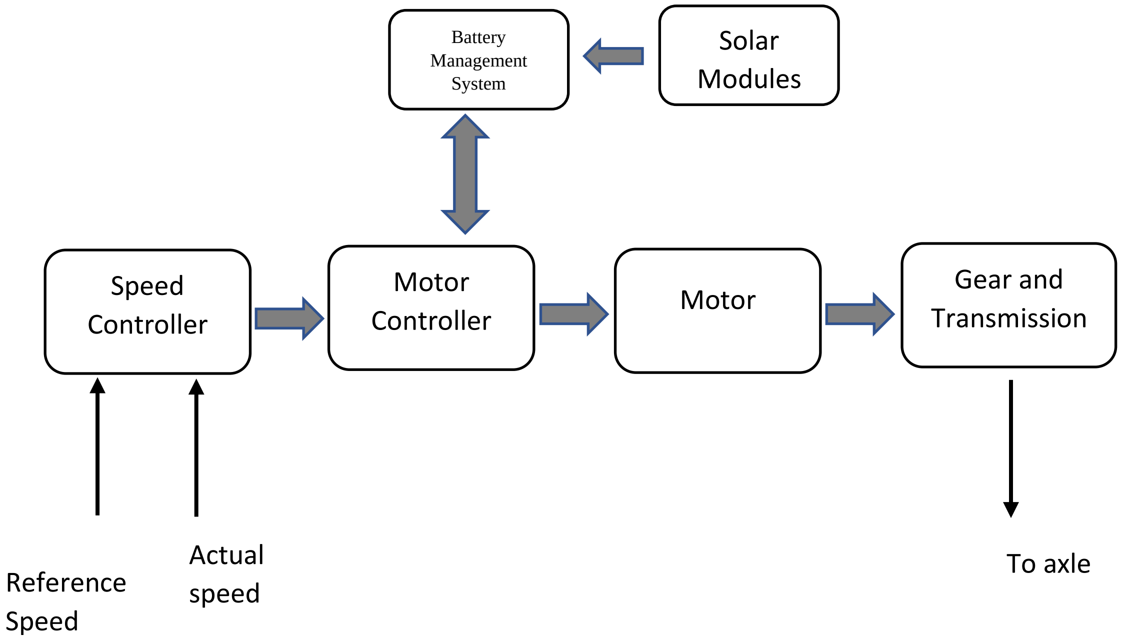


Fig 3.1 Block diagram of ELECTRIC VEHICLE

The above diagram represents the basic block diagram of solar electric vehicle. Here speed controller continuously takes reference speed and actual speed as feedback parameters and compares them. This speed controller gives control signals to motor controller according to driver requirements. This motor controller then controls all the parameters of the motor like speed torque voltage to get required output. The output of the motor is mechanically transmitted to axle by gear and transmission mechanism.

Motor controller take supply from the battery management system. Motor controller must be able control regenerate power also. This regenerative power can charge the battery. Solar subsystem also charges the battery management system whenever it is subjected to irradiance.

CHAPTER 4

SIMULATION MODELS AND SUBSYSTEMS

4.1COMPLETE SIMULATION DIAGRAM OF SOLAR ELECTRIC VEHICLE

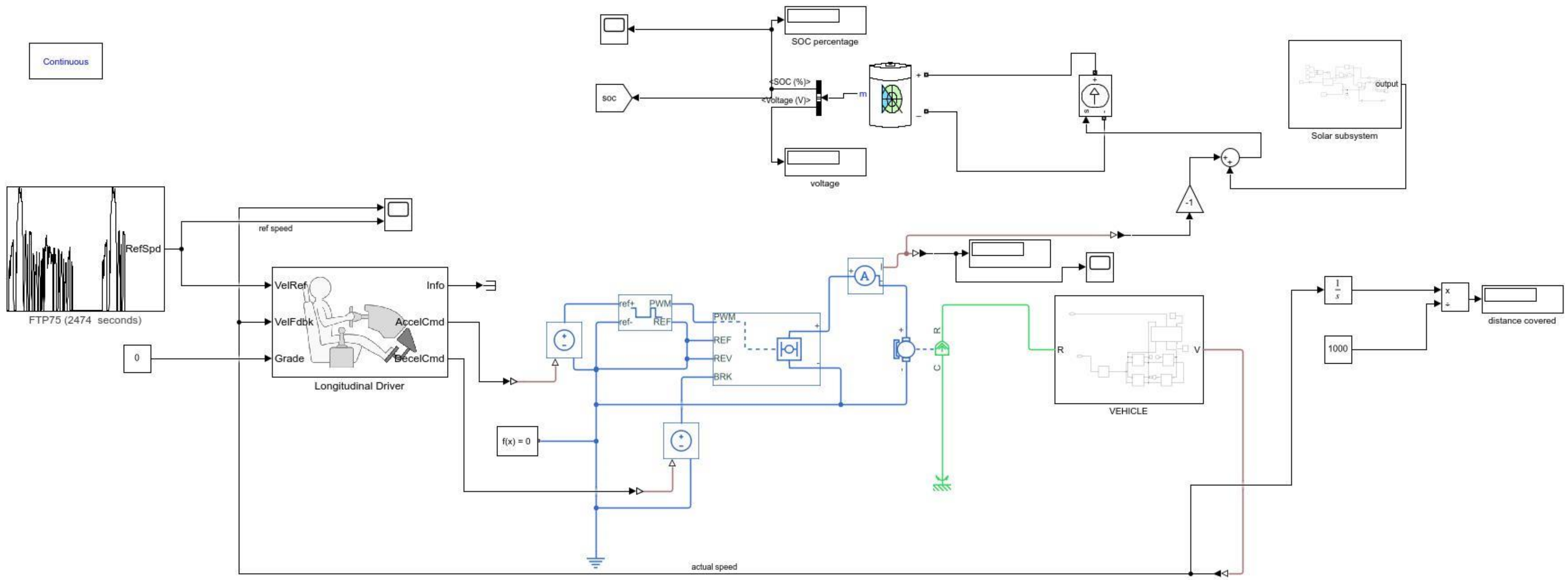


fig 4.1 simulation diagram

This connection diagram represents the simulation diagram of solar electric vehicle Different subsystems used in this are elaborated in subsequence sections. We give drive cycle source the longitudinal driver block which also take actual speed as feedback and compare both. This driver block controls the motor controller. The shaft of the motor (R port) is connected to the r port of vehicle subsystem.

