STUDY OF BATTERY CHARGING AND DISCHARGING CHARACTERISTICS OF DIFFERENT BATTERIES ON DIFFERENT LOADS

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ABSTRACT

Earlier Lead Acid batteries were available and used widely since Lithium Ion batteries were not discovered .The Lead Acid are still used since they have low cost of initial investment and have low specific energy and are capable of high discharge rates . When Lithium Ion batteries came into practice , they were found to be having light weight , able to provide constant power ,are temperature tolerant and charging is fast and safe .Though Lead Acid battery are cheap in initial investment but lithium Ion battery although costly requires less investment and service . Since nowdays both batteries intermixed charging is used . The mobile charging is done in car itself. The car charged from lead acid or lithium ion depends upon type of battery used . Whereas mobile has lithium ion battery . So when mobile charging is done in car , there is intermixing of two batteries. And so a study forcasing the characteristics nature in regards to charging and discharging regimes i.e state of charge and current naturehood during these period is envitable . So now we are charging Lithium Ion battery with Lead Acid or Lithium Ion or vice –versa .So due to this at times , we observe that there is too much delay in charging . So it becomes evident to check the Charging and Discharging characteristics of both Lead Acid and Lithium Ion batteries separately and also through their series-parallel combinations to discover the malfunctioning in it in order to raise the points so that further more work could be done in this respect . By studying the nature both through the display and waveforms , we are able to demonstrate the peculiarities and able to derive the basic inbuilt in their charging and discharging patterns . Thus we are getting much better throughput in understanding .

"Batteries with good characteristics will help the user to operate their devices safely .A good battery has to be dependable and reliable on load varying working conditions .A rectified Battery management system not only possess good energy density but it also not affected by the temperature variations developed in working environment .So an attempt is made to survey the SOC and current characteristics to understand their limitations .

CHAPTER 1 INTRODUCTION

1.1 DETAILS OF LEAD ACID BATTERY:-

The lead-acid batteries provide the best value for power and energy per kilowatt-hour; have the longest life cycle and a large environmental advantage in that they are recycled at an extraordinarily high rate. No other chemistry can touch the infrastructure that exists for collecting, transporting and recycling lead-acid batteries. The rechargeable and secondary batteries category includes lead acid batteries. Despite the battery's low energy-to-volume and energy-to-weight ratios, it can deliver higher surge currents. This refers to the fact that lead acid cells have a high power-to-weight ratio. These are the batteries that transform chemical energy into electrical energy by using lead peroxide and sponge lead. Because of the elevated cell voltage levels and low cost, these are commonly used in substations and power systems.

Types of Lead Acid Battery :- **Sealed Type** – This type of lead-acid battery is merely a variation on the flooded type. About the fact that no one has access to each cell in the battery, the internal architecture is nearly identical to that of a flooded form. The biggest difference with this form is that there is a sufficient volume of acid to allow for a smooth flow of chemical reactions during the battery's existence.

VRLA Form – Also known as a sealed type of battery, these are known as Valve Controlled Lead Acid batteries. At the point of charging, the value controlling process allows for the stable evolution of O_2 and H_2 gases.

AGM Type – This is an Absorbed Glass Matte battery, which allows the electrolyte to be stopped at the plate material. This type of battery improves the discharge and charging processes' performance. These are mostly used in motorsports and engine start-up applications.

Gel Type – This is a wet type of lead-acid battery in which the electrolyte in the cell is silica-based, causing the material to stiffen. As compared to other forms, the recharge voltage values of the cell are small, and it also has more sensitivity.

Lead Acid Battery Chemical Reaction:- The chemical reaction in the battery occurs primarily during the discharging and recharging processes, and it is described as follows: When the battery is fully charged, the anode and cathode are PbO_2 and Pb, respectively. As these are associated with resistance, the battery is discharged, and the electrons are charged in the opposite direction. The H_2 ions pass into the anode and fuse together to form an atom. It reacts with PbO_2 to produce $PbSO_4$, which is white in color. Similar to the sulfate ion, the sulfate ion moves into the cathode, where it is converted into SO_4. It becomes lead sulfate as it reacts with the lead cathode.

$PbSO_4 + 2H = PbO + H_2O$ $\quad$ $PbO + H_2SO_4 = PbSO_4 + 2H_2O$ $\quad$ $PbO_2 + H_2SO_4 + 2H = PbSO_4 + 2H_2O$

The cathode and anodes are connected to the negative and positive edges of the DC supply during the recharging process. The positive H_2 ions pass into the cathode, gaining two electrons and becoming an H_2 atom. It forms lead and sulphuric acid after a chemical reaction with lead sulfate.

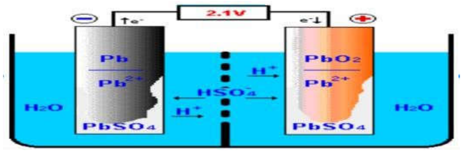


Figure :- Lead Acid battery chemistry

1.2 DETAILS OF LITHIUM – ION BATTERY:-

Lithium –Ion batteries are now popular in majority of electronic portable devices like Mobile phone, Laptop, Digital Camera, etc. due to their long lasting power efficiency. These are the most popular rechargeable batteries with advantages like best energy density, negligible charge loss and no memory effect. Li-Ion battery uses Lithium ions as the charge carriers which move from the negative electrode to the positive electrode during discharge and back when charging. During charging, the external current from the charger applies an over voltage than that in the battery. This forces the current to pass in the reverse direction from the positive to the negative electrode where the lithium ions get embedded in the porous electrode material through a process called Intercalation. The Li- Ions pass through the non-aqueous electrolyte and a separator diaphragm. The electrode material is intercalated lithium compound.

The negative electrode of the Li-Ion battery is made up of carbon and the positive electrode is a metal oxide. The most commonly used material in the negative electrode is Graphite while that in the positive electrode may be Lithium cobalt oxide, Lithium ion phosphate or Lithium manganese oxide. Lithium salt in an organic solvent is used as the electrolyte. The electrolyte is typically a mixture of organic carbonates like Ethylene carbonate or Diethyl carbonate containing lithium ions. The electrolyte uses anion salts like Lithium hexa fluoro phosphate, Lithium hexa fluoro arsenate monohydrate, Lithium per chlorate, Lithium hexa fluoro borate etc. Depending upon the salt used, the voltage, capacity and life of the battery varies. Pure lithium reacts with water vigorously to form lithium hydroxide and hydrogen ions. So the electrolyte used is non aqueous organic solvent. The electrochemical role of the electrodes charge between anode and cathode depends on the direction of current flow.

Li Ion Battery Reaction:-

In the Li-Ion battery, both the electrodes can accept and release lithium ions. During the Intercalation process, the lithium ions move into the electrode. During the reverse process called de intercalation, the lithium ions move back. During discharging, the positive lithium ions will be extracted from the negative electrodes and inserted into the positive electrode. During the charging process, the reverse movement of lithium ions takes place.

Advantages of Lithium – Ion Battery:-

1. Light weight compared to other batteries of similar size
2. Available in different shape including Flat shape
3. High open circuit voltage that increases the power transfer at low current
4. Very low self-discharge rate of 5-10% per month. Self-discharge is around 30% in NiCd and NiMh batteries.
5. Eco-friendly battery without any free lithium metal .

Disadvantages of Li-Ion Battery:

1. The deposits inside the electrolyte over time will inhibit the flow of charge. This increases the internal resistance of the battery and the cell's capacity to deliver current gradually decreases.
2. High charging and high temperature may leads to capacity loss
3. When overheated, Li-Ion battery may suffer thermal run away and cell rupture.

Applications :-
Lithium Ion batteries find a massive range of applications right from smart watches to renewable energy storage systems to electric vehicles. The upcoming innovations in Lithium Ion batteries include factors which can help the battery tolerate fast charging, offer higher capacity and increased safety.

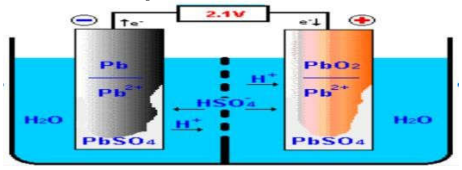


Figure :- Lead Acid battery chemistry

Lead Acid Battery Life :- The optimum operating temperature for a lead acid battery is 250 degrees Celsius, or 770 degrees Fahrenheit. Longevity is shortened as the temperature spectrum widens. According to the law, any 80°C rise in temperature decreases the battery's half-life.

A performance-operated battery with a 250C operating temperature has a lead acid battery life of ten years. And it only has a 5-year life span when maintained at 330 degrees Celsius.

Applications:-Used in electric motors , Submarines ,Nuclear submarines.

1.3 MATLAB:

Matlab is a high-level language with interactive environment which enables to performing computationally intensive tasks faster than with traditional programming languages such ac C , C++ and FORTRAIN . It has various componenets to support simulation of various complex electrical and power electronics systems .

1.3.1 Simulink:

Simulink is a plateform for multidomain simulation and Model-Based Design for dynamic systems . It provides an interactive graphical environment and a customizable set of block libraries and can be extended for specialized applications . Simulink library Information inserts a table that lists library links in the current model , system , or block .

1.3.2 Simscape:

Simscape extends Simulink with tools for modelling and simulating basic electrical circuits and detailed electrical power systems. These tools facilitate modelling of the generation , Transmission , distribution , and consumption of electrical power , as well as its conversion into mechanical power . Sim Power System is well suited for the development of complex , self-contained power systems and power utility applications .

1.4 Battery Performance Parameters:-

The Performance Parameters of Battery are SOC(State of Charge) ,Depth of Discharge and Charging and Discharging rates .

1.4.1 SOC :-It gives the ratio of the amount of energy presently stored in the battery to the Nominal rated capacity . It is the fraction of the battery capacity that has been used over the total available from the battery .

1.4.2 Depth of Discharge :- The Depth of Discharge of a battery determines the fraction of power that can be withdrawn from the battery .

1.4.3 Charging and Discharging rates :- The Depth of Discharge of a battery determines the fraction of power that can be withdrawn from the battery .The charging rate , in Amps , is given in the amount of charge added to the battery per unit time . The charge /discharge rate may be specified directly by giving the current .The discharging rate is determined by the amount of time it takes to fully discharge the battery .

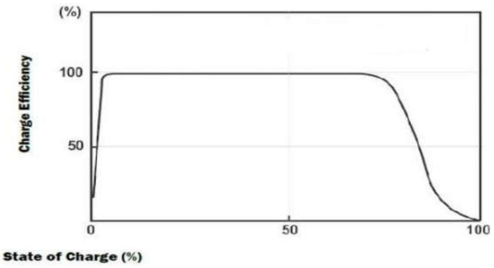


Figure :- Graph between State of charge and charge Efficiency
[taken from https://images.app.goo.gl/Bkfjh4dpoq5vjVrb7]

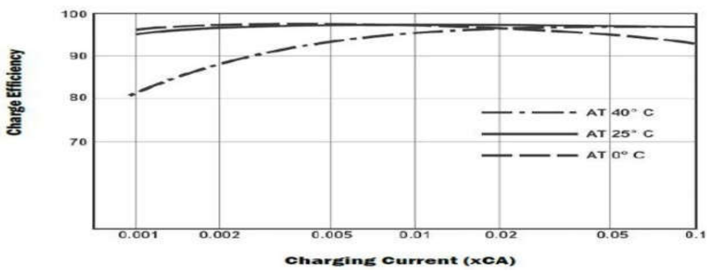


Figure :- Graph between Charging current & Charge Efficiency
[taken from https:/images.app.goo.gl/ynyLfVPo7ryjkBJR8]

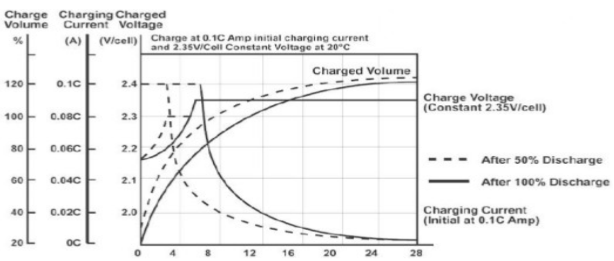


Figure :-Lead Acid battery charge characteristics taking case that charging is non continuous and peak voltage higher .
[taken from https://images .app.goo.gl/rpHc6SqFDgmt9yLu7]

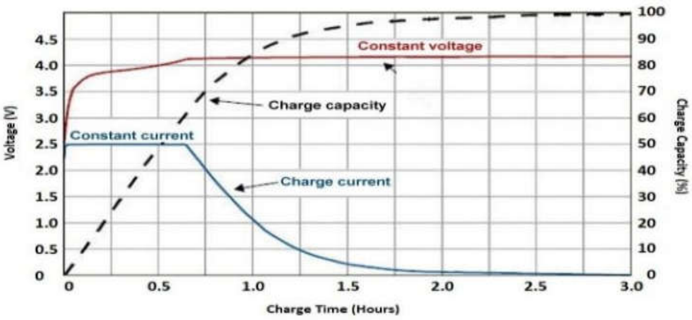


Figure :- Charge curve of Lithium –Ion Battery
[taken from https://images.app.goo.gl/swhnxN2u5BKkpdTSA]

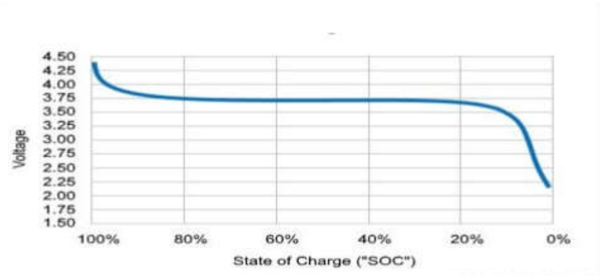


Figure :-Discharge curve of Lithium–Ion Battery
[taken from https://images.app.goo.gl/ShA9AsHvVyz4YTwY7]

PROBLEM STATEMENT-
To observe the SOC and charging current of different batteries in series and parallel combination with different loads using Matlab Simulink and Simscape .

OBJECTIVE–
1. Identifying time duration while charging different batteries separately and in different combination.
2. Identifying variation in charging current characteristics of different batteries .
3. Design and develop the circuit for display of SOC and charging current for different varying loads through simulation.
4. Experimentation and validation of results.
5. Analysis of results**.**

1.5 OUTLINE OF THE REPORT:-
The report consists of discussing the Analysis ,modelling and simulation of various Series –Parallel combination of Lead-acid and Lithium-Ion battery spread over four chapters as given below:
Chapter 1 :- Introduces Batteries and its application and classification of batteries , modelling and performance parameters .
Chapter 2 :- Presents literature review on the background of types of batteries and their characteristics and objective of study .
Chapter 3:- Presents simulation results and discussion of Lead- acid and Lithium –Ion battery for the desired load .
Chapter 4:- Deals with Conclusion & Future scope.

CHAPTER 2 RESULT & DISCUSSION:-

2.1 LEAD ACID BATTERY CHARGING:

DC VOLTAGE SOURCE:-12 VOLT **LEAD ACID NOMINAL VOLTAGE:-7.2 VOLT** **RATED CAPACITY:-55Ah** **INITIAL STATE OF CHARGE:-45%**
BATTERY RESPONSE TIME:-30 SECONDS

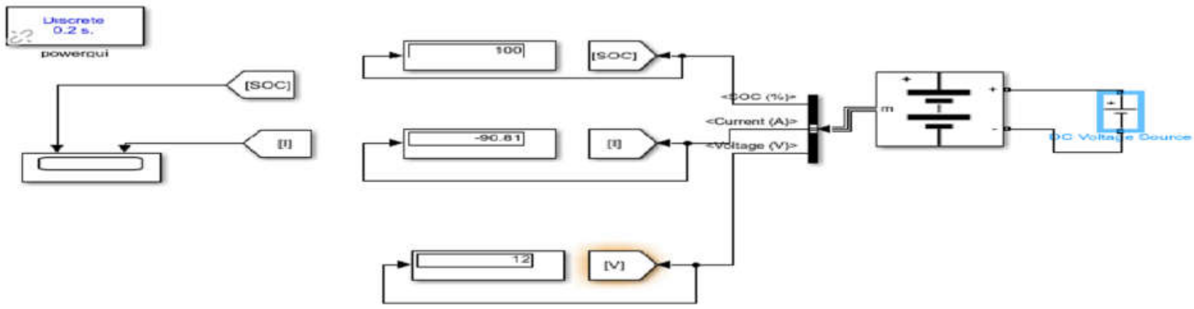


Figure 1.1 :- CIRCUIT DIAGRAM OF LEAD-ACID BATTERY CHARGING FOR 425 SECONDS

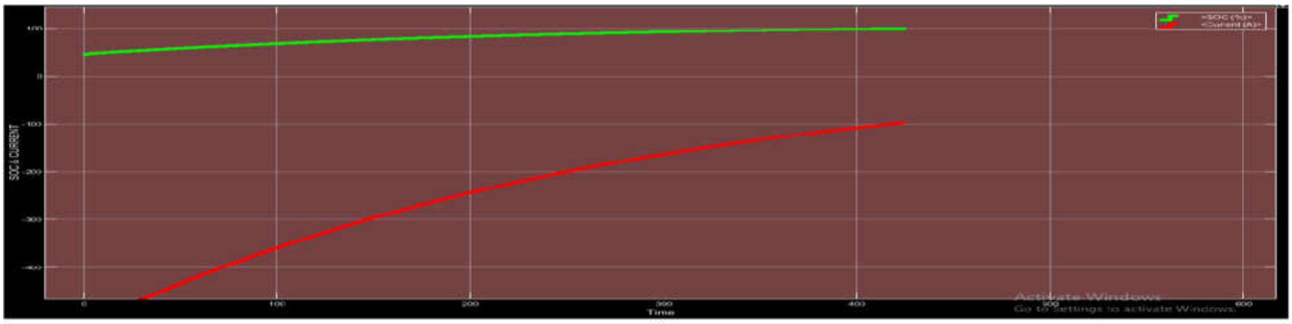


Figure 1.2:- SOC & CURRENT WAVEFORM OF LEAD ACID BATTERY CHARGING FOR 425 SECONDS

2.2 LITHIUM ION BATTERY CHARGING:

DC VOLTAGE SOURCE=12 VOLT LITHIUM ION NOMINAL VOLTAGE:-7.2 VOLT RATED CAPACITY:-55Ah
INITIAL STATE OF CHARGE:-45% BATTERY RESPONSE TIME:-30 SECONDS