The output of the vehicle body is m/s. Hence, if we integrate it in continuous time ,(by 1/s block) we get distance covered in meters .We get distance covered in kms,if we divide it with 1000.

Whenever the motor is rotated in +ve direction it will discharge the battery ,meanwhile if motor is operating in regenerative mode, the battery will charge .Solar subsystem also charges the battery when it is subjected irradiance.

4.2 VEHICLE BODY SUBSYSTEM :

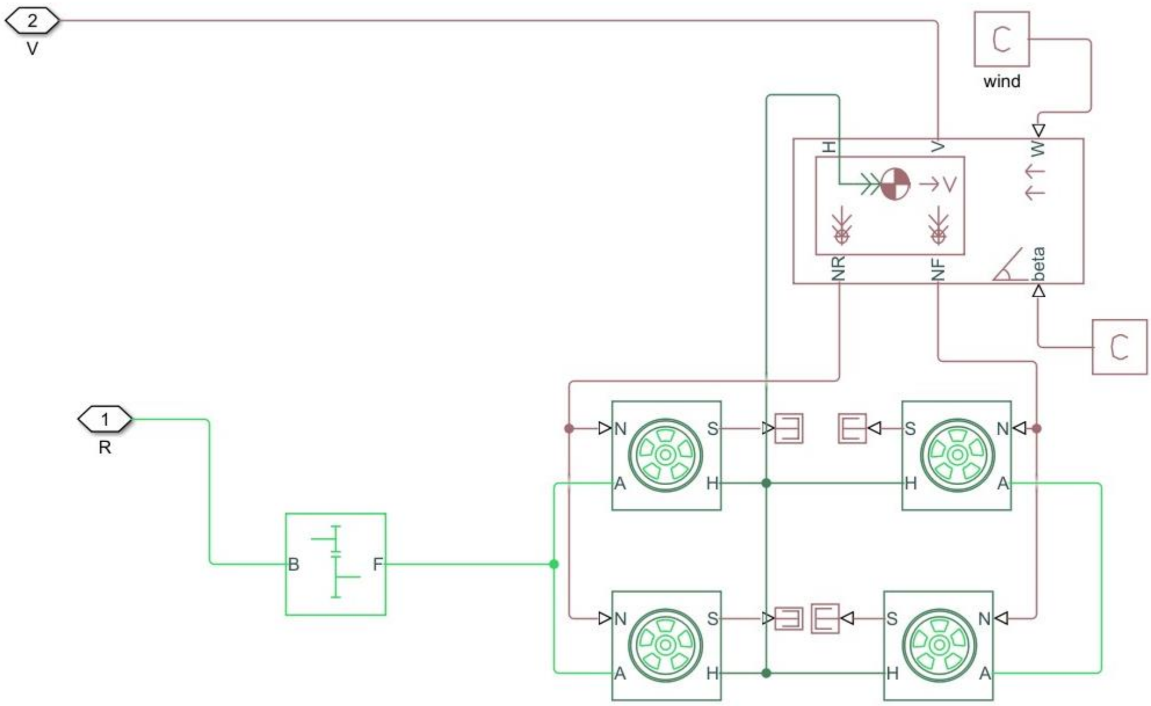


fig 4.2 Vehicle body subsystem

Vehicle subsystem mainly consists of vehicle body block and tire block. Hub port of the vehicle body and all tires are connected together. Here slip port of tire is not used and hence terminated with physical signal terminator. The beta (road inclination angle) port is connected to physical signal constant whose value is zero as our assumption is road has no inclination. Two front tires are connected to single axle by connected the axle port of two tired together. (similarly for back tires). Back axle is connected to the mechanical output of the through simple gear. NR port of vehicle body is connected to the N port of the both back axle two tires.(similar to front tires) V port is taken as output from the vehicle subsystem.

4.3 SOLAR SUBSYSTEM :

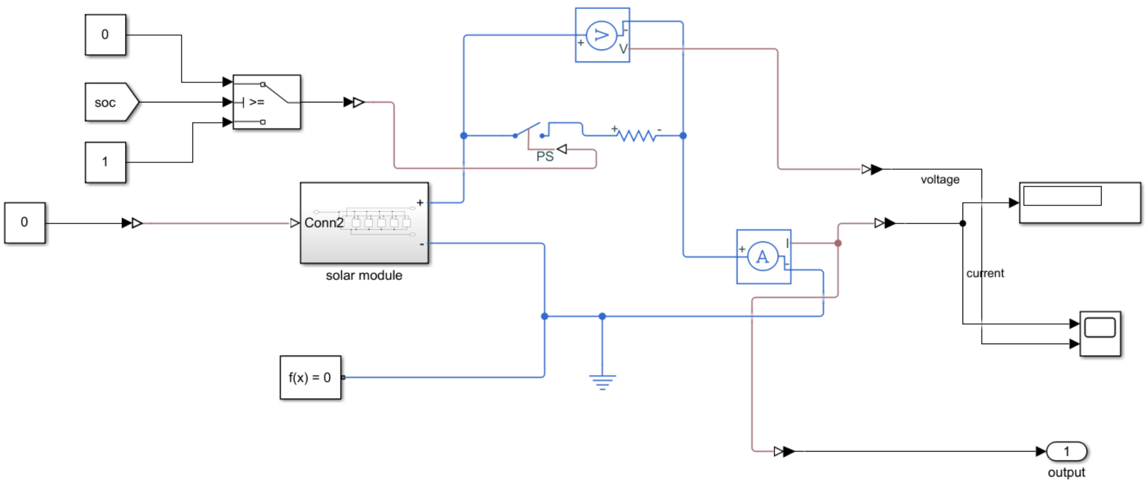


Fig 4.3 solar subsystem

The above diagram shows us the solar subsystem . Solar subsystem is designed in such away that if battery percentage (SOC) reaches 100%,then the output from this subsystem must be zero .This function is achieved by using block and physical signal controlled switch block.

SOLAR MODULE :

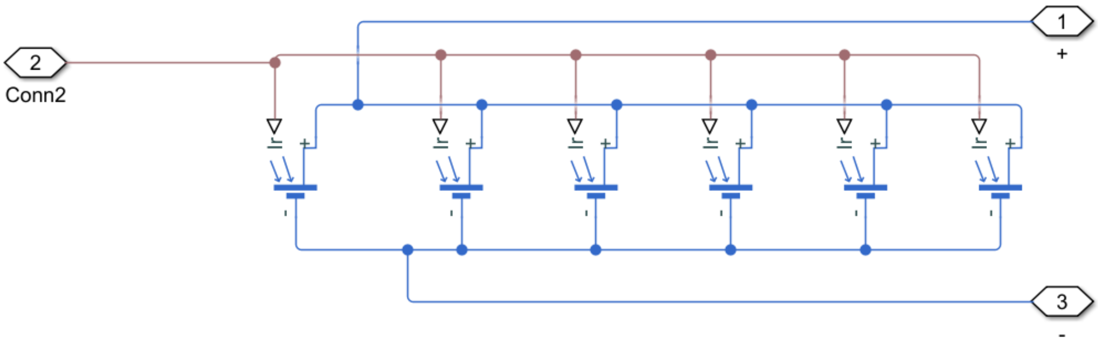


Fig 4.4 solar module

This (fig 4.4)diagram represents the internal design connection of solar cells .Here 5 modulkes,each module consists of 9 series cells are connected in parallel .Each module has rating of short circuit current of 2A and open circuit voltage of 4volts.

4.4 THEORETICAL CALCULATIONS

Torque :

$$\text{Power P} = \frac{2\pi NT}{60} \text{ watts}$$

$$\text{Torque T} = \frac{60*P}{2\pi N}$$

$$= \frac{60*10000}{2*\pi*1950}$$

$$= 48.97 \text{ Nm}$$

SPEED :

$$\text{Angular speed } \omega = \frac{2\pi N}{60} \text{ rad/sec}$$

$$= 204.20 \text{ rad/sec}$$

$$\text{Velocity in m/s } v = \omega * r \text{ m/s}$$

$$= 204.20*0.3$$

$$= 61.26 \text{ m/s}$$

$$\text{Velocity in kmph } V = 220.236 \text{ km/hr}$$

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Drive cycles used :