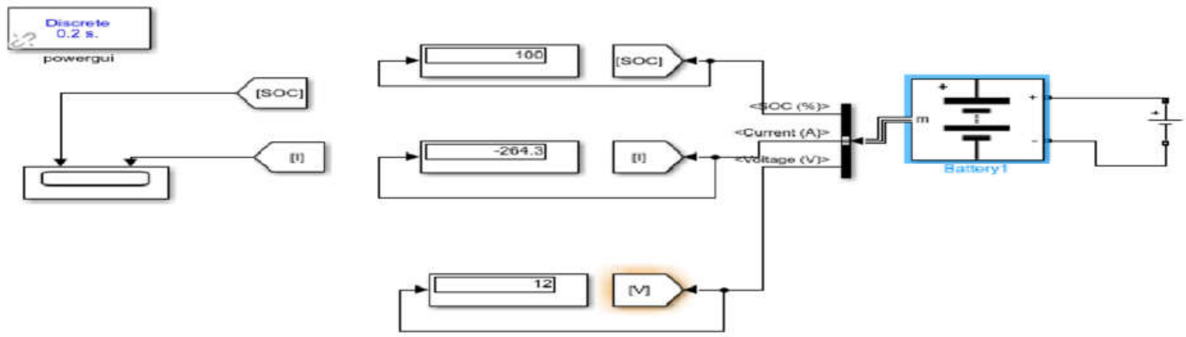


Figure 1.3 :- LITHIUM ION BATTERY CHARGING FOR 425 SECONDS

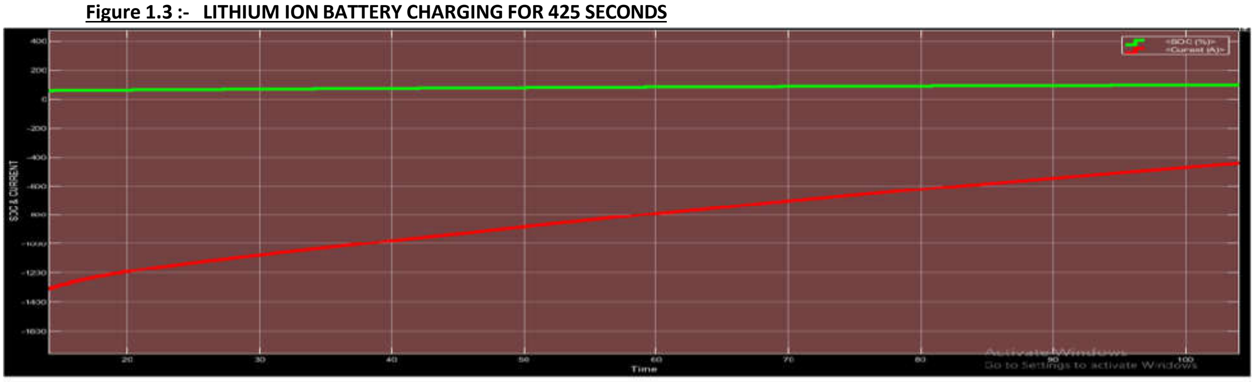


Figure 1.4:- SOC & CURRENT WAVEFORM OF LITHIUM ION BATTERY CHARGING FOR 135 SECONDS

2.3 LEAD ACID- LEAD ACID SERIES BATTERY CHARGING :

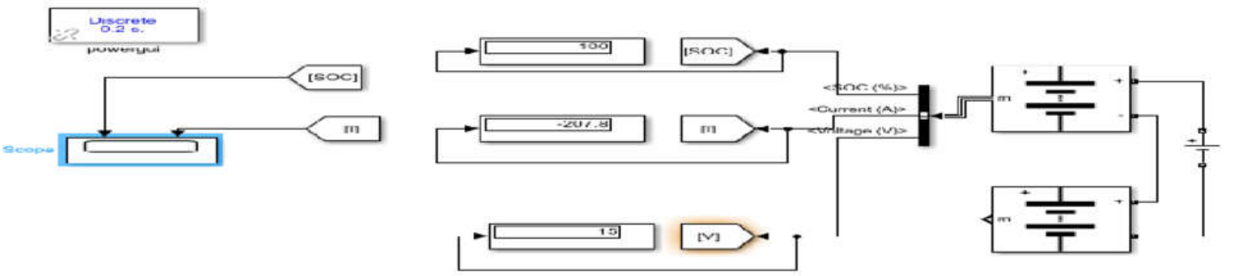


FIGURE 1.5:- CIRCUIT DIAGRAM OF LEAD-ACID & LEAD-ACID BATTERY SERIES CHARGING FOR 1 HOUR

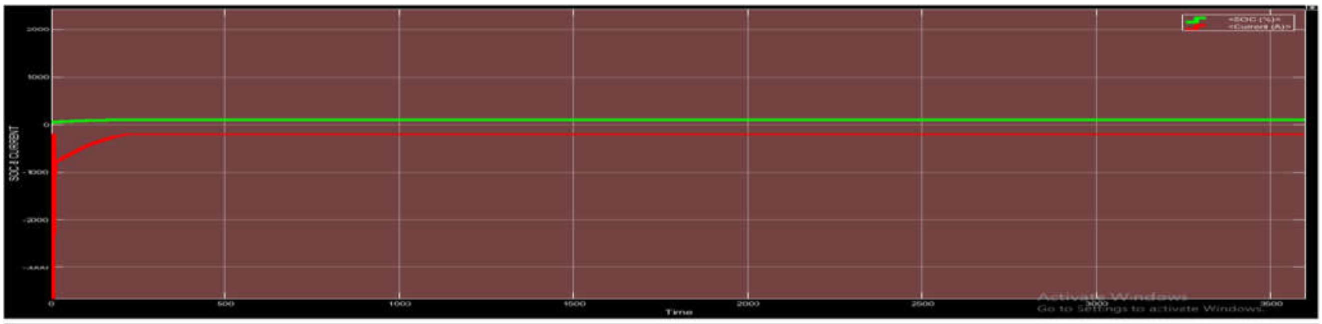


Figure1.6:- SOC & CURRENT WAVEFORMM OF LEAD ACID & LEAD ACID BATTERY SERIES CHARGING

2.4 LITHIUM ION-LEAD ACID SERIES BATTERY CHARGING :

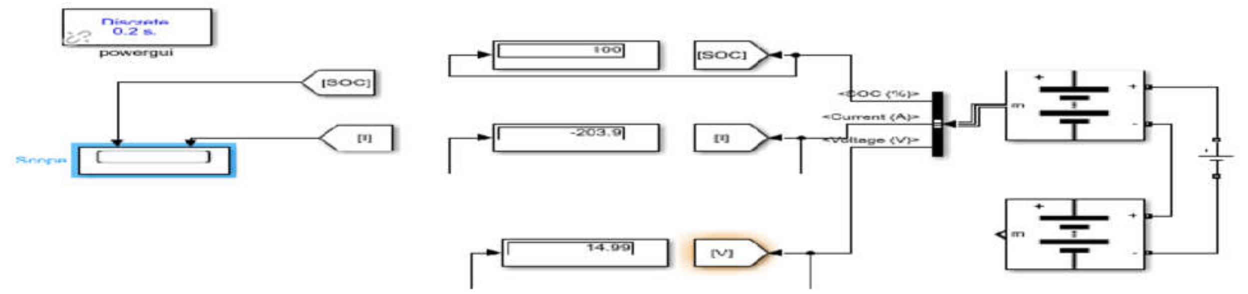


FIGURE 1.7:- LEAD ACID BATTERY CONNECTED IN SERIES WITH LITHIUM ION BATTERY FOR 1 HOUR

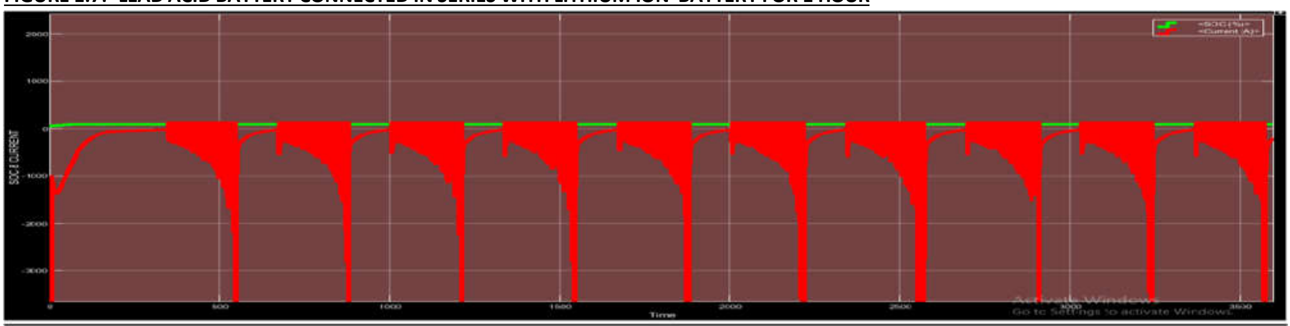


FIGURE 1.8:-SOC & CURRENT WAVEFORM OF LEAD ACID BATTERY CONNECTED SERIES WITH LITHIUM ION BATTERY FOR 1 HOUR

2.5 LITHIUM ION-LITHIUM ION SERIES CHARGING:

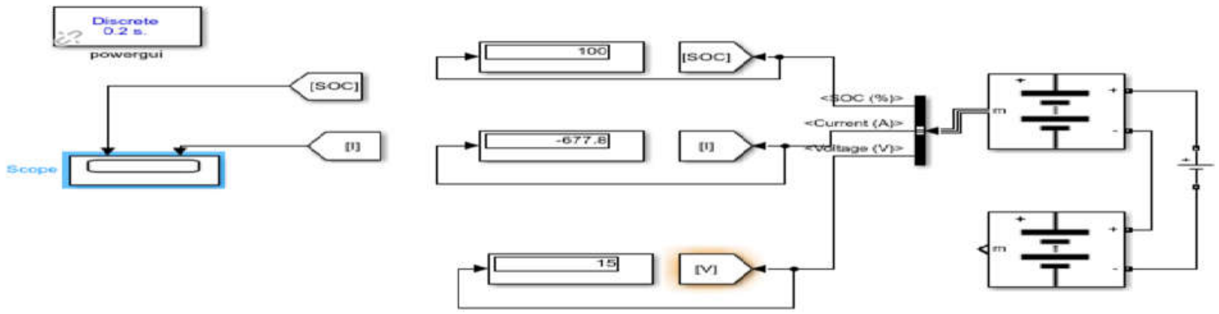


FIGURE 1.9:-CIRCUIT DIAGRAM OF LITHIUM ION BATTERY CONNECTED IN SERIES WITH LITHIUM ION BATTERY FOR 1 HOUR

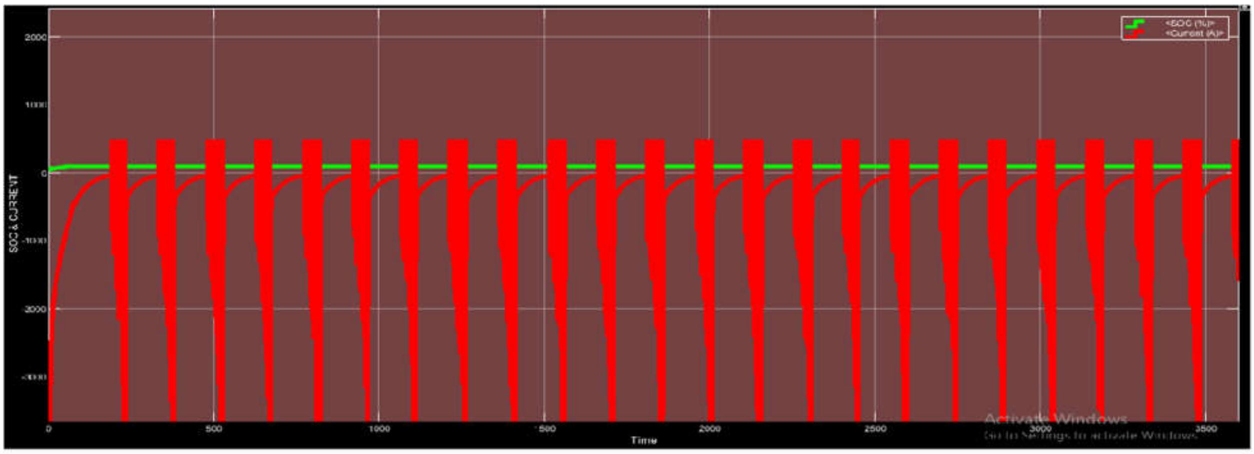


FIGURE 1.10:-SOC & CURRENT WAVEFORM OF LITHIUM ION BATTERY CONNECTED SERIES WITH LITHIUM ION BATTERY FOR 1 HOUR

2.6 LEAD ACID-LEAD ACID BATTERY PARALLEL CHARGING: **DC VOLTAGE SOURCE=15 VOLT**

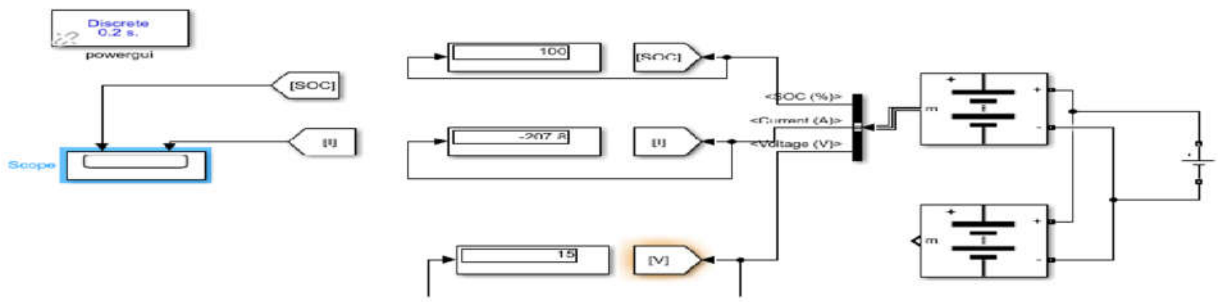


Figure 1.11:-CIRCUIT DIAGRAM OF BOTH LEAD ACID BATTERY FOR PARALLEL CHARGING FOR 1 HOUR

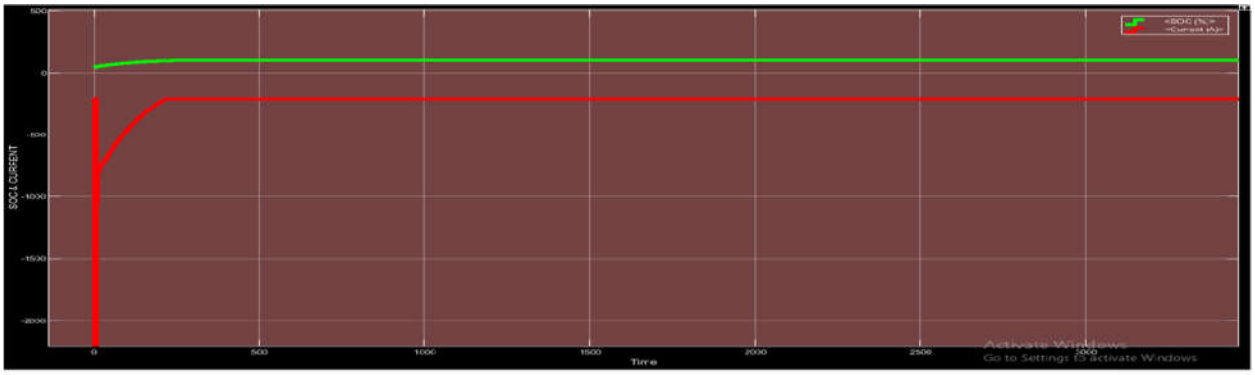


Figure 1.12:- SOC & CURRENT WAVEFORM OF BOTH LEAD ACID BATTERY CONNECTED IN PARALLEL FOR CHARGING FOR 1 HOUR

2.7 LEAD ACID-LITHIUM ION BATTERY PARALLEL CHARGING: **DC VOLTAGE SOURCE=12 VOLT FOR BOTH BATTERIES:- NOMINAL VOLTAGE:-7.2 VOLT RATED CAPACITY:-55Ah INITIAL STATE OF CHARGE:-45% BATTERY RESPONSE TIME:-30 SECONDS**