1.FTP75

2.CUEDC

3.BAC

4.EUDC

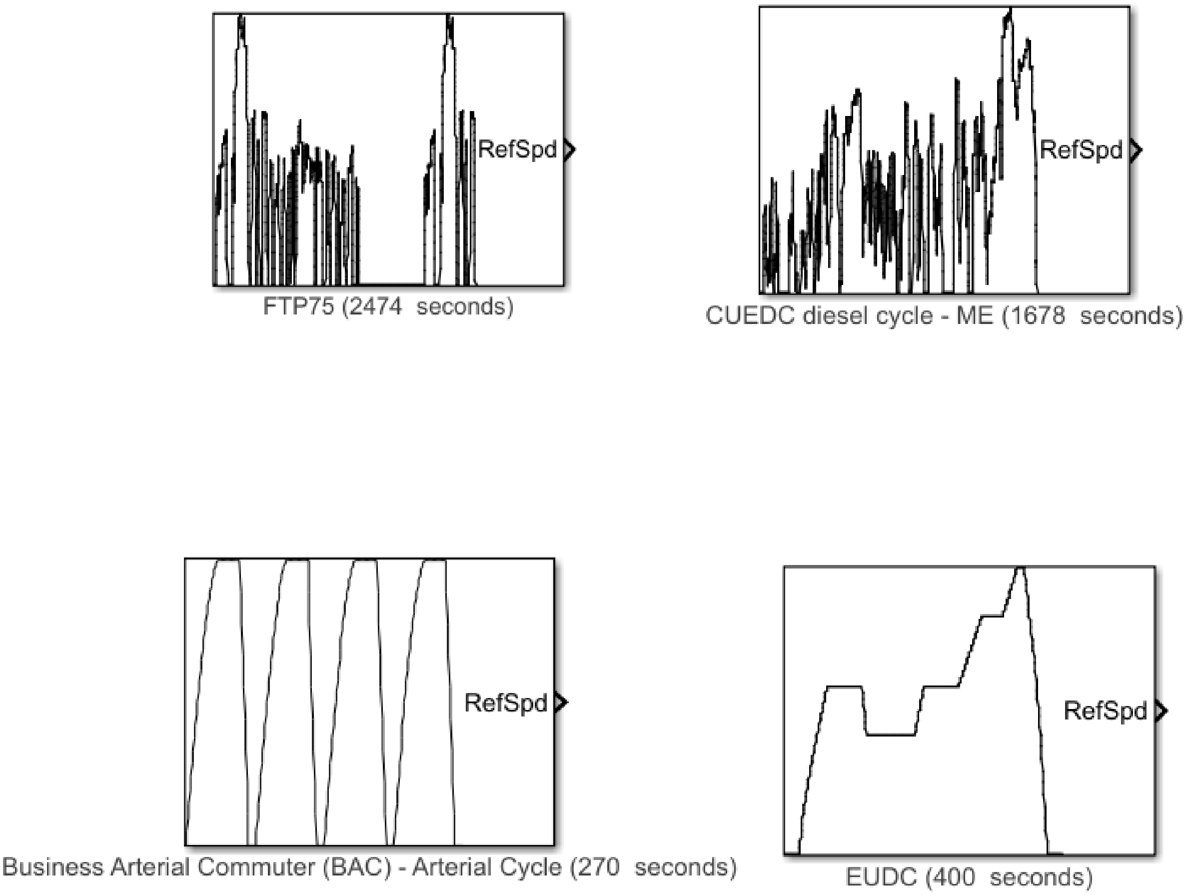


Fig 5.1 drive cycles

FTP75

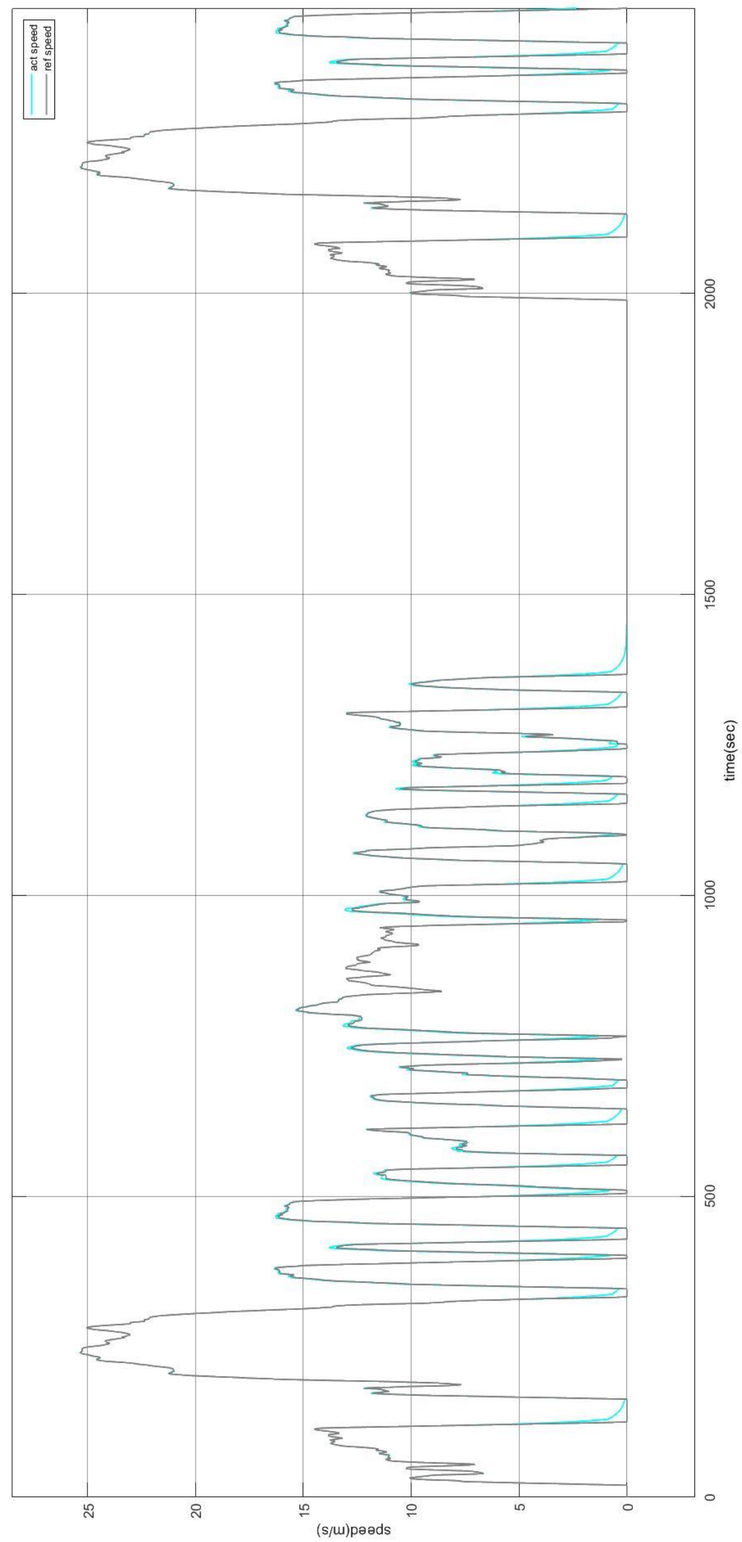


Fig 5.2 FTP75 drive cycle

This graph represents the simulation results when the vehicle is driven with FTP 75 drive cycle. Both actual speed and reference speed are plotted in single graph for result observation.

FTP75 SOC

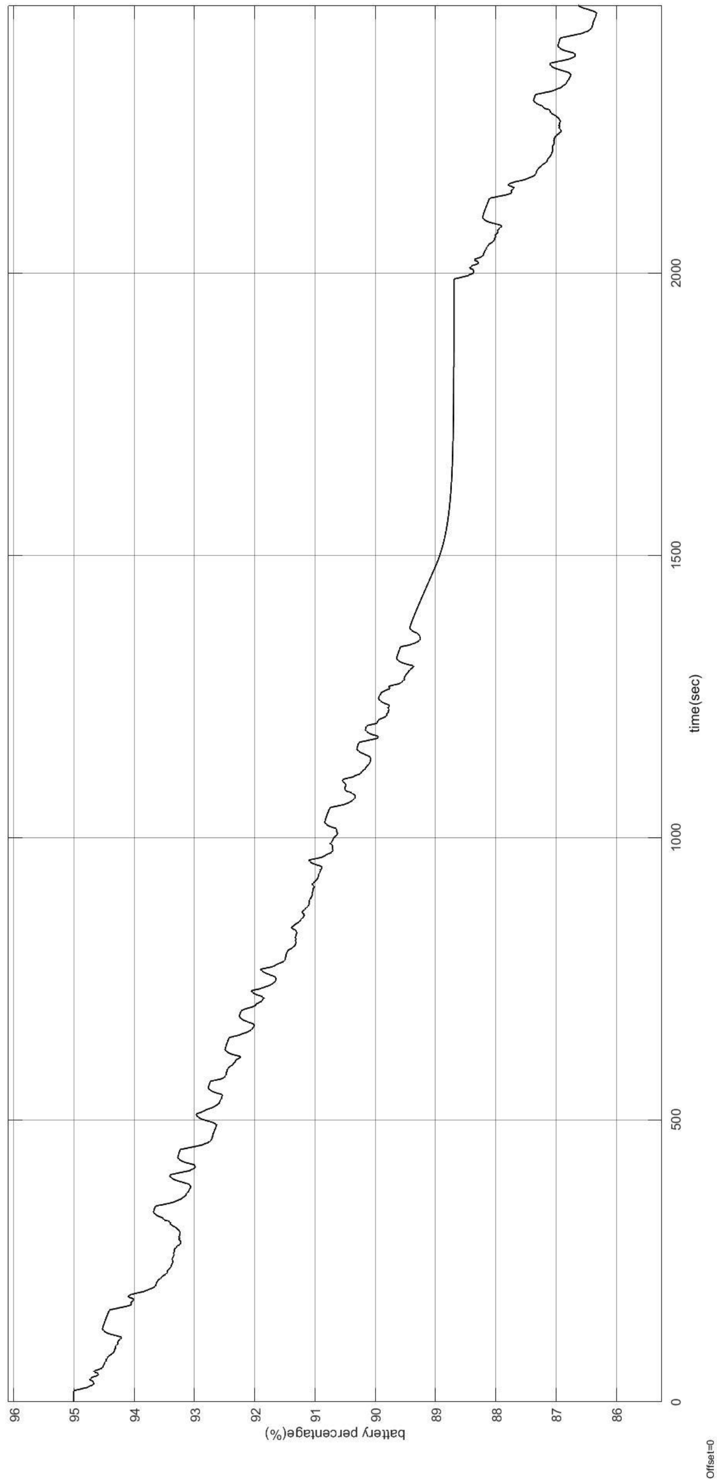


Fig 5.3 soc for FTP75 drive cycle

This graph represents the battery percentage variation when vehicle is subjected to FTP 75 drive cycle .Here we can observe the charging of the battery when the motor is operating in regenerative mode.

WITHOUT SOLAR

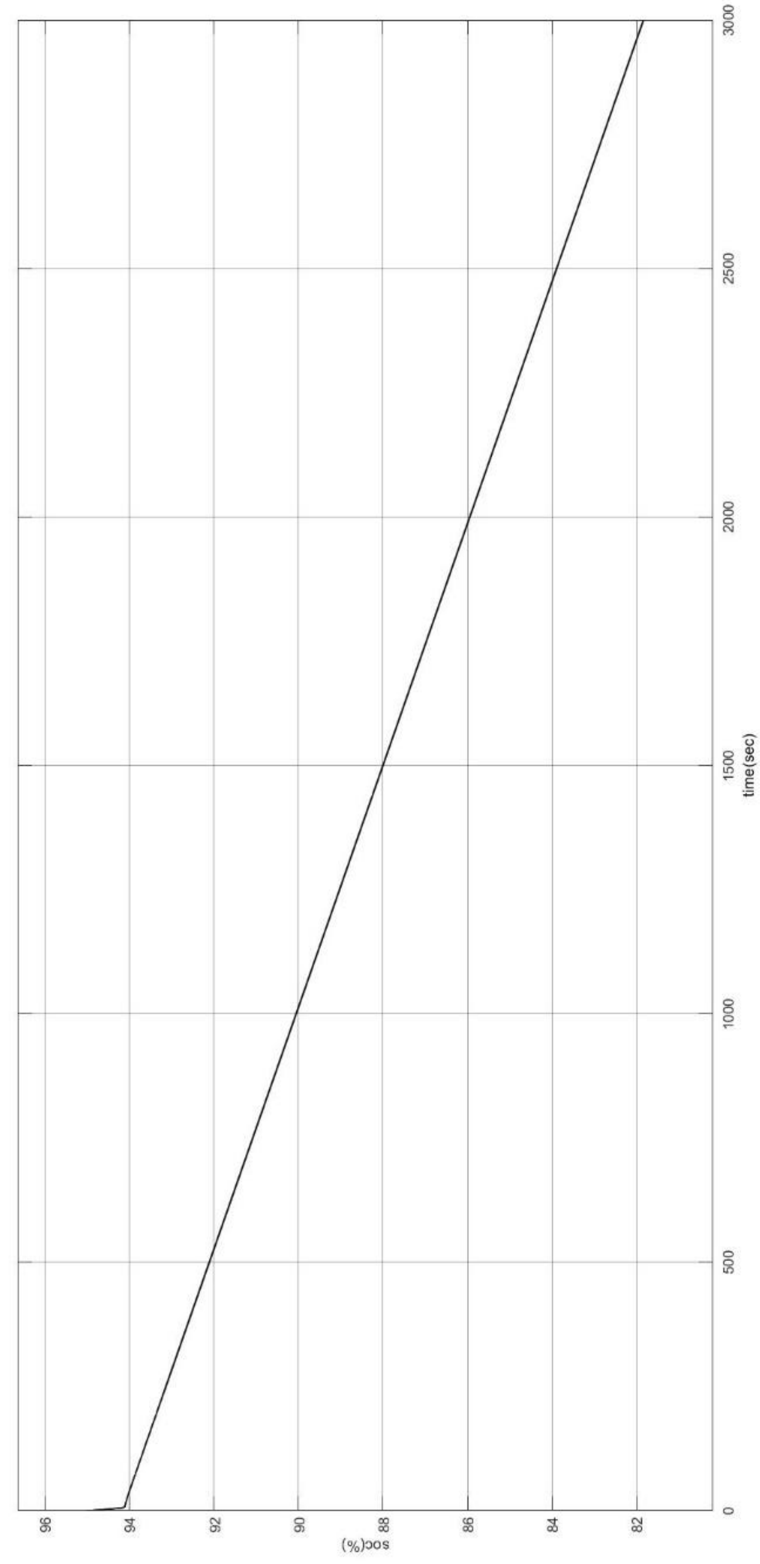
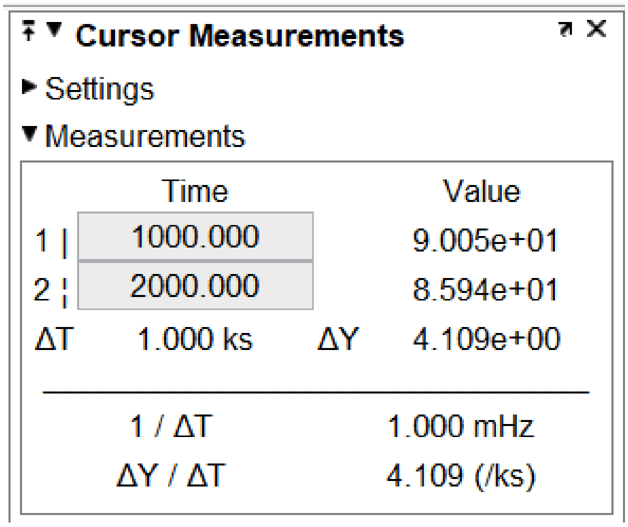