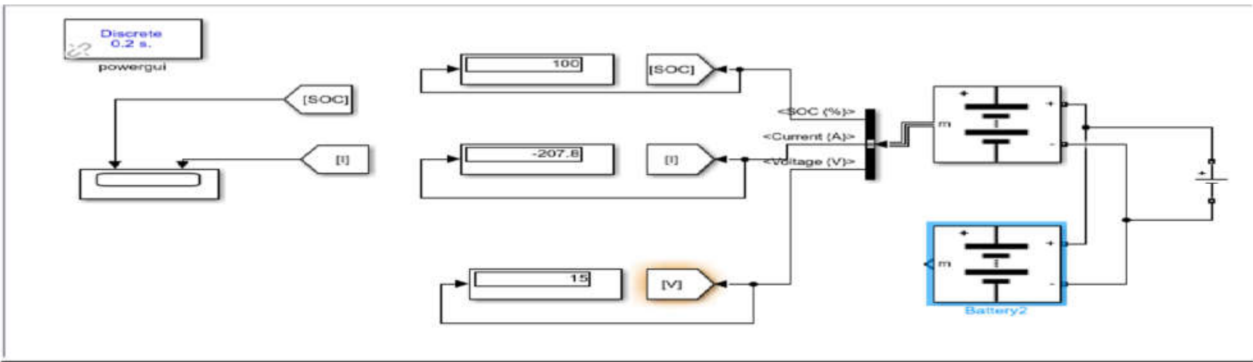


Figure 1.13:-LEAD ACID BATTERY & LITHIUM ION BATTERY PARALLEL CHARGING FOR I HOUR

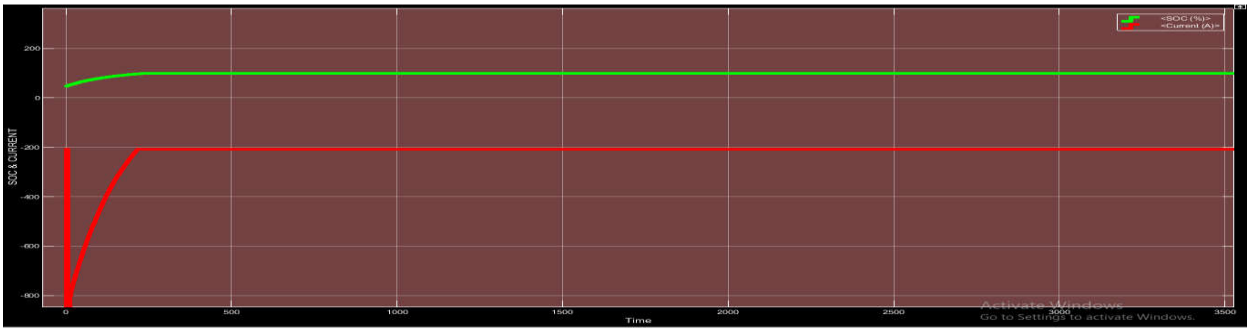


Figure 1.14:-SOC & CURRENT WAVEFORM OF LEAD ACID BATTERY & LITHIUM ION BATTERY FOR PARALLEL CHARGING FOR 1 HOUR

2.8 LITHIUM ION-LITHIUM ION BATTERY PARALLEL CHARGING:

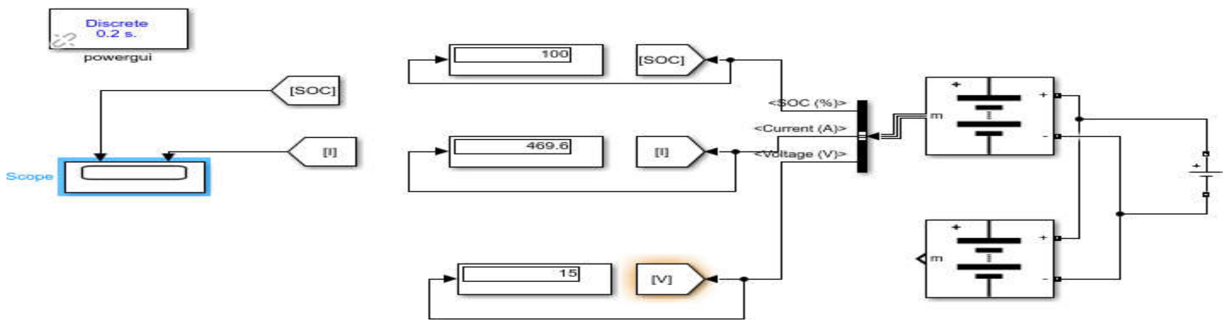


Figure 1.15:-LITHIUM ION BATTERY & LITHIUM ION BATTERY PARALLEL CHARGING FOR I HOUR

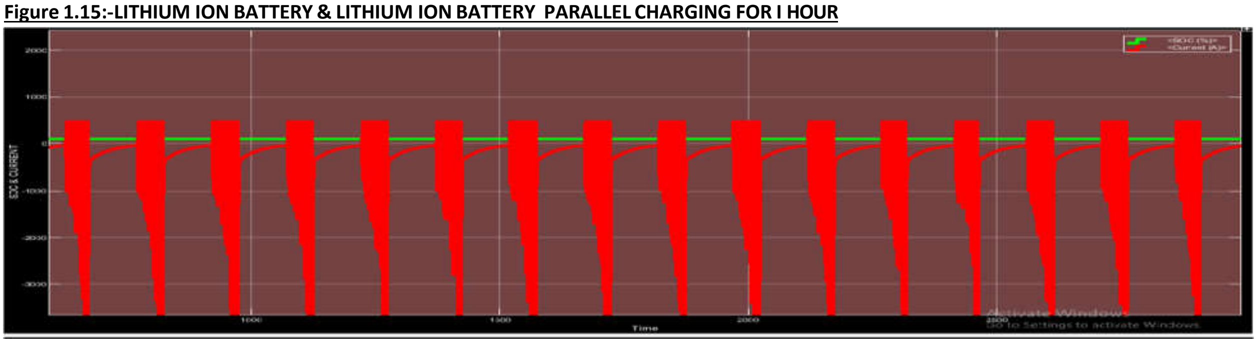


Figure 1.16:-SOC & CURRENT WAVEFORM OF LITHIUM ION BATTERY & LITHIUM ION BATTERY FOR PARALLEL CHARGING FOR 1 HOUR

2.9 LEAD ACID BATTERY DISCHARGE: **Initially the battery charging is taken as 100% and nominal voltage of battery is taken as 7.2 volt .**

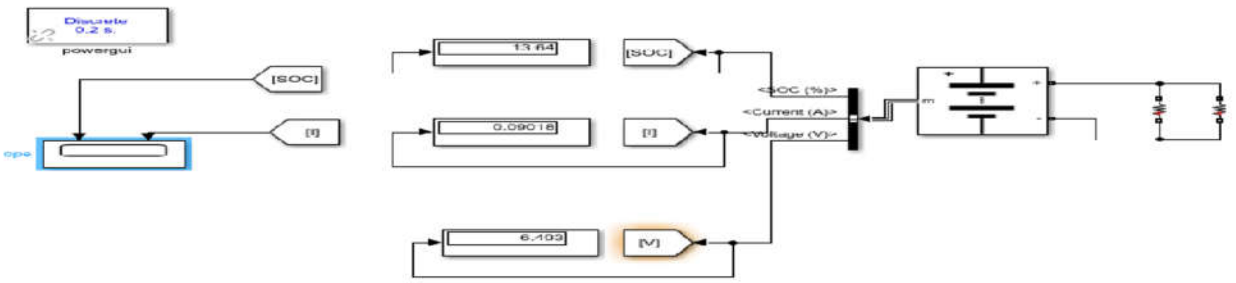


Figure1.17:- DISCHARGE OF LEAD ACID BATTERY WITH LOAD RESISTANCE 72 OHMS FOR 500 HOURS

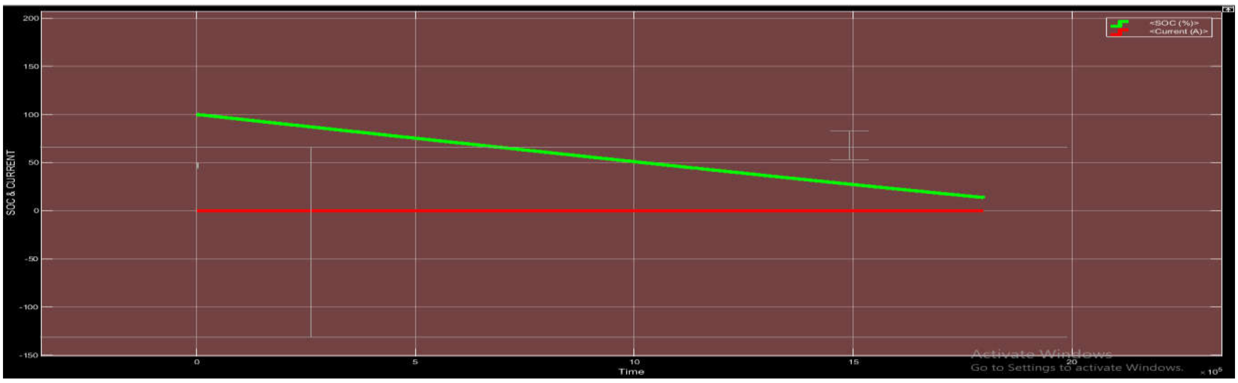


Figure 1.18:- SOC & CURRENT WAVEFORM OF LEAD ACID BATTERY DISCHARGE FOR 500 HOURS

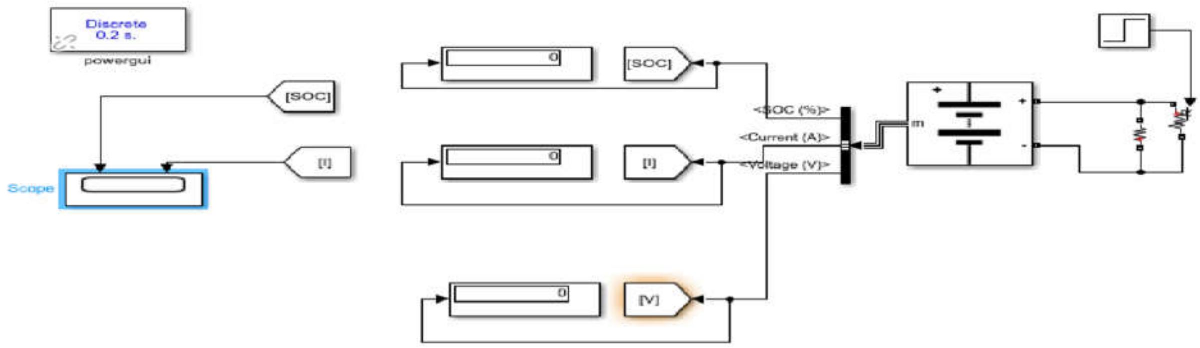


Figure 1.19:-DISCHARGE OF LEAD ACID BATTERY WITH LOAD AS STEP SIGNAL FOR 25 HOURS

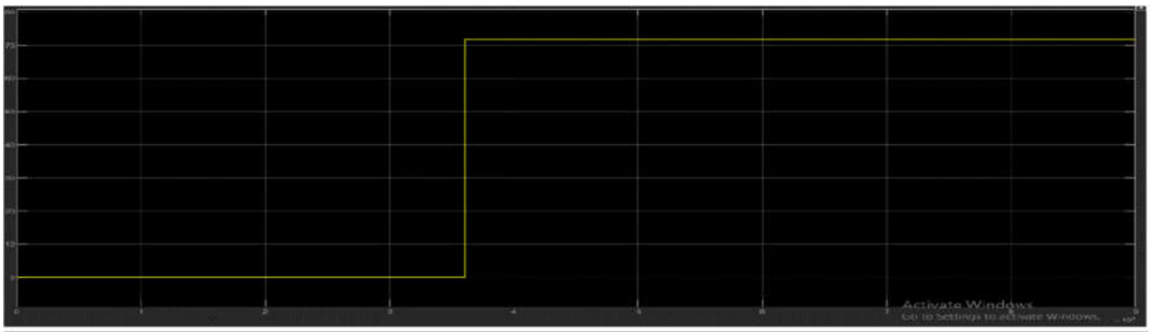


Figure 1.20:- FIGURE SHOWING STEP SIGNAL

Figure 1.21:- IMAGE SHOWING DETAILS OF STEP SIGNAL

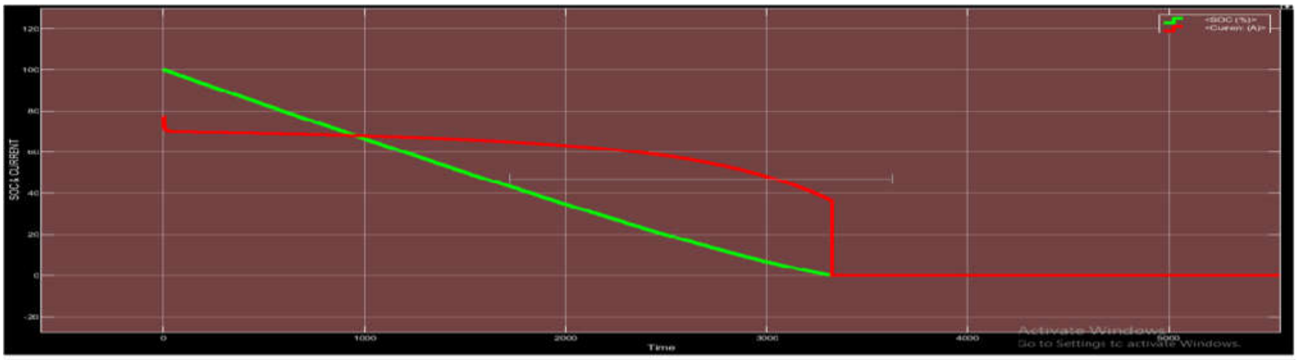


Figure 1.22:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID BATTERY CONNECTED TO STEP SIGNAL FOR 25 HOURS

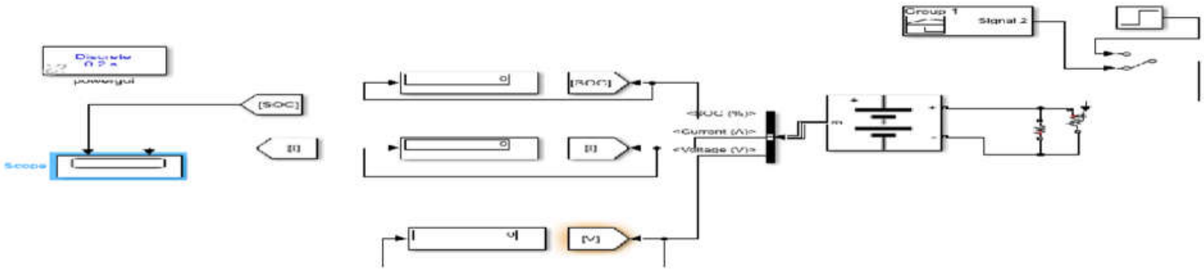


Figure 1.23:- CIRCUIT DIAGRAM OF LEAD ACID BATTERY DISCHARGE CONNECTED TO LOAD OF STEP SIGNAL WITH RAMP START PROVIDED BY SIGNAL BUILDER FOR 250 HOURS

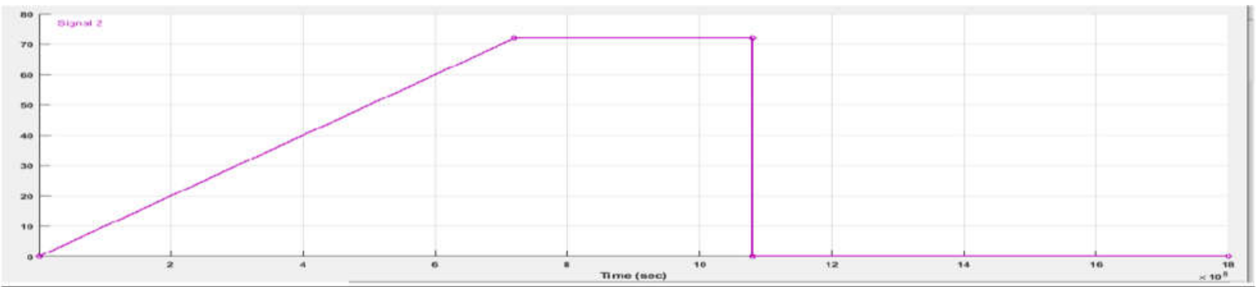


Figure1.24:- IMAGE OF STEP SIGNAL WITH RAMP START DEVELOPED IN SIGNAL BUILDER

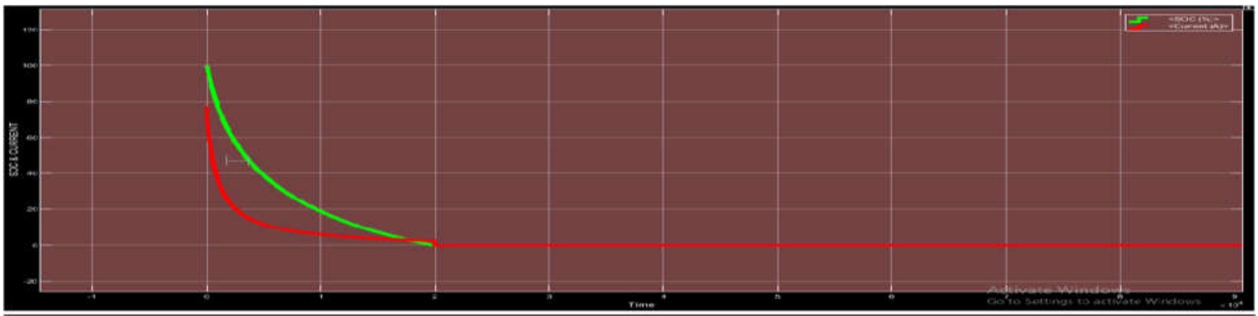


Figure1.25:- SOC & CURRENT WAVEFORM OF LEAD ACID BATTERY DISCHARGE CONNECTED TO LOAD OF STEP SIGNAL WITH RAMP START FOR 250 HOURS

3.0 LITHIUM ION BATTERY DISCHARGE:

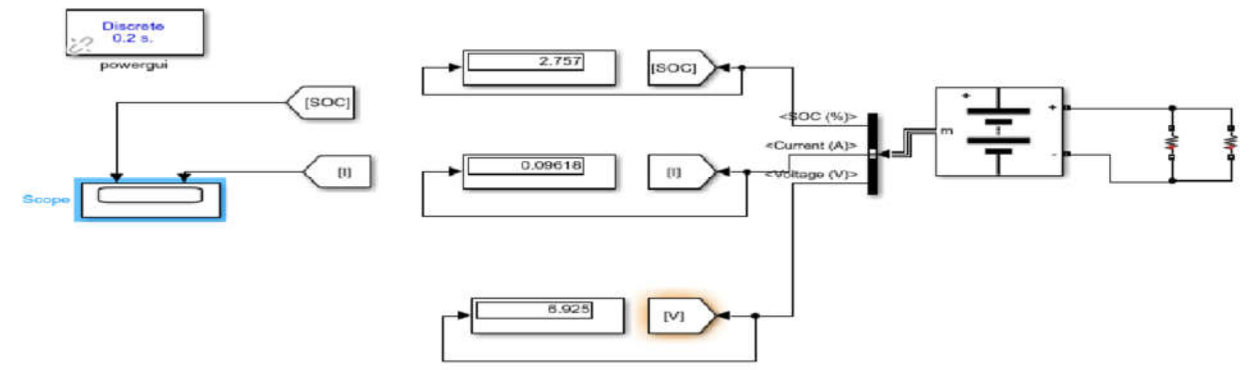


Figure 1.26:- CIRCUIT DIAGRAM OF DISCHARGE OF LITHIUM ION BATTERY WITH LOAD RESISTANCE 72 OHMS FOR 500 HOURS

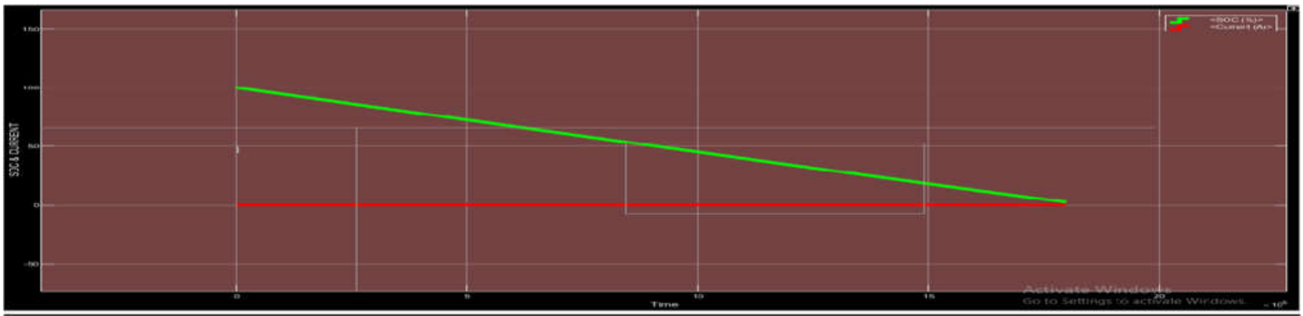


Figure 1.27:- SOC & CURRENT WAVEFORM OF LITHIUM ION BATTERY DISCHARGE FOR 500 HOURS

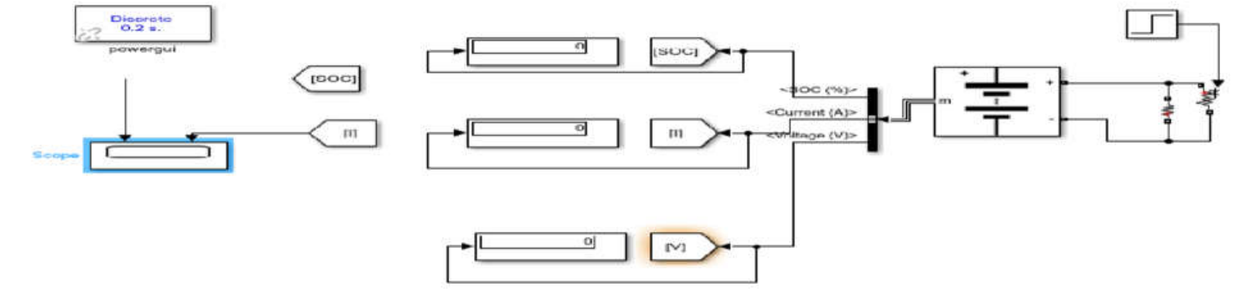


Figure 1.28:- DISCHARGE OF LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 25 HOURS

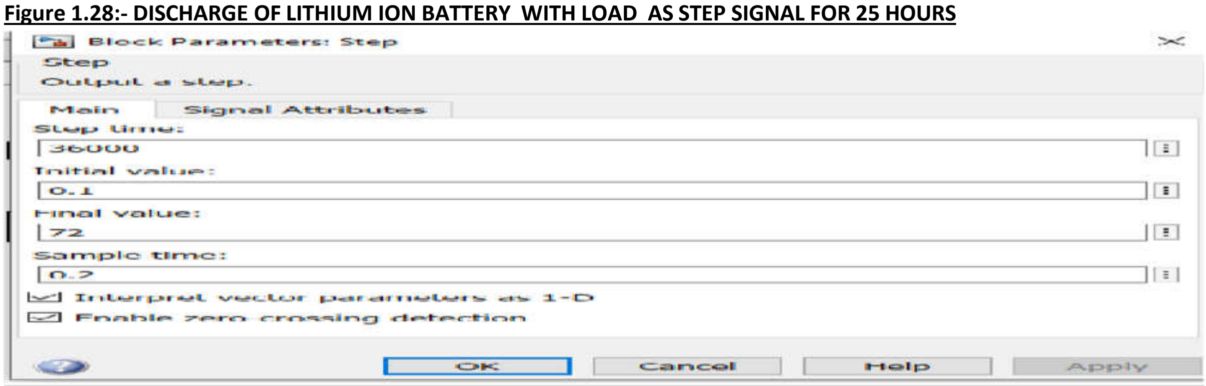


Figure 1.29:- IMAGE SHOWING DETAILS OF STEP SIGNAL

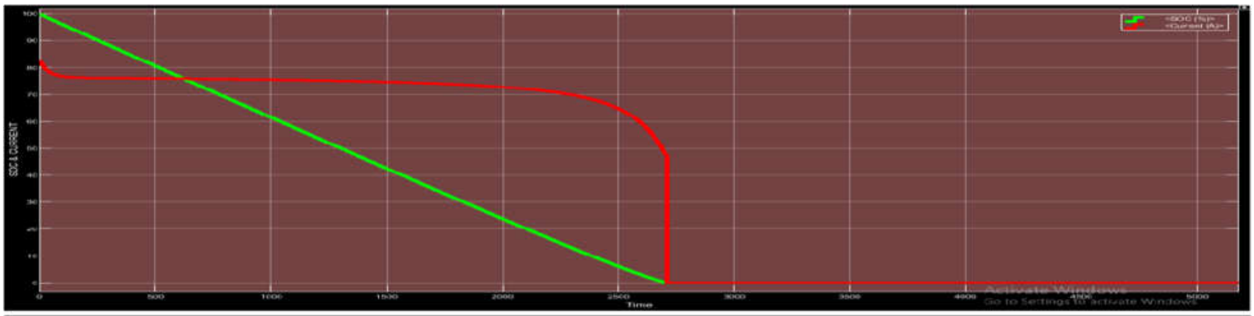


Figure 1.30:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION BATTERY CONNECTED TO STEP SIGNAL FOR 25 HOURS

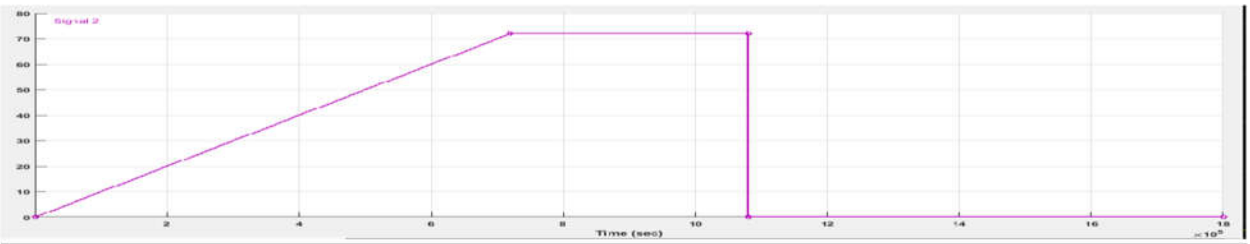


Figure 1.31:- IMAGE OF STEP SIGNAL WITH RAMP START DEVELOPED IN SIGNAL BUILDER

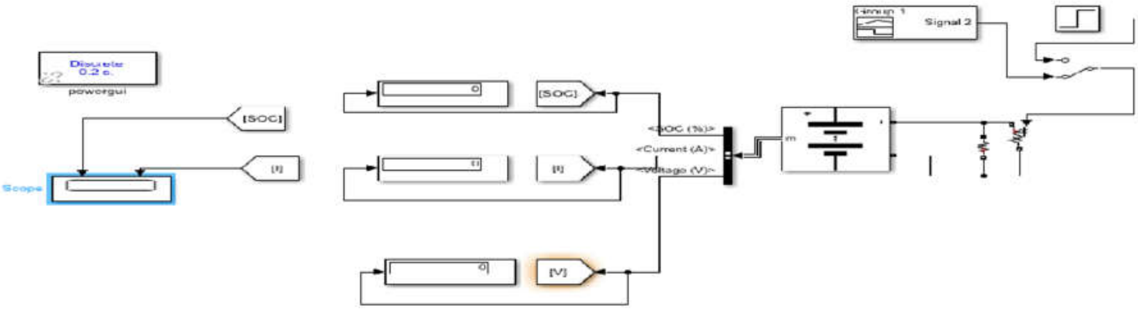


Figure 1.32:- CIRCUIT DIAGRAM OF DISCHARGE OF LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 20 HOURS

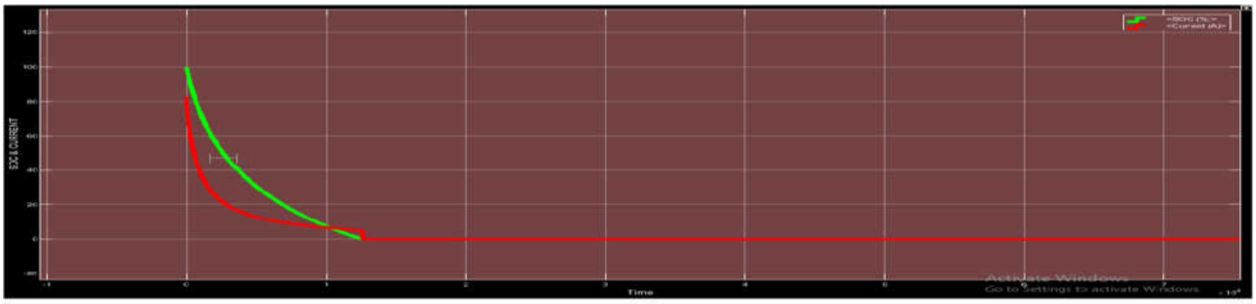


Figure 1.33:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION BATTERY CONNECTED TO LOAD AS STEP SIGNAL WITH RAMP START FOR 20 HOURS

3.1 LEAD ACID-LEAD ACID SERIES BATTERY DISCHARGE:

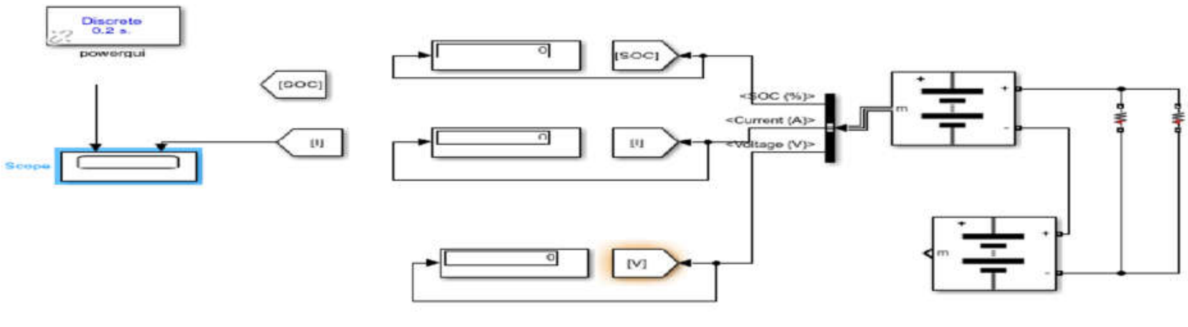


Figure 1.34:-DISCHARGE OF LEAD ACID-LEAD ACID SERIES BATTERY WITH LOAD AS 72 OHM RESISTANCE FOR 500 HOURS

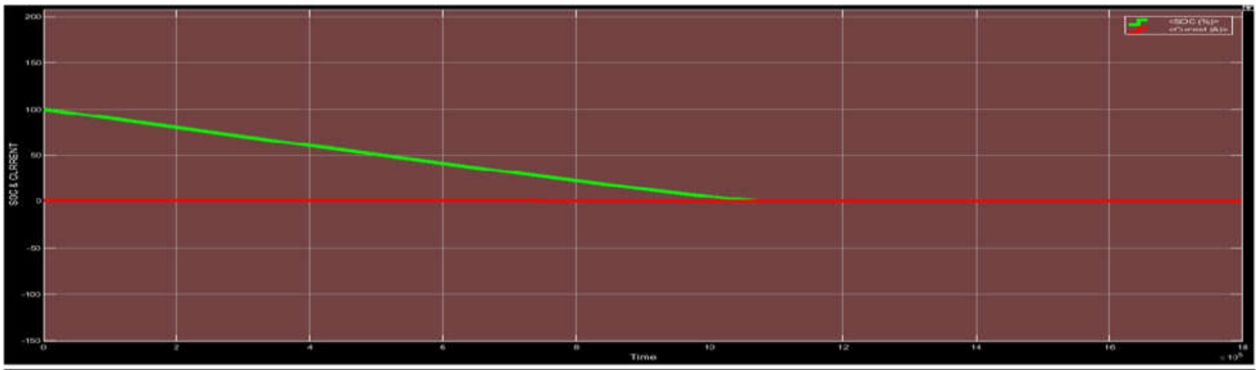


Figure1.35:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID-LEAD ACID SERIES BATTERY CONNECTED TO LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

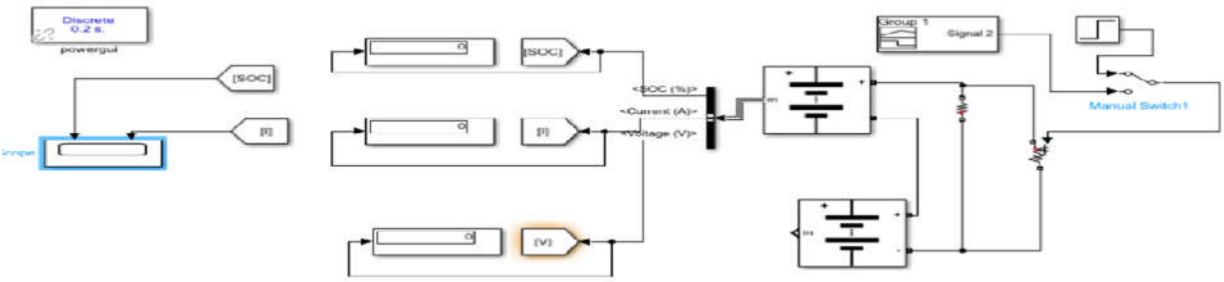


Figure 1.36:- CIRCUIT DIAGRAM OF DISCHARGE OF LEAD ACID-LEAD ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 500 HOURS

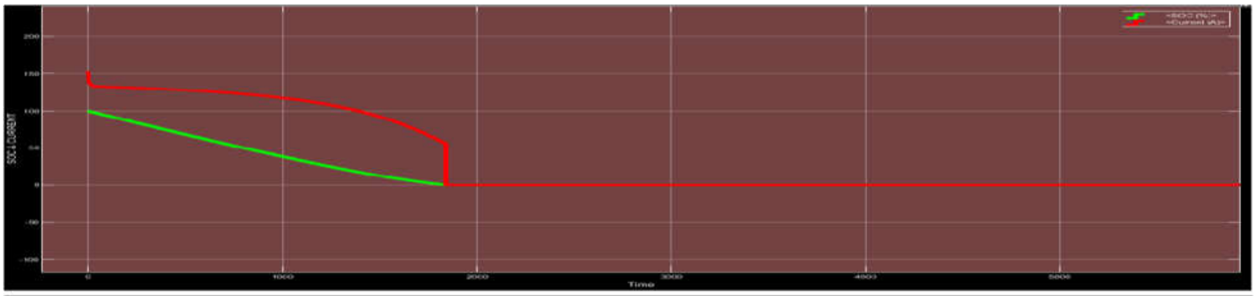


Figure1.37:-SOC & CURRENT WAVEFORM OF OF DISCHARGE OF LEAD ACID-LEAD ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 500 HOURS

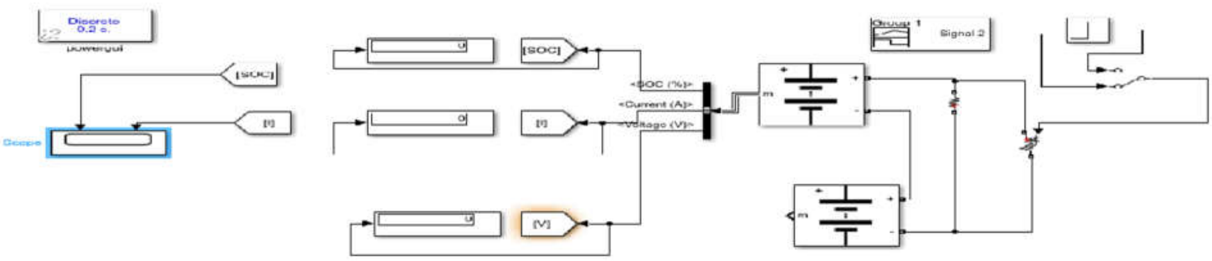


Figure1.38:- CIRCUIT DIAGRAM OF DISCHARGE OF LEAD ACID-LEAD ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START DEVELOPED BY SIGNAL BUILDER FOR 500 HOURS

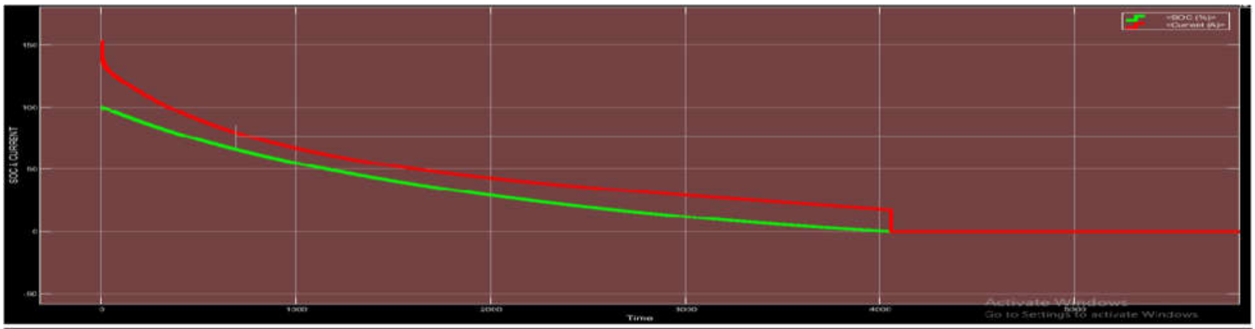


Figure 1.39:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID-LEAD ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START DEVELOPED BY SIGNAL BUILDER FOR 500 HOURS

3.2 LEAD ACID-LITHIUM ION SERIES BATTERY DISCHARGE:

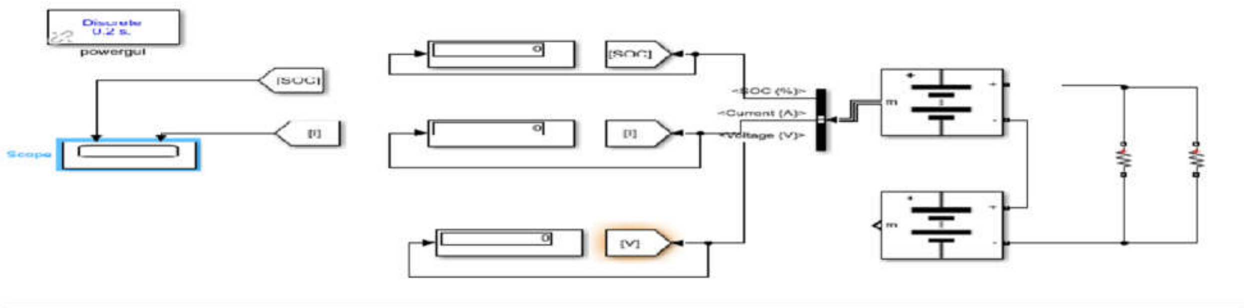


Figure 1.40:-DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

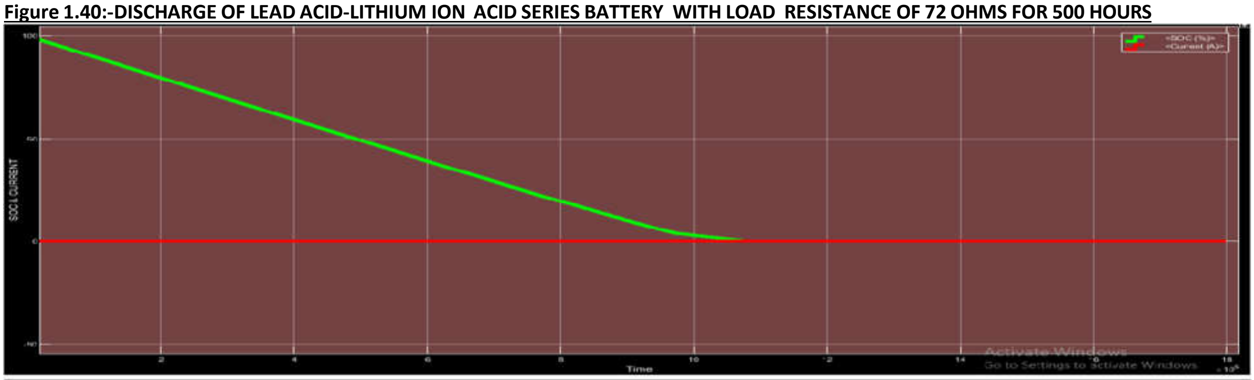


Figure 1.41:- WAVEFORM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

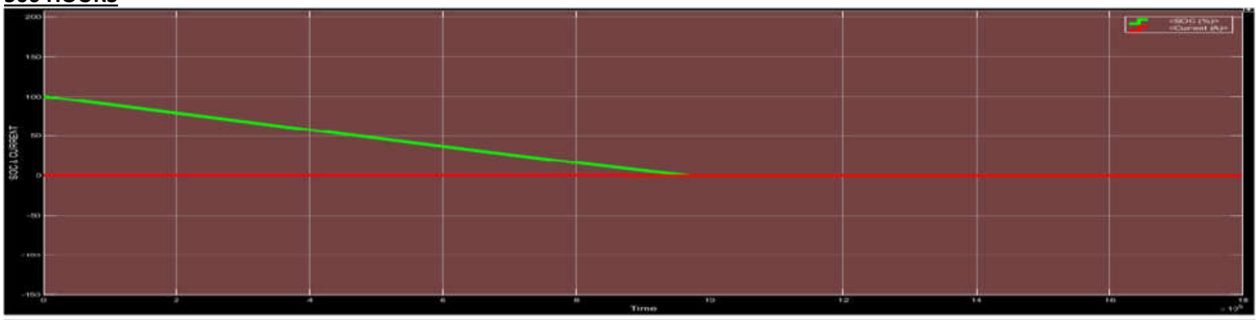
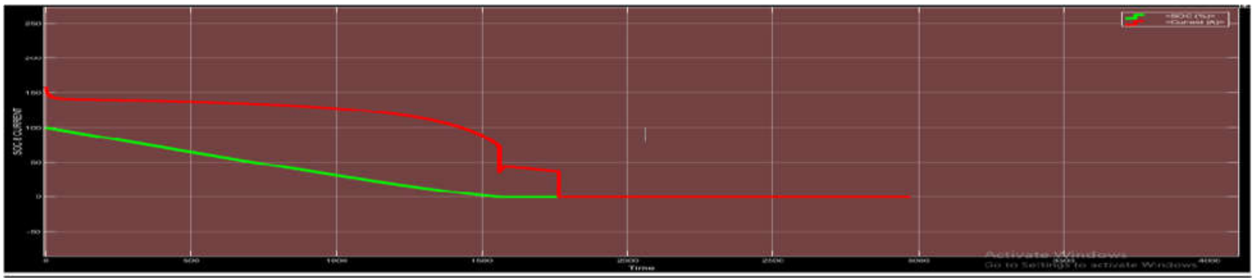
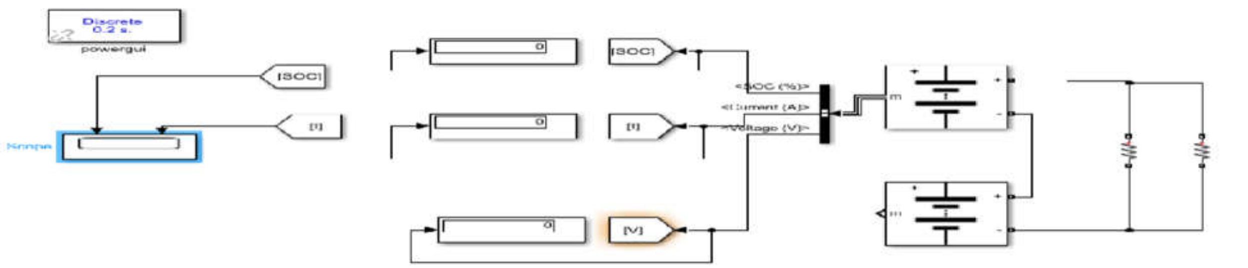


Figure 1.42:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL FOR 500 HOURS

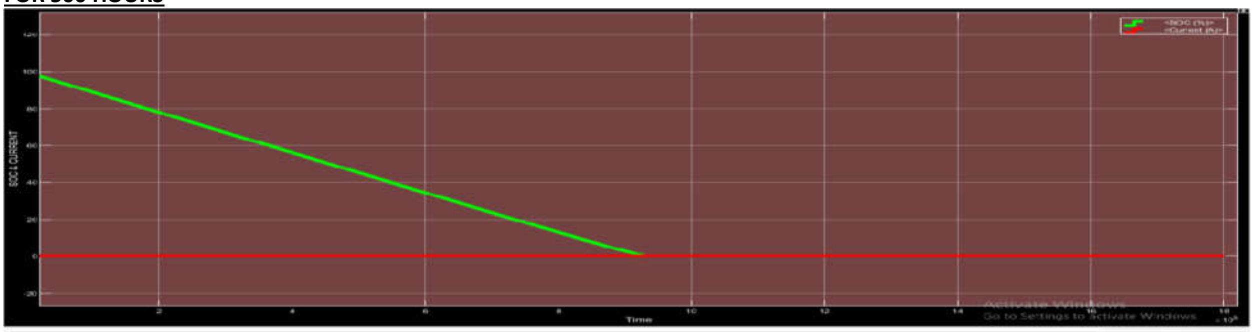


<u>Figure 1.43:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 500 HOURS</u>

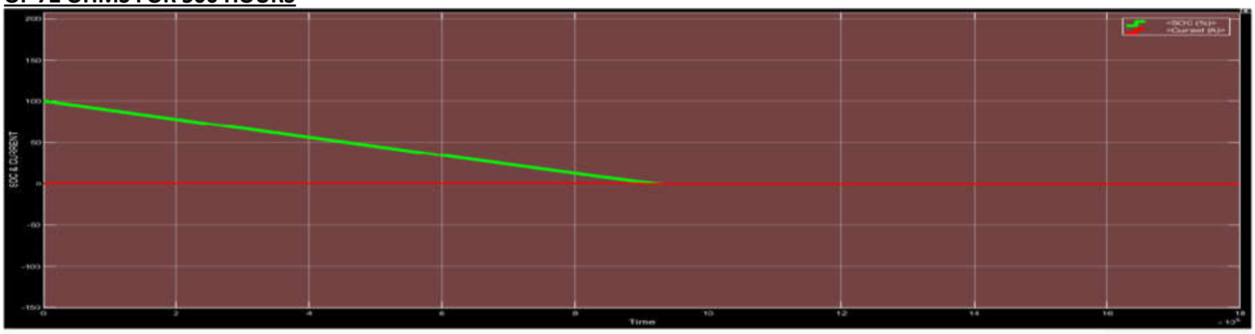
<u>3.3 LITHIUM ION-LITHIUM ION SERIES BATTERY DISCHARGE:</u>



<u>Figure 1.44:- CIRCUIT DIAGRAM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS</u>



<u>Figure 1.45:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS</u>



<u>Figure1.46:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL FOR 500 HOURS</u>

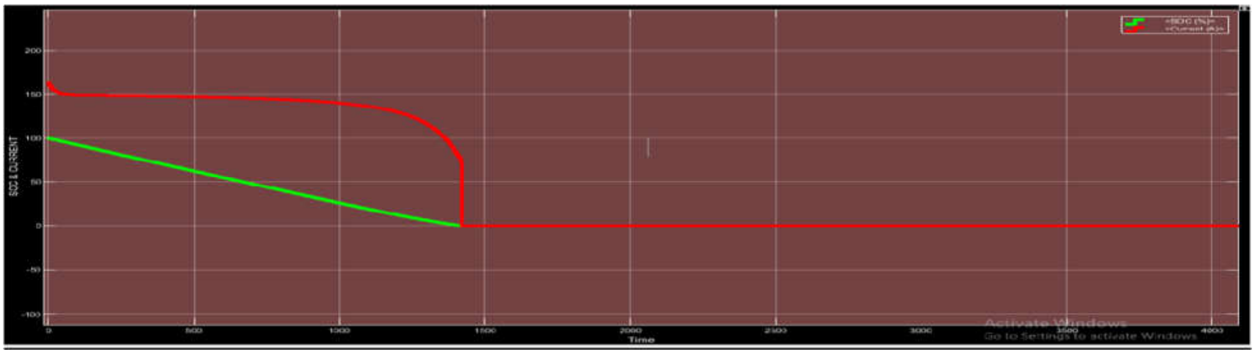


Figure 1.47:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 500 HOURS

3.4 LEAD ACID BATTERY PARALLEL DISCHARGE:

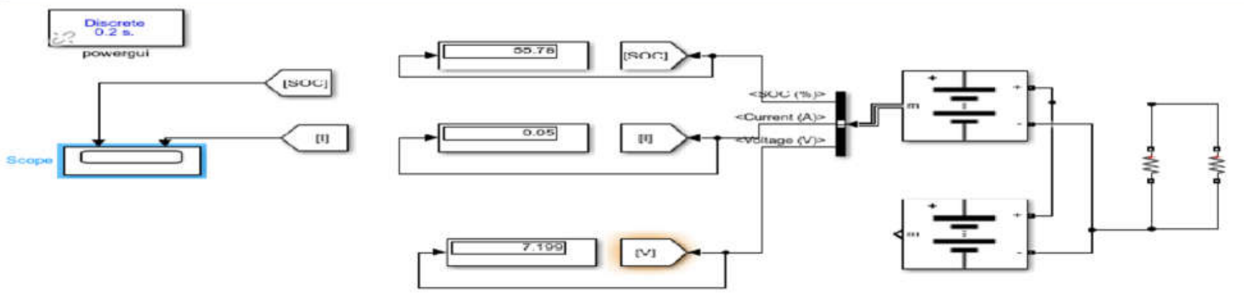


Figure 1.48:- DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LEAD ACID ACID BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

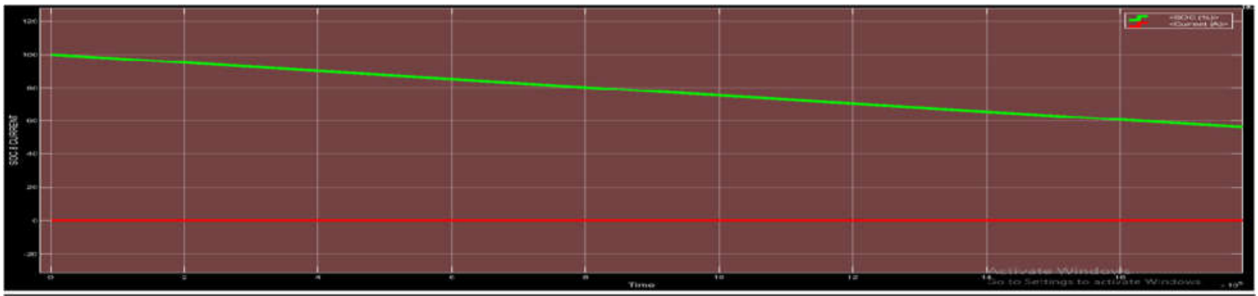


Figure 1.49:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LEAD ACID BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

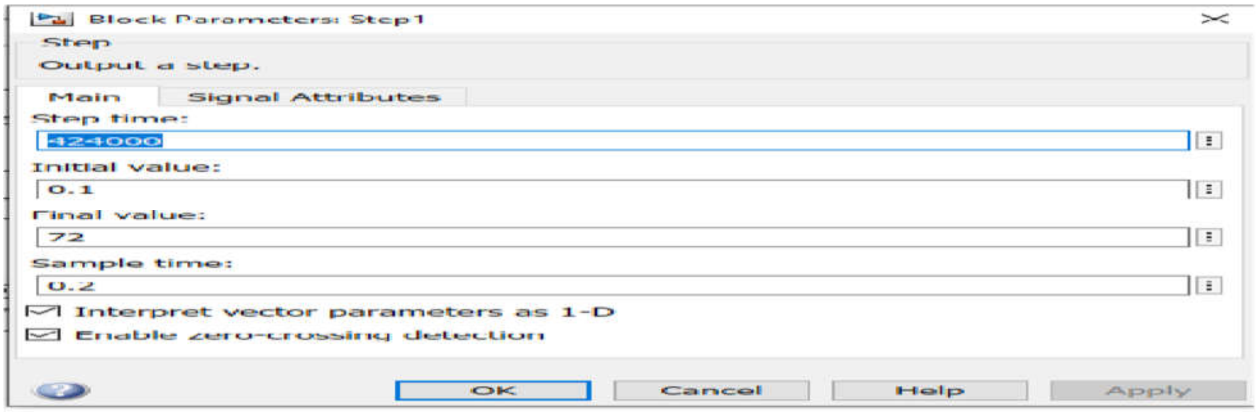


Figure 1.50:- IMAGE SHOWING DETAIL OF STEP SIGNAL

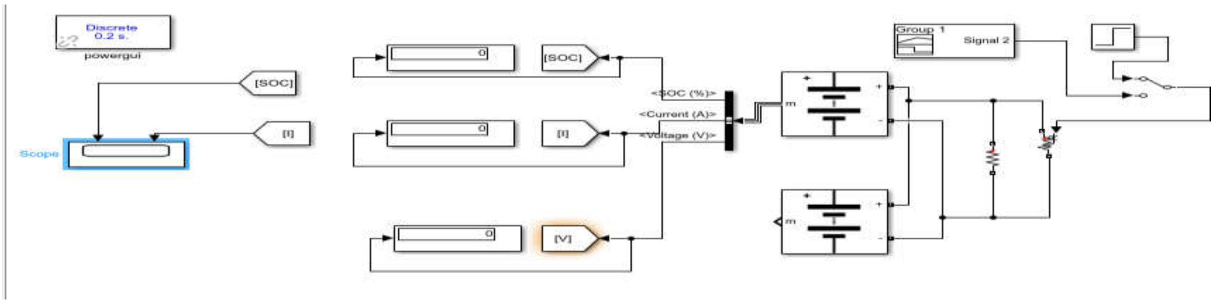


Figure 1.51:-DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LEAD ACID ACID BATTERY WITH LOAD AS STEP SIGNAL FOR 500 HOURS

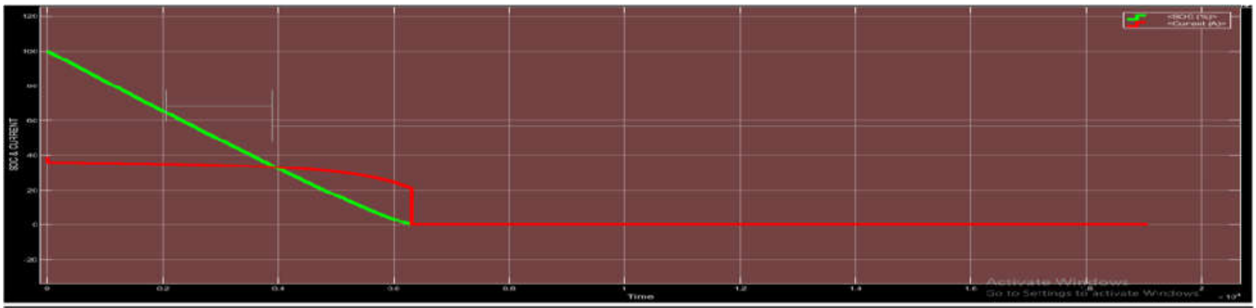


Figure 1.52:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LEAD ACID ACID BATTERY WITH LOAD AS STEP SIGNAL FOR 500 HOURS

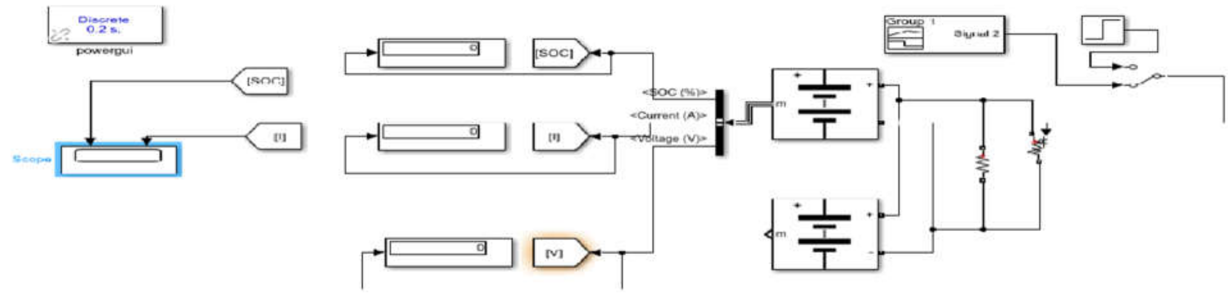


Figure 1.53:- DISCHARGE OF PARALLEL CONNECTED LEAD ACID- LEAD ACID BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START DEVELOPED BY SIGNAL BUILDER FOR 500 HOURS

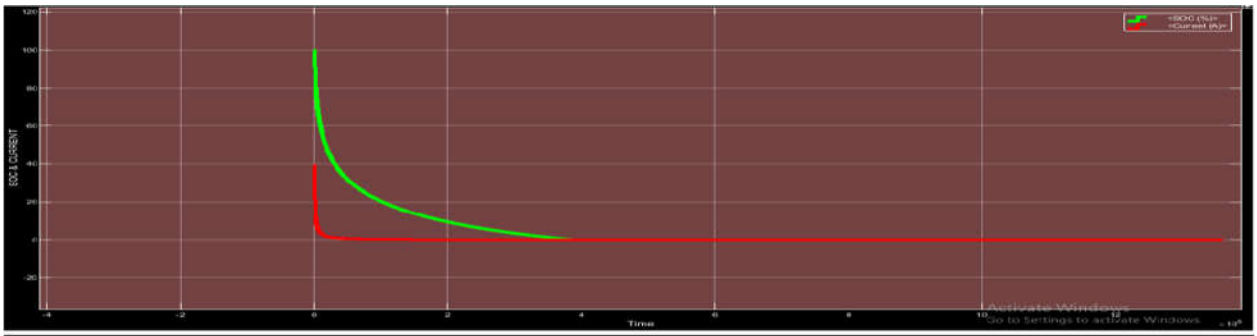


Figure 1.54:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LEAD ACID BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START DEVELOPED BY SIGNAL BUILDER FOR 500 HOURS

3.5 LEAD ACID-LITHIUM ION BATTERY PARALLEL DISCHARGE:

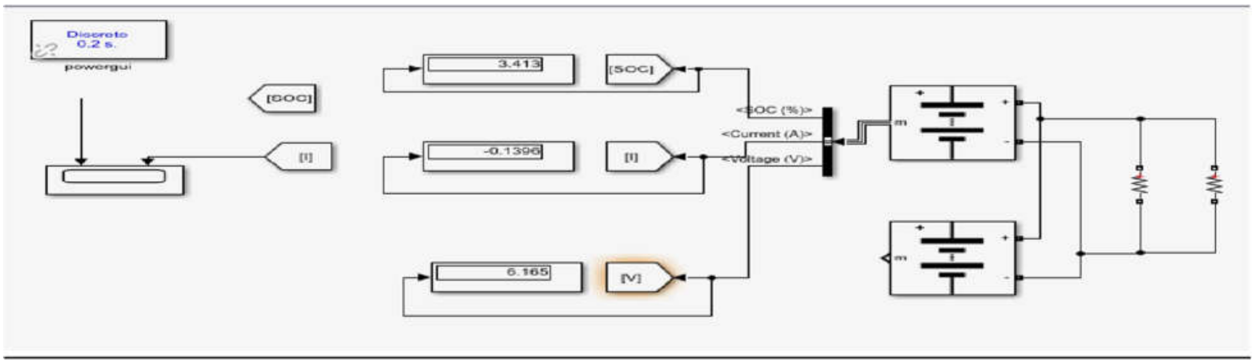


Figure 1.55:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD RESISTANCE 72 OHMS FOR 470 HOURS

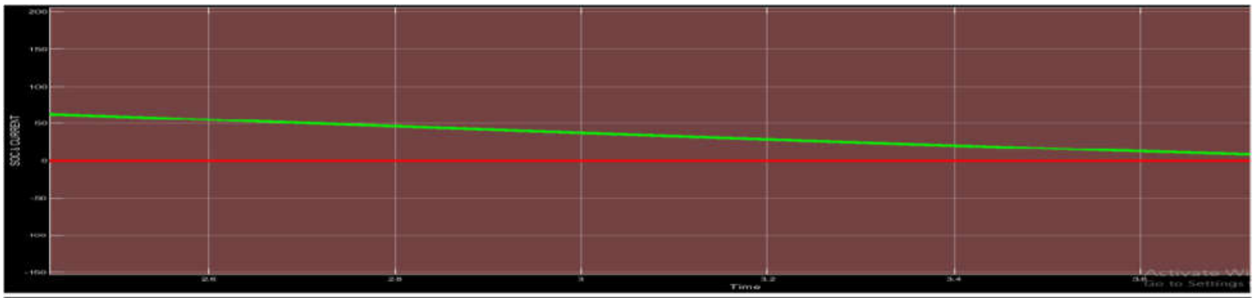


Figure 1.56:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD RESISTANCE 72 OHMS FOR 470 HOURS

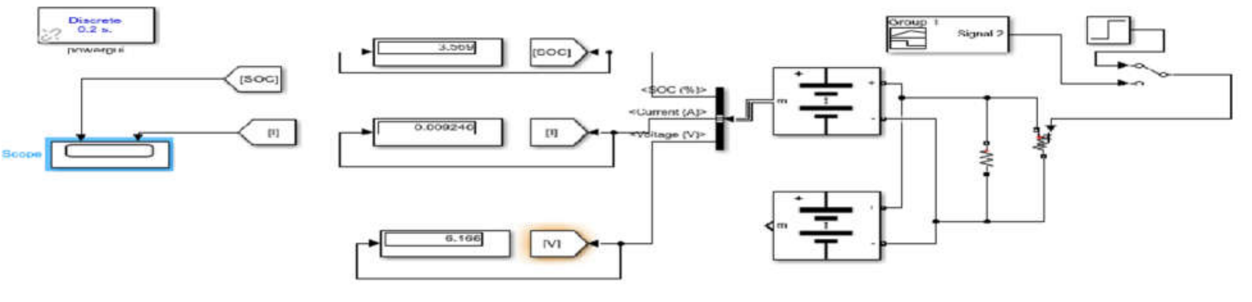


Figure 1.57:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 140 HOURS

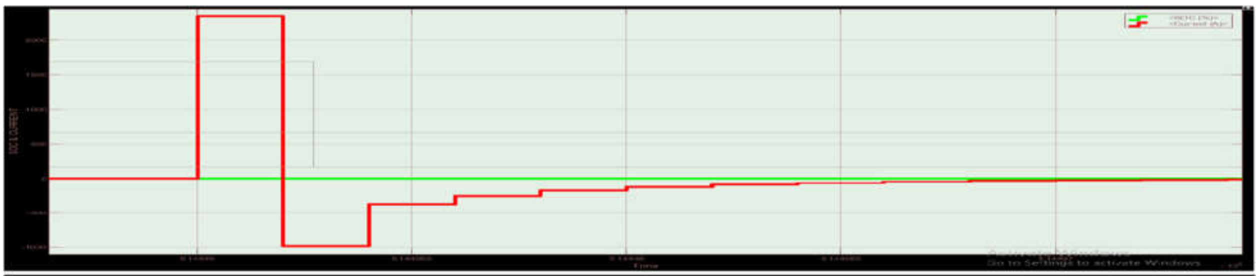


Figure 1.58:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 140 HOURS

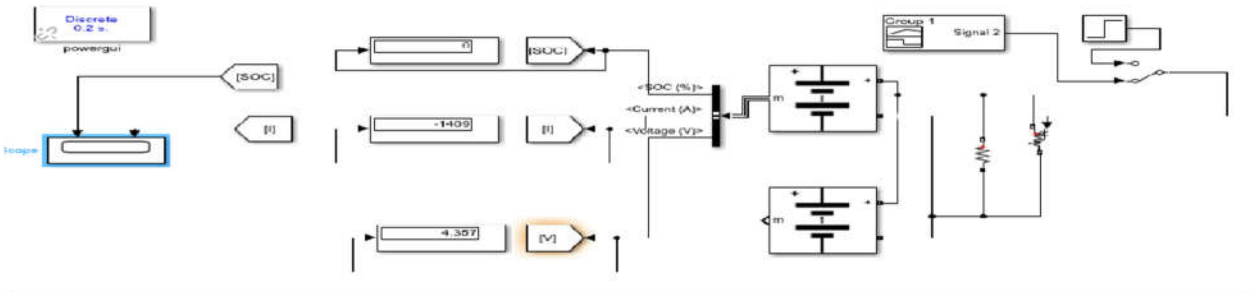


Figure 1.59:-DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 200 HOURS

Figure 1.60:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 200 HOURS

3.16 LITHIUM ION-LITHIUM ION BATTERY PARALLEL DISCHARGE:

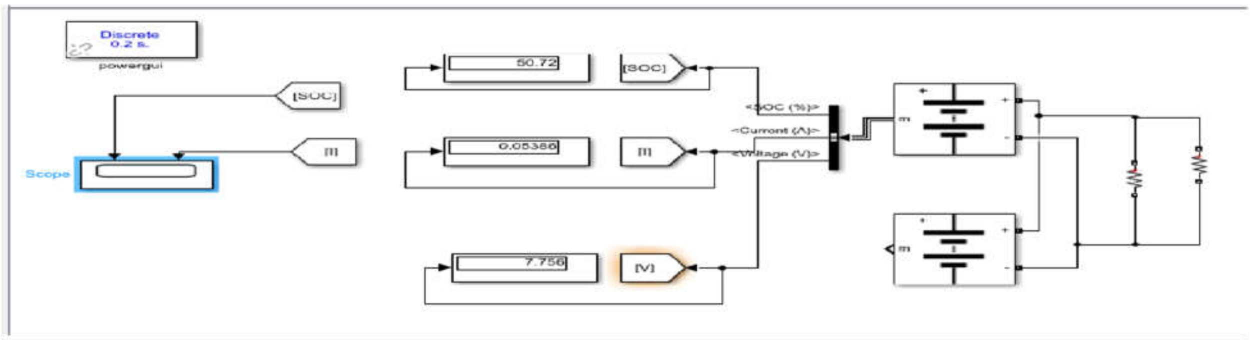


Figure 1.61:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS 72 OHMS FOR 500 HOURS

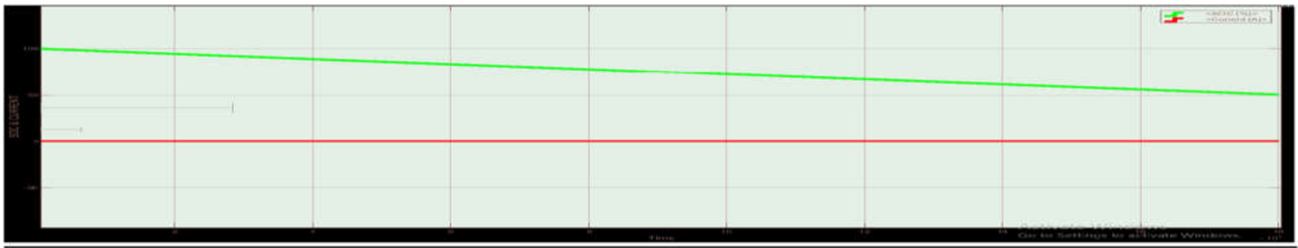


Figure 1.62:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS 72 OHMS FOR 500 HOURS

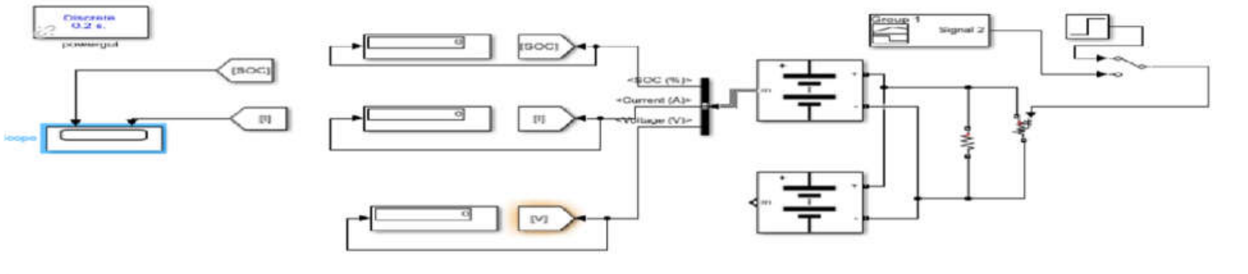


Figure 1.63:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 6 HOURS

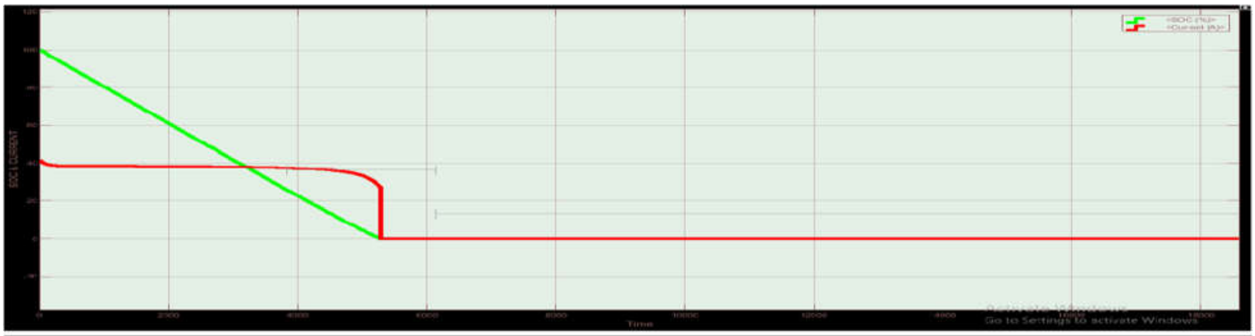


Figure 1.64:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 6 HOURS

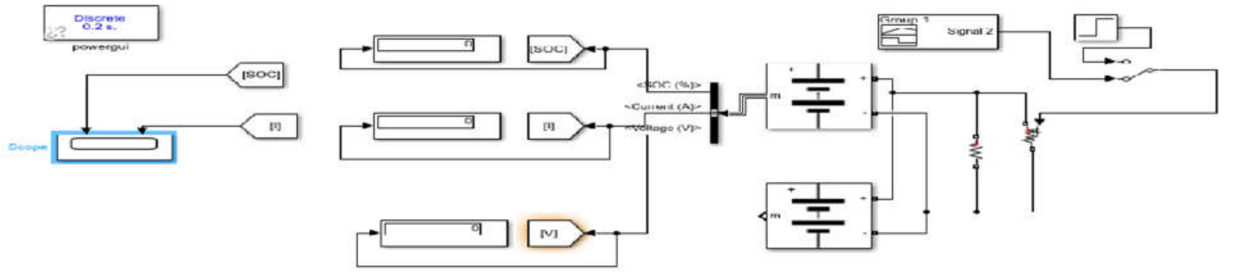


Figure 1.65:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 80 HOURS

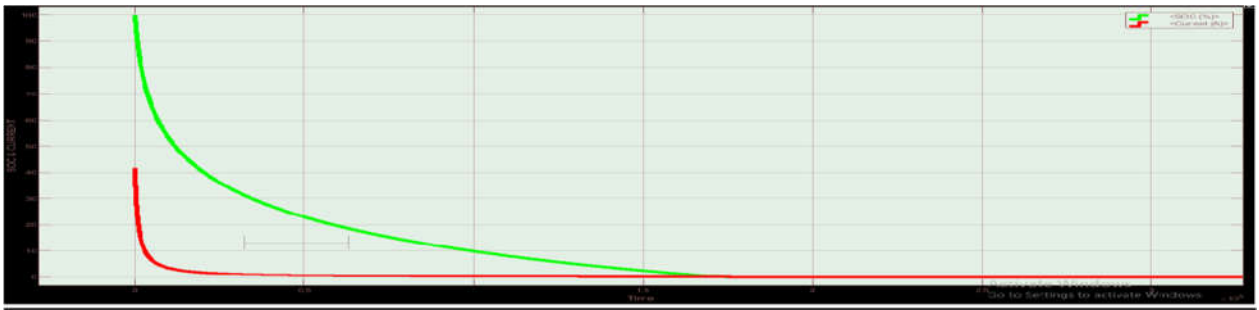


Figure 1.66:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 80 HOURS

3.6 PV ARRAY IS CONNECTED TO LEAD ACID OR LITHIUM BATTERY WITH A BUCK CONVERTER WHICH IS FURTHER CONNECTED TO INVERTER WHICH IN TURN CONNECTED TO RECTIFIER & BOOST CONVERTER TO A LEAD ACID OR LITHIUM ION BATTERY

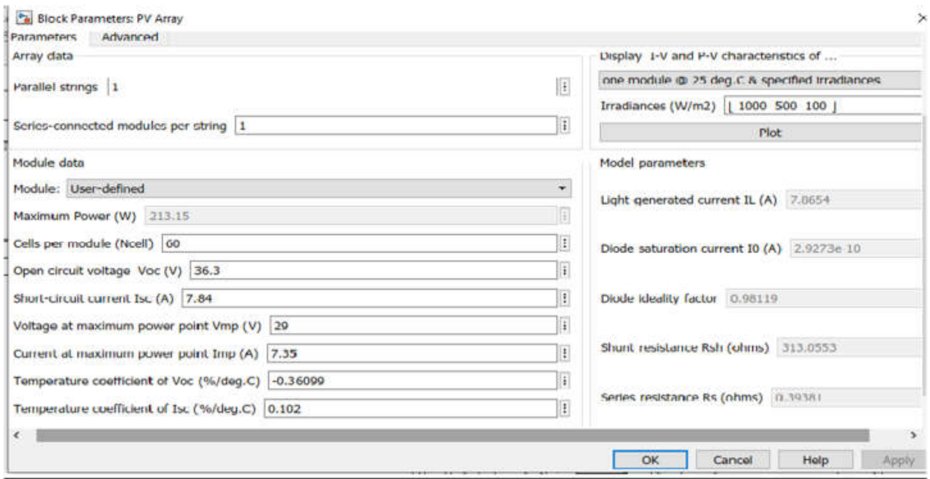
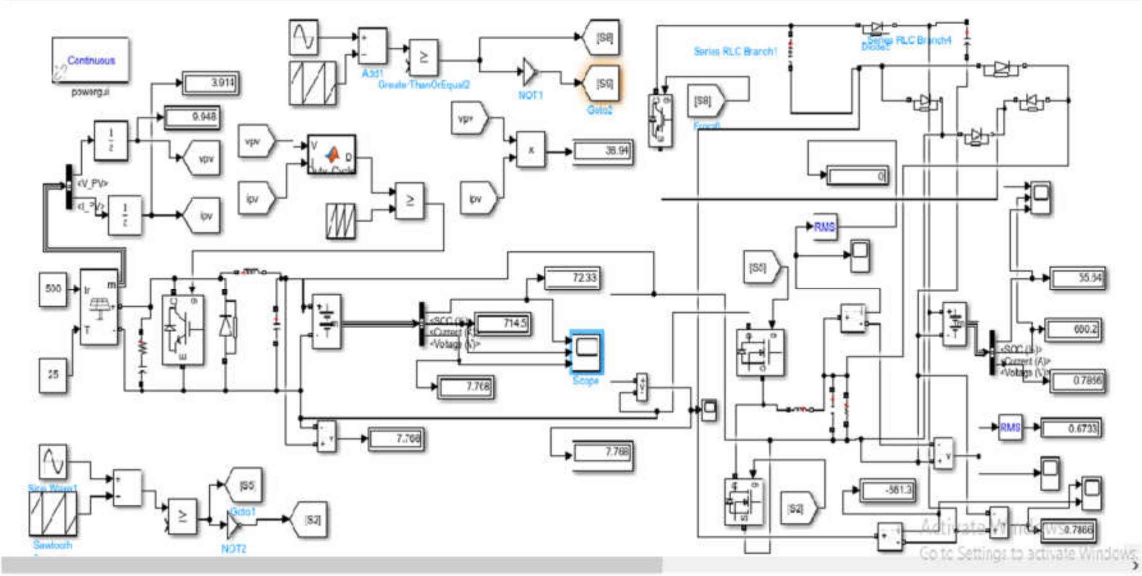


Figure 1.67 PV-ARRAY DETAILS

MATLAB Function

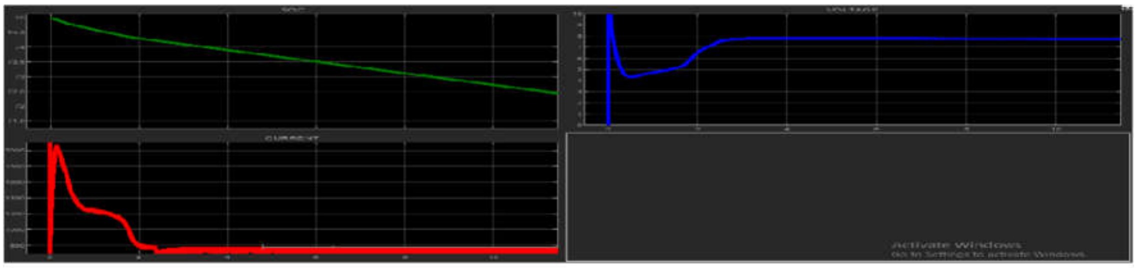
```
function D = Duty_Cycle(V,I)
Dmax = 0.95;
Dmin = 0;
Dinit = 0.95;
DelD = 0.0001;
persistent Vold Pold Dold;
datatype = 'double';
if isempty(Vold)
    Vold = 0;
    Pold =0;
    Dold =Dinit;
end

P = V*I;
dV = V-Vold ;
dP = P - Pold;
if dP ~= 0;
    if dP < 0;
        if dV<0
            D = Dold-DelD;
        else
            D = Dold - DelD;
        end
    else
        if dV < 0
            D = Dold + DelD;
    else
        D = Dold - DelD;
    end
    end

else D = Dold;
end
if D >= Dmax || D < Dmin
    D = Dold;
end
Dold = D;
Vold = V;
Pold = P;
```

Figure 1.68:- **<u>MATLAB FUNCTION FOR DUTY CYCLE</u>**



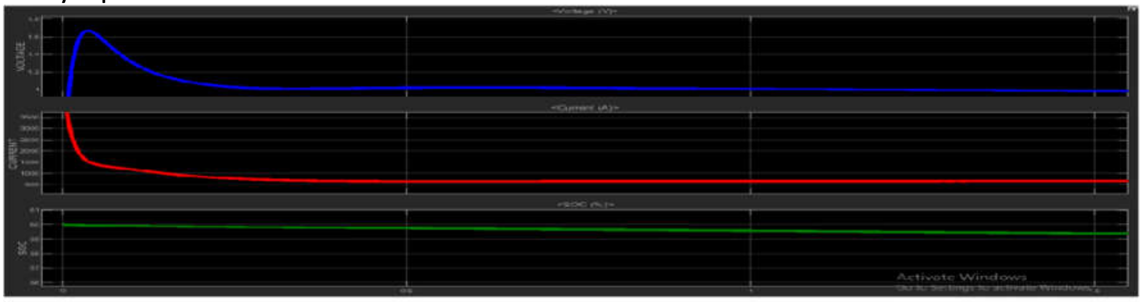
<u>Figure 1.69:- CIRCUIT DIAGRAM OF PV ARRAY CONNECTED TO LEAD ACID BATTERY WITH A BUCK CONVERTER WHICH IS FURTHER CONNECTED TO INVERTER WHICH IN TURN CONNECTED TO RECTIFIER & BOOST CONVERTER TO A LEAD ACID BATTERY</u>

<u>DETAIL OF LEAD ACID BATTERY CONNECTED TO PV ARRAY THROUGH A BUCK CONVERTER :-</u> nominal voltage=12 volt rated capacity=100ah initial state of charge=75% battery response time=1 second

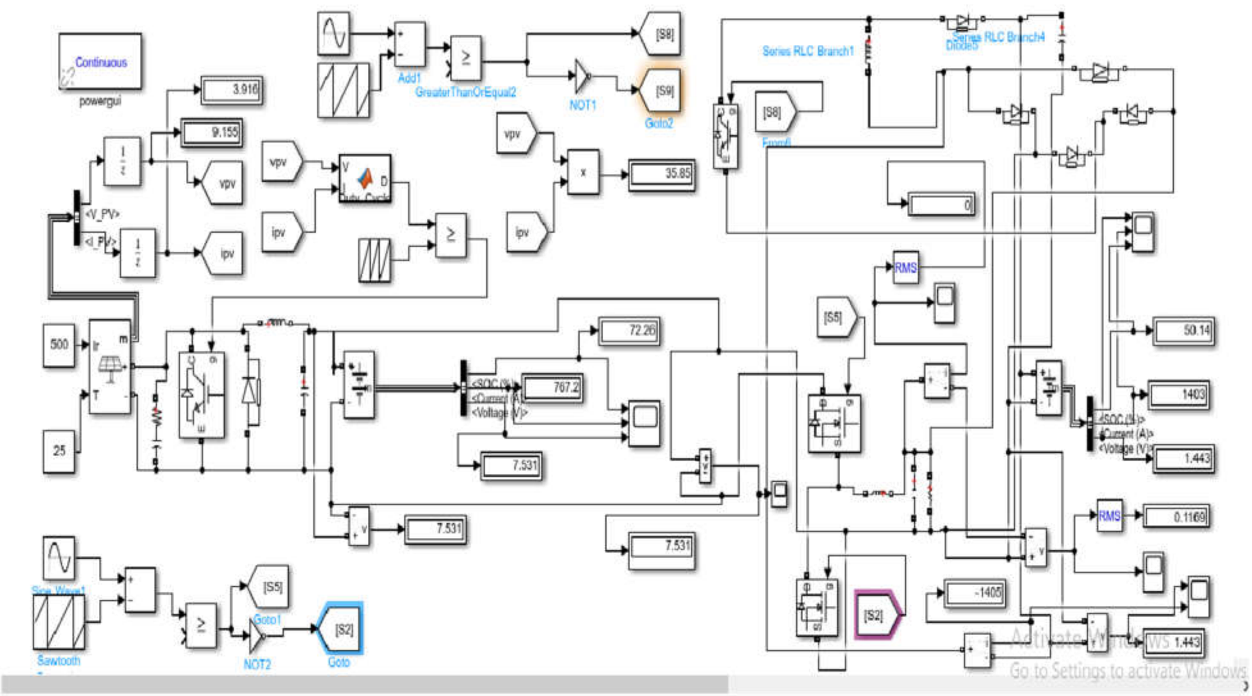


<u>Figure 1.70:- SOC , CURRENT & VOLTAGE CHARACTERISTICS OF LEAD ACID BATTERY CONNECTED TO PV-ARRAY THROUGH A BUCK CONVERTER</u>

<u>DETAILS OF LEAD ACID BATTERY CONNECTED TO OUTPUT AS LOAD:-</u> nominal voltage=3.7 volt rated capacity=50Ah initial state of charge=60% battery response time=1 second



<u>Figure 1.71:- SOC , CURRENT & VOLTAGE CHARACTERISTICS OF LEAD ACID BATTERY CONNECTED TO OUTPUT AS LOAD</u>



<u>Figure1.72:- CIRCUIT DIAGRAM OF PV ARRAY CONNECTED TO LEAD ACID BATTERY WITH A BUCK CONVERTER WHICH IS FURTHER CONNECTED TO INVERTER WHICH IN TURN CONNECTED TO RECTIFIER & BOOST CONVERTER TO A LITHIUM ION BATTERY</u>

DETAIL OF LEAD ACID BATTERY CONNECTED TO PV-ARRAY THROUGH A BUCK CONVERTER:- nominal voltage=12 volt rated capacity=100Ah initial state of charge=75% battery response time=1 second

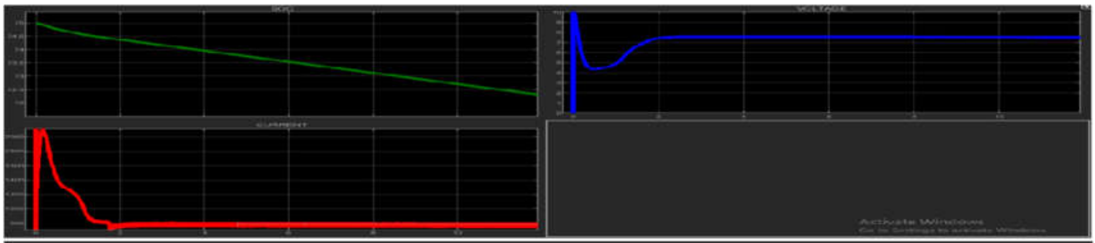


Figure1.73:- SOC , CURRENT & VOLTAGE CHARACTERISTICS OF LEAD ACID BATTERY CONNECTED TO PV-ARRAY THROUGH A BUCK CONVERTER

DETAIL OF LITHIUM ION BATTERY CONNECTED TO OUTPUT AS LOAD:- **nominal voltage=3.7 volt rated capacity=50Ah initial state of charge=60% battery response time=1 second**

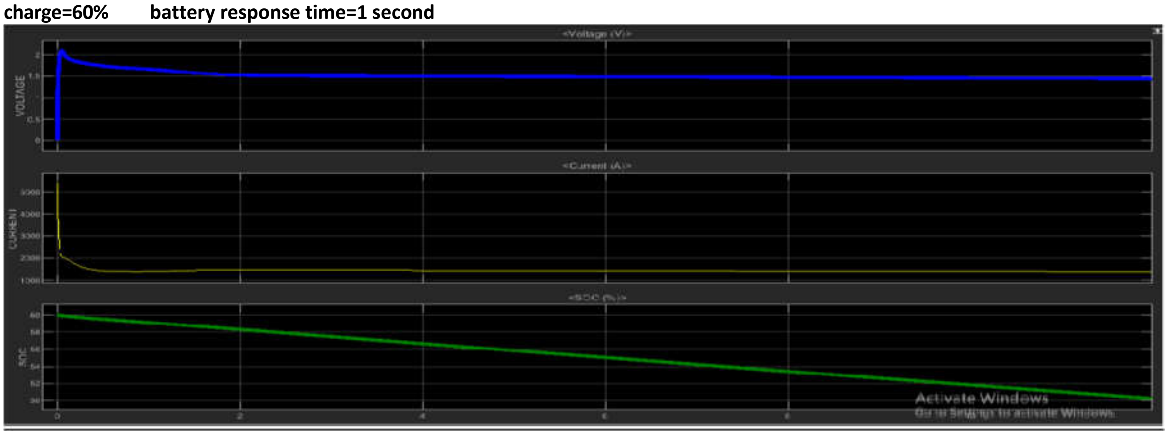


Figure1.74:- SOC , CURRENT & VOLTAGE CHARACTERISTICS OF LITHIUM ION BATTERY CONNECTED TO OUTPUT AS LOAD

3.7 PV ARRAY CONNECTED TO LITHIUM ION BATTERY WITH A BUCK CONVERTER WHICH IS FURTHER CONNECTED TO INVERTER WHICH IN TURN CONNECTED TO RECTIFIER & BOOST CONVERTER TO A LITHIUM ION BATTERY OR LEAD ACID BATTERY

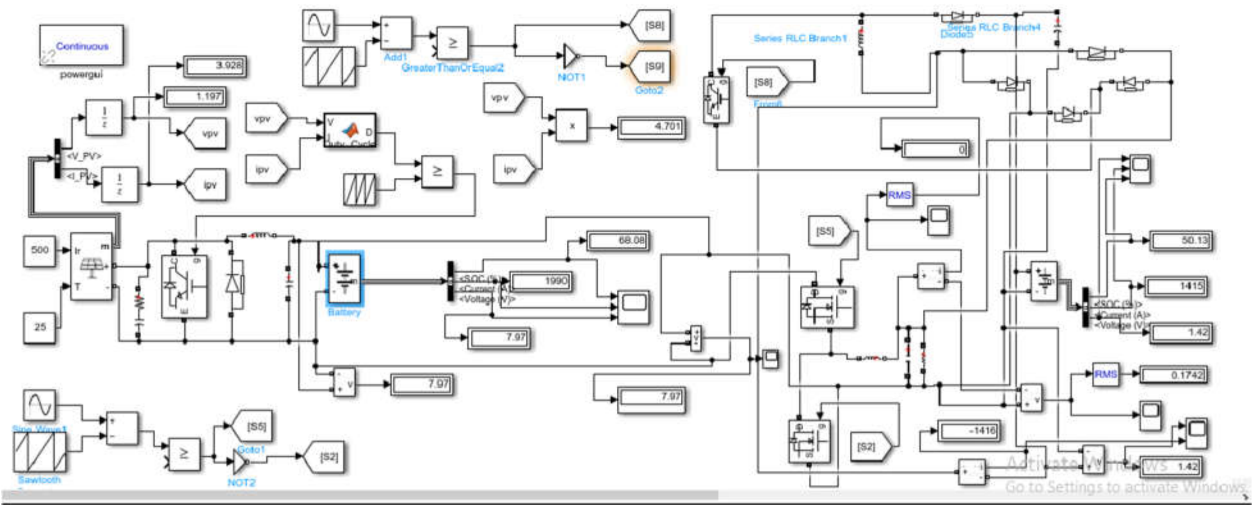


Figure1.75:- CIRCUIT DIAGRAM OF PV ARRAY CONNECTED TO LITHIUM ION BATTERY WITH A BUCK CONVERTER WHICH IS FURTHER CONNECTED TO INVERTER WHICH IN TURN CONNECTED TO RECTIFIER & BOOST CONVERTER TO A LITHIUM ION BATTERY

DETAIL OF LITHIUM ION BATTERY CONNECTED TO CONNECTED TO PV-ARRAY THROUGH A BUCK CONVERTER:- **nominal voltage=12 volt rated capacity=100Ah initial state of charge=75% battery response time=1 second**

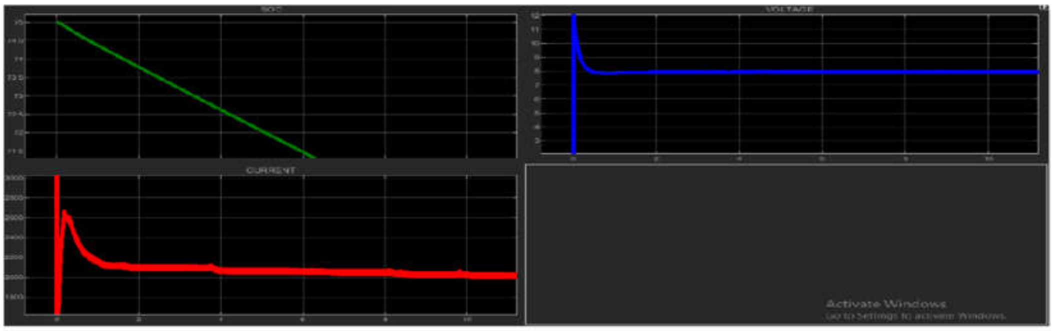


Figure1.76:- SOC , CURRENT & VOLTAGE CHARACTERISTICS OF LITHIUM ION BATTERY CONNECTED TO PV-ARRAY THROUGH A BUCK CONVERTER

DETAIL OF LITHIUM ION BATTERY CONNECTED TO CONNECTED TO OUTPUT AS LOAD:- :- **nominal voltage=3.7 volt rated capacity=50Ah initial state of charge=60% battery response time=1 second**

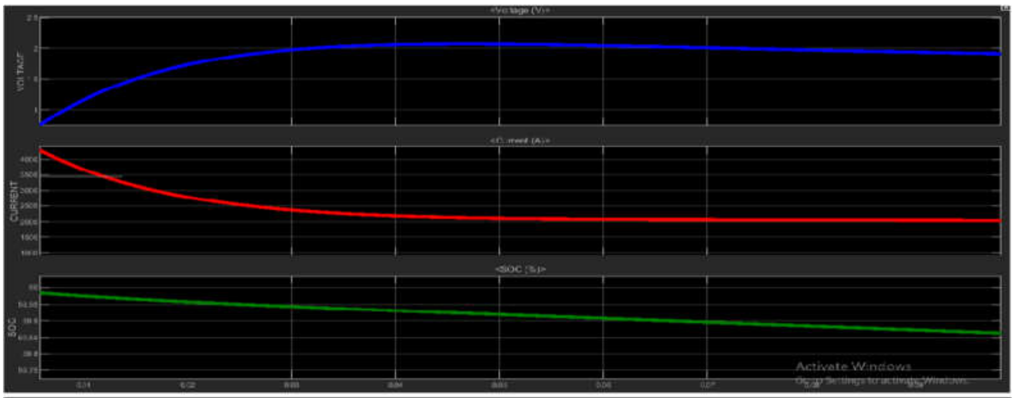


Figure 1.77:- SOC , CURRENT & VOLTAGE CHARACTERISTICS OF LITHIUM ION BATTERY CONNECTED TO OUTPUT AS LOAD

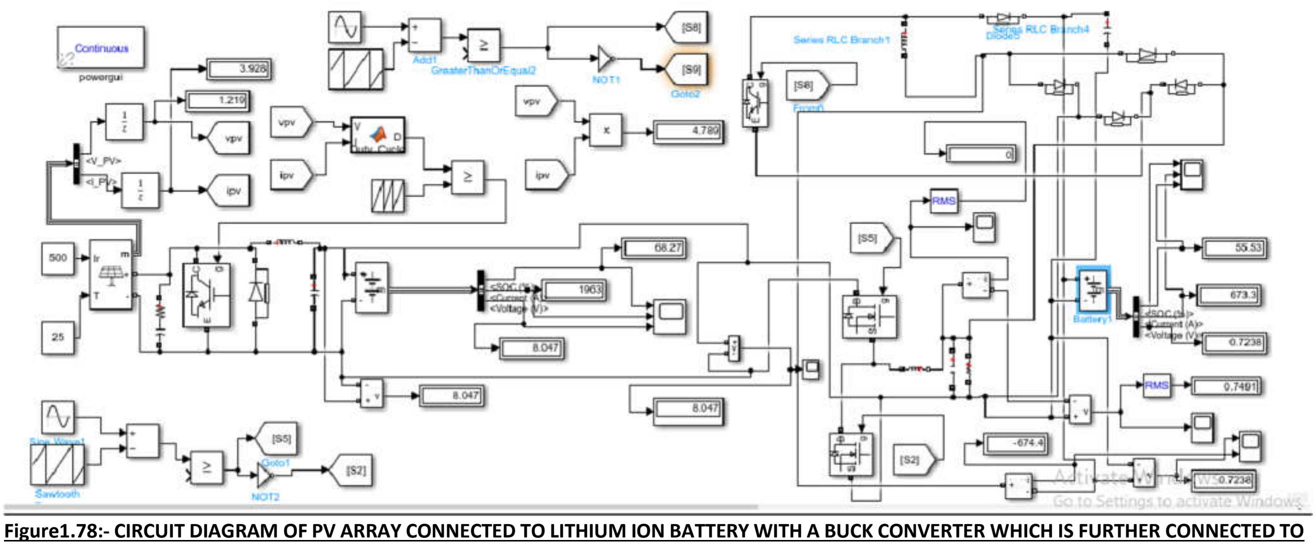


Figure1.78:- CIRCUIT DIAGRAM OF PV ARRAY CONNECTED TO LITHIUM ION BATTERY WITH A BUCK CONVERTER WHICH IS FURTHER CONNECTED TO INVERTER WHICH IN TURN CONNECTED TO RECTIFIER & BOOST CONVERTER TO A LEAD ACID BATTERY

DETAIL OF LITHIUM ION BATTERY CONNECTED TO CONNECTED TO PV-ARRAY THROUGH A BUCK CONVERTER:- nominal voltage=12 volt rated capacity=100Ah initial state of charge=75% battery response time=1 second

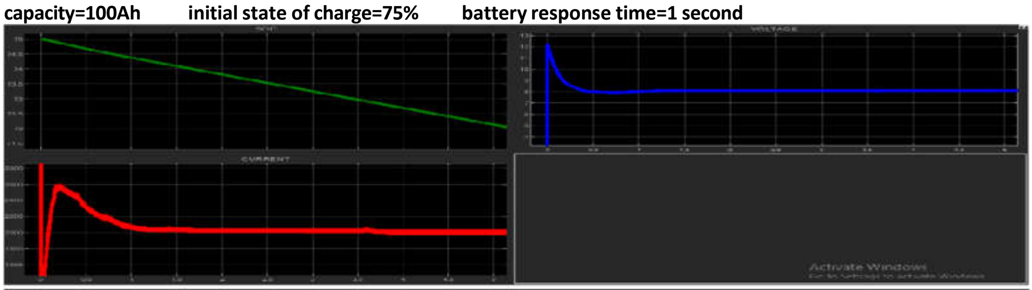


Figure 1.79:- SOC , CURRENT & VOLTAGE CHARACTERISTICS OF LITHIUM ION BATTERY CONNECTED TO PV-ARRAY THROUGH A BUCK CONVERTER

DETAIL OF LEAD ACID BATTERY CONNECTED TO CONNECTED TO OUTPUT AS LOAD:- nominal voltage=3.7 volt rated capacity=50Ah initial state of charge=60% battery response time=1 second

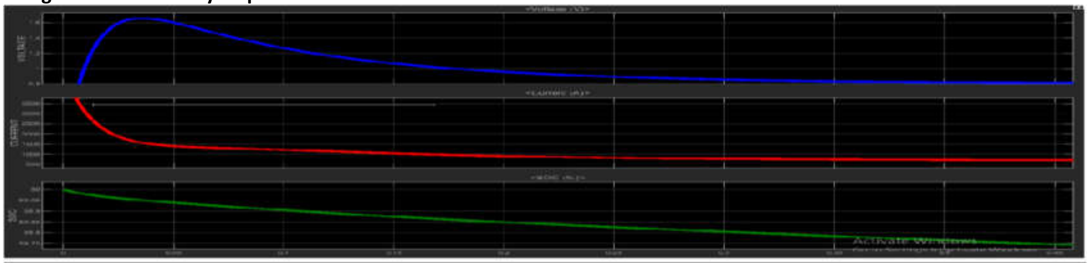


Figure 1.80:- SOC , CURRENT & VOLTAGE CHARACTERISTICS OF LEAD ACID BATTERY CONNECTED TO OUTPUT AS LOAD

CHAPTER 4 ANALYSIS:-

4.1 ANALYSIS OF LEAD ACID BATTERY CHARGING :- Initially the SOC & nominal voltage of Lead Acid battery taken as 45% and 7.2 volt . The SOC reaches to 100% and charging current becomes -96.81 milli Ampere within a period of 425 seconds .The charging current was more initially and reduced by time i.e with 24 volt DC source for charging lead acid battery of initial voltage of 7.2 volt , the charging currenr reduces exponentially .

4.2 ANALYSIS OF LITHIUM ION BATTERY CHARGING :-Initially the SOC & nominal voltage of Lithium Ion battery taken as 45% and 7.2 volt . The SOC reaches to 100% and charging current becomes -264.3 milli Ampere within a period of 425 seconds .The charging current was more initially and reduced by time i.e with 24 volt DC source for charging lead acid battery of initial voltage of 7.2 volt , the charging current reduces somewhat linearly .

4.3 ANALYSIS OF LEAD ACID –LEAD ACID SERIES BATTERY CHARGING :-Initially the SOC & nominal voltage of both Lead Acid battery taken as 45% and 7.2 volt . The SOC reaches to 100% and charging current becomes -207.8 milli Ampere within a period of 1 hour as observed . .The charging current was more initially and reduced to constant i.e with 30 volt DC source for charging lead acid battery of initial voltage of 7.2 volt , the charging currenr becomes constant.

4.4 ANALYSIS OF LEAD ACID –LITHIUM ION SERIES BATTERY CHARGING :-Initially the SOC & nominal voltage of Lead Acid & lithium ion battery taken as 45% and 7.2 volt . The SOC reaches to 100% and charging current becomes -203.9 milli Ampere within a period of 1 hour as observed . The charging current was more initially and reduced to constant i.e with 30 volt DC source for charging lead acid battery of initial voltage of 7.2 volt , the charging current initially increases & in a short time reduces and then after a small interval of regular 500 seconds , it further increases and then reduces again and this continues .

4.5 ANALYSIS OF LITHIUM ION –LITHIUM ION SERIES BATTERY CHARGING :-Initially the SOC & nominal voltage of both lithium ion battery taken as 45% and 7.2 volt . The SOC reaches to 100% and charging current becomes -677.8 milli Ampere within a period of 1 hour as observed . The charging current was more initially and reduced to constant i.e with 30 volt DC source for charging lead acid battery of initial voltage of 7.2 volt , the charging current initially increases & in a short time reduces and then after a small interval of regular 200 seconds , it further increases and then reduces again and this continues .

4.6 ANALYSIS OF LEAD ACID –LEAD ACID PARALLEL BATTERY CHARGING :-Initially the SOC & nominal voltage of both lead acid & lead acid battery taken as 45% and 7.2 volt . The SOC reaches to 100% and charging current becomes -207.8 milli Ampere within a period of 1 hour as observed . The charging current was more initially and reduced to constant i.e with 15 volt DC source for charging lead acid battery of initial voltage of 7.2 volt , the charging current initially increases & then reduces and this reduced current maintains constant throughout .

4.7 ANALYSIS OF LEAD ACID –LITHIUM ION PARALLEL BATTERY CHARGING :-Initially the SOC & nominal voltage of both lead acid & lead acid battery taken as 45% and 7.2 volt . The SOC reaches to 100% and charging current becomes -207.8 milli Ampere within a period of 1 hour as observed . The charging current was more initially and reduced to constant i.e with 15 volt DC source for charging lead acid battery of initial voltage of 7.2 volt , the charging current initially increases & then reduces and this reduced current maintains constant throughout i.e the behavior is same as for leadacid-lead acid parallel battery charging .

4.8 ANALYSIS OF LITHIUM ION –LITHIUM ION PARALLEL BATTERY CHARGING :- Initially the SOC & nominal voltage of both lead acid & lead acid battery taken as 45% and 7.2 volt . The SOC reaches to 100% and charging current becomes 469.6 milli Ampere within a period of 1 hour as observed i.e with 15 volt DC source for charging lead acid battery of initial voltage of 7.2 volt , the charging current initially very low & then reduces and this reduced current maintains constant throughout .

4.9 ANALYSIS OF LEAD ACID DISCHARGE:- For a period of 500 hour , the lead acid discharges from 100% to 13.64% and low discharge current develops and voltage reduces to 6.49 volt from 7.2 volt when 72 ohms resistance is connected at load & with step load , the current reduces in step and the for step signal with ramp start load , the the current purely reduces exponentially and then becomes constant .

4.10 ANALYSIS OF LITHIUM ION DISCHARGE:- For a period of 500 hour , the lead acid discharges from 100% to 2.757% and low discharge current develops and voltage reduces to 6.925 volt when 72 ohms resistance is connected at load & with step load , the current reduces in step with little curvature and finally becomes constant and the for step signal with ramp start load , the current purely reduces exponentially and then becomes constant .

4.11 ANALYSIS OF LEAD ACID-LEAD ACID SERIES DISCHARGE:- The SOC reduces from 100% to 0% within a period of 300 hours & current almost remains constant for 72 ohms resistance at load . For step , the current reduces in a step format and finally becomes constant & SOC reduces to 0% in nearly 1800 seconds . For step with ramp start , the soc reduces to 0 % in 4000 seconds & current droops exponentially with a step end and finally becomes constant .

4.12 ANALYSIS OF LEAD ACID-LITHIUM ION SERIES DISCHARGE:- The SOC reduces from 100% to 0% within a period of 300 hours & current remains constant throughput for 72 ohms resistance at load .For step , the SOC reduces to 0% in 250 hours & current constant throughput . For step The SOC reduces to 0% in 250 hours and current constant throughput .Fopr step with ramp start , the soc reduces to 0 % in 1200 seconds & current reduces to nearly zero in a step format with a curvature in 1750 seconds .

4.13 ANALYSIS OF LITHIUM ION-LITHIUM ION SERIES DISCHARGE:- The SOC reduces from 100% to 0% within a period of 250 hours & current remains low constant throughput for 72 ohms resistance at load .For step , the SOC reduces to 0% in 250 hours & current constant throughput . For step , The SOC reduces to 0% in 250 hours and current remains low throughput .For step with ramp start , the soc reduces to 0 % in 1400 seconds & current reduces to nearly zero , becomes constant at it , in a step format with a curvature in 1400 seconds .

4.14 ANALYSIS OF LEAD ACID –LEAD ACID PARALLEL DISCHARGE :- The SOC reduces TO 58% in 500 hours and current remains low constant throughput for 72 ohms resistance at load .For step load , the the SOC reduces to 0 in 170 hours & reduces in a step format to a low constant current . For step load with ramp start , the SOC reduces exponentially to zero in 110 hours and current remains constant low.

4.15 ANALYSIS OF LEAD ACID –LITHIUM ION PARALLEL DISCHARGE :- The SOC reduces to 3.413% in 470 hours and current remains low constant throughput for 72 ohms resistance at load .For step load , the the SOC reduces to 0 & current first increases & then continuously decreases in step format to low current in 165 hours . For step with ramp start load also , the same is observed .

4.16 ANALYSIS OF LITHIUM ION-LITHIUM ION PARALLEL DISCHARGE:- The SOC reduces to 50.72% in 500 hours and current remains low constant throughput for 72 ohms resistance at load .For step load , the the SOC reduces to 0 in 140 hours & current reduces in step format to finally constant zero current in . For step with ramp start load also , the SOC reduces to zero in 40 hours & current droops to zero and becomes constant throughput .

4.17 ANALYSIS OF PV ARRAY CONNECTED TO LEAD ACID BATTERY WITH A BUCK CONVERTER WHICH IS FURTHER CONNECTED TO INVERTER WHICH IN TURN CONNECTED TO RECTIFIER & BOOST CONVERTER TO A LEAD ACID BATTERY OR LITHIUM ION BATTERY:-

FOR INPUT LEAD ACID BATTERY TO PV ARRAY AND BUCK CONVERTER:-The SOC reduces from 75% to 72.5 % in 11 seconds. The voltage begins with the spike at peak voltage 10 volt and then becomes constant at 8 volt and current begins with spike and then reduces to 800 mille ampere and becomes constant.

FOR OUTPUT LEAD ACID BATTERY AS LOAD:-The SOC reduces from 60% initial charging to 30% in 1.5 seconds. The voltage begins with a spike at 16 volt and reduces to 1 volt .The current begins with a spike & reduces to 100 mille ampere constant current.

FOR OUTPUT LITHIUM ION BATTERY AS LOAD:-

The SOC reduces from 60% initial charging to 52% in 12 seconds. The voltage begins with a spike at 16 volt and reduces to 1.5 volt .The current begins with a spike & reduces to 1300 mille ampere constant current .

4.18 ANALYSIS OF PV ARRAY CONNECTED TO LITHIUM ION BATTERY WITH A BUCK CONVERTER WHICH IS FURTHER CONNECTED TO INVERTER WHICH IN TURN CONNECTED TO RECTIFIER & BOOST CONVERTER TO A LITHIUM ION BATTERY OR LEAD ACID BATTERY :-

FOR INPUT LITHIUM ION BATTERY TO PV ARRAY AND BUCK CONVERTER:-

The SOC reduces from 75% to 70 % in 6 seconds. The voltage begins with the spike at peak voltage 10 volt and then becomes constant at 8 volt and current begins with spike and then reduces to 2000 mille ampere and becomes constant .

FOR OUTPUT LEAD ACID BATTERY AS LOAD:-

The SOC reduces from 60% to 58 % in 0.1 seconds. The voltage reduces from 1.8 volt to 0.8 volt & current then reduces from 2000 mille ampere to 800 mille ampere and becomes constant .

FOR OUTPUT LITHIUM ION BATTERY AS LOAD:-

The SOC reduces from 60% to 58 % in 0.45 seconds. The voltage increases exponentially to1.8volt & droops down to 0.8 volt & current begins with a spike, reaches above 5000 mille ampere and then reduces from to 800 mille ampere and becomes constant .

TABLE 1.1 SIMULATION RESULT OF BATTERY CHARGING

CHARGING OF BATTERIES WITH INITIAL STATE OF CHARGE = 45%		
LEAD ACID BATTERY	425 SECONDS	100%
LITHIUM ION BATTERY	100 SECONDS	100%
LEAD ACID- LEAD ACID SERIES BATTERY CHARGING	140 SECONDS	100%
LITHIUMION – LEAD ACID SERIES BATTERY CHARGING	70 SECONDS	100%
LITHIUMION- LITHIUMION SERIES BATTERY CHARGING	60 SECONDS	100%
LEAD ACID- LEAD ACID PARALLEL BATTERY CHARGING	225 SECONDS	100%
LEADACID- LITHIUMION PARALLEL BATTERY CHARGING	250 SECONDS	100%
LITHIUMION – LITHIUM ION PARALLEL BATTERY CHARGING	80 SECONDS	100%

TABLE 1.2 SIMULATION RESULT OF BATTERY DISCHARGING

DISCHARGING OF BATTERIES WITH INITIAL STATE OF CHARGE = 100% WITH LOAD AS 72 OHM RESISTANCE		
LEAD ACID BATTERY	500 HOURS	13.64%
LITHIUM ION BATTERY	500 HOURS	2.757%
LEAD ACID-LEAD ACID SERIES BATTERY DISCHARGING	275 HOURS	0%
LITHIUMION –LEAD ACID SERIES BATTERY DISCHARGING	300 HOURS	0%
LITHIUMION-LITHIUMION SERIES BATTERY DISCHARGING	250 HOURS	0%
LEAD ACID-LEAD ACID PARALLEL BATTERY DISCHARGING	500 HOURS	55.78%
LEADACID-LITHIUMION PARALLEL BATTERY DISCHARGING	470 HOURS	3.413%
LITHIUMION-LITHIUMION PARALLEL BATTERY DISCHARGING	500 HOURS	50.72%

CHAPTER 5 SUMMARY & CONCLUSION

5.1 Summary: **The analysis and design of batteries charging and discharging have been carried out for various performances parameters of voltages and loads. For charging , the fixed voltage source of 12 volt for 7.2v battery and fixed voltage source of 24 volt for series charging is used . The loads vary from purely resistive load or step load to step load with ramp at start. Namely Lead Acid, Lithium Ion and their series and parallel combination have been designed to deliver output characteristics with fixed DC voltage source for charging and also outputs of Discharging of batteries studied with load variations seen through display and waveform characteristics .This work was carried out with the help of Matlab-Simulink . The result of simulation are presented for comparison . These design concepts are validated through simulation in the matlab and the results are presented for analysis of various batteries.**

5.2 Conclusion: **The depth of discharge and battery capacity is strongly affected by the discharge rate of the battery. The battery capacity degrades due to sulfation and shedding of extra material .The degradation of battery capacity depends most strongly on the interrelationship between the following parameters:-**

1. **The charging/discharging regime which the battery has experienced**
2. **The exposure to prolonged periods of low discharge.**
3. **The average temperature of the battery over its lifetime.**

Reducing internal resistance improves battery output , enhances energy efficiency which in turn leads to higher reliability .The specific energy density for lead acid is 30-50 Wh/Kg and for lithium ion , it is 100-135 Wh/Kg with Manganese as salt . The cycle life with 80% discharge for lead acid is 200-300 hours and for lithium ion, it is 1000-2000hours with phosphate as salt .The internal resistance of Lead acid with 12 volt battery pack is less than 100 milli ohm whereas for lithium ion battery, it is 25-50 milli ohm per cell. The initial state of charge of both batteries set at 45% and it is found that Lead acid battery takes 425 seconds to full charge while Lithium Ion Battery takes 100 seconds to full charge. So charging of Lithium Ion battery is fastest. With initial state set to full charge, it was found that Lead Acid Battery discharge to 13.64% in 500 hours while Lithium Ion Battery in the same period discharge to 2.757% with load resistance set at 72 ohms in both cases. While lead acid charging through simulation, it is seen that initially the charging current is high and the charging current reduces exponentially with time onwards. Theoretically if lead acid battery is being discharged very quickly, then the discharge current is high but practically if discharged for long period of 500 hours with load resistance nearly 100 ohms, the discharge current is constant. while in Lithium Ion Charging, the charging current develops constant current algorithm and it is observed, unlike Lead Acid, where charging current decreases exponentially , here in Lithium Ion Battery , the current deduces to constant naturehood in a very short period of time duration .Even seen in Lithium Ion also like in Lead Acid that discharging for 500 hours results to constancy in current characteristics .

CHAPTER 6 FUTURE SCOPE

Lead acid battery is used in every type of vehicle because they have proven to be very cost effective method for storing sufficient power and energy .They are inexpensive and simple to manufacture. Due to growth in automobile and Interruptible Power Source (UPS), there is potential increase in the market of these batteries. But lead and sulphuric acid which are two main components can poison solid and ground water and so are threat to human health and the environment .While lead acid can take 10 hours to charge, the lithium ion takes 3 hours and few minutes to charge, depending on the size of the battery. The lithium ion accepts a faster rate of current, charges quickly than lead acid batteries .The solid state Lithium battery is a new development and steps forward from current Lithium Ion Batteries. The Solid State Batteries combine the performance of conventional Lithium Ion and Lithium polymer with higher safety for use in different applications. It promises lower cost, more power, and longer range, faster