Fig 5.4 SOC WITHOUT SOLAR



This graph represents battery percentage variation keeping output from solar subsystem zero. We can observe that slope of this curve is 4.109 for 1000 seconds.

SOC WITH SOLAR

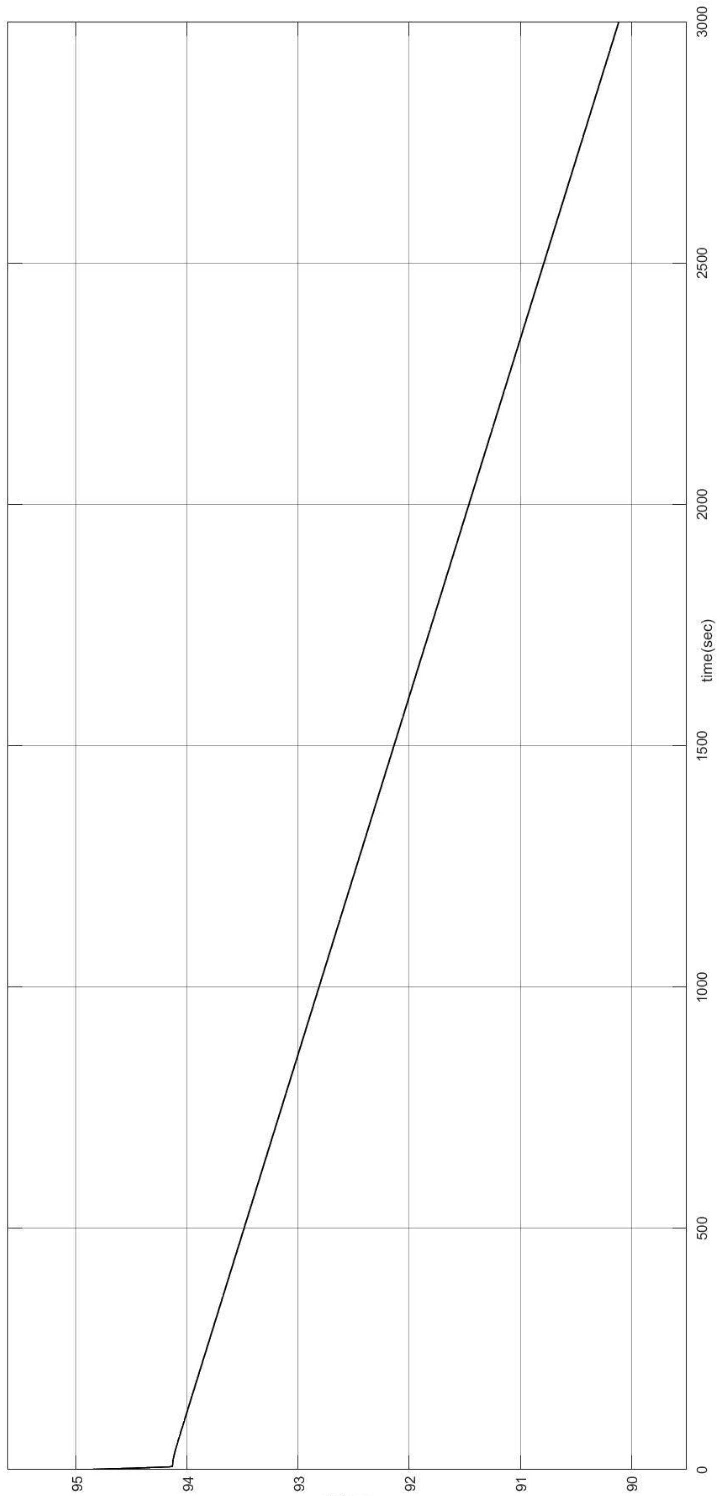
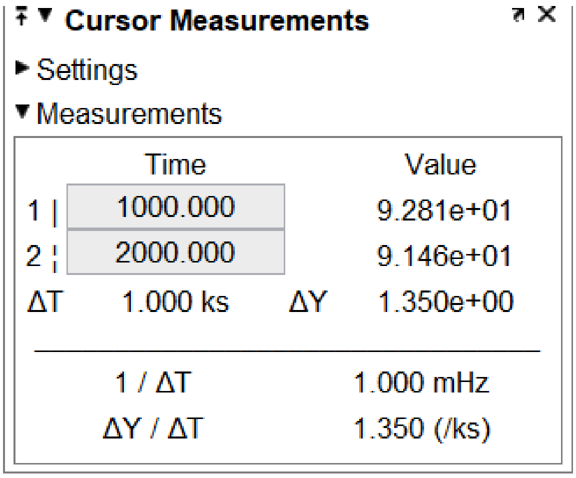


Fig 5.5 soc graph (with solar)



This graph represents battery percentage variation while vehicle is supplied with both battery cells and solar modules. We can observe that slope of this curve is 1.350 for 1000 seconds. Irradiance used for this test is 300.

From the above two observations we can say that the discharge rate of the battery is reduced while the vehicle is running with the aid of solar modules which is expected (without solar module discharge slope is 4.109 and with solar module discharge rate is 1.350) .

BAC DRIVE CYCLE

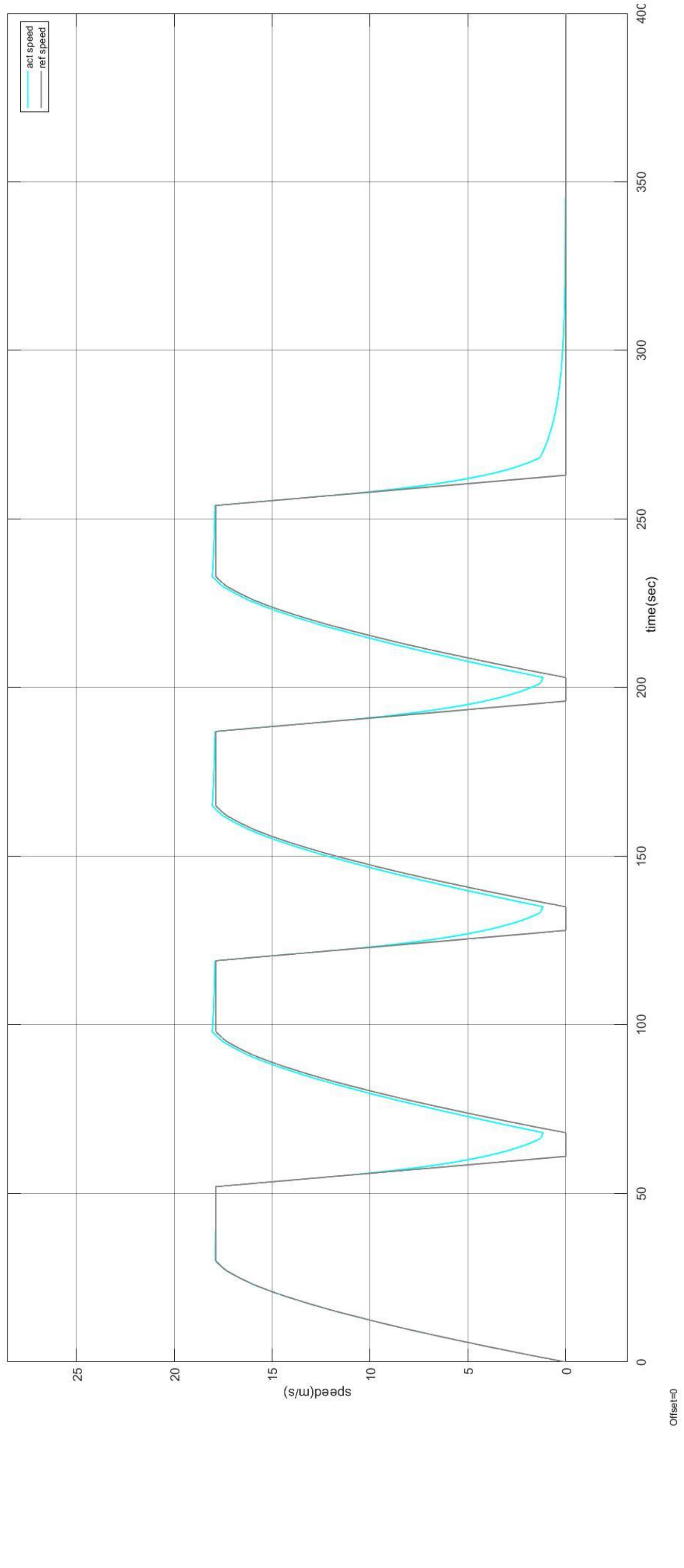


Fig 5.6 BAC drive cycle

SOC FOR BAC DRIVE CYCLE

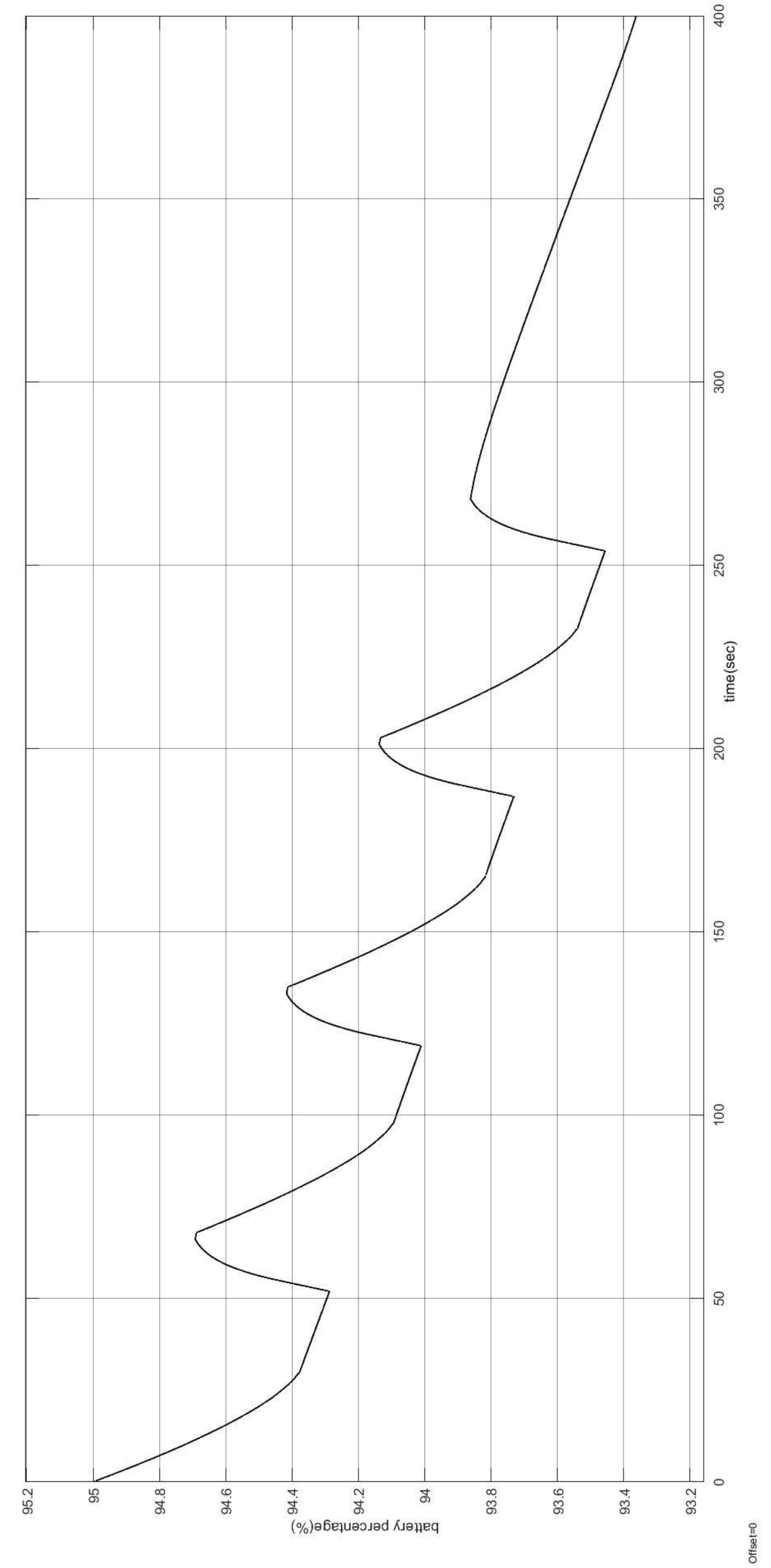


Fig 5.7 SOC variation for bac drive cycle

Above fig 5.5 shows graph of actual speed attained by the vehicle and reference drive cycle velocity variations with respect to time .Here we can observe that actual speed is not following the path of the reference speed when the vehicle is subjected to steep changes in speed in this drive cycle after 50 seconds there is steep change in the speed , due to inertia of the vehicle it cannot follow the reference speed at this fast variations .In the SOC graph we also observed that while speed is reducing battery is charging due to regenerative braking.

5.2 DRIVE CYCLE ANALYSIS:

Drive cycle	Irradiance (w/m^2)	SOC (%)	Distance covered (kms)
FTP75	0	86.5	18.65
	500	89.93	
EUDC	0	93.42	6.993
	300	93.87	
BAC	0	93.83	3.32
	400	94.13	
CEUDC	0	88.07	15.08
	800	91.8	

Table 5.1 drive cycle analysis

Above table shows us the data of battery percentage and distance covered when vehicle is simulated with different drive cycle. For this analysis, we kept initial charge of the battery as 95%. Here we can observe that variation in battery percentage when it is run with and without solar module. If solar module is subjected to more irradiance for more time, we can observe a considerable difference between SOC of battery driven with different drive cycle. This is the reason for slight deviation (in battery percentage with and without solar module) for EUDC drive cycle as compared to FTP 75 drive cycle.

CHAPTER 6

FUTURE SCOPE AND CONCLUSION

6.1 FUTURE SCOPE

By using this simulation, we can test the performance of the electric vehicle in different aspects. Testing the electric vehicle by practically implementing is too costly, so by using this type of simulations we can perform difference test and observe the results very and observe the results very simply. We can easily modify the simulation as per our future advancement modification requirements. We can test the simulation with different types of motors by replacing the dc motor block in proposed system.

6.2 CONCLUSION:

In this study we observed response of electric vehicle model subjected to different drive cycles and we found the battery energy consumption variations with and without aid of solar modules. We also observed the power feeding back to batteries in regenerative mode of operation.

6.3 REFERENCES

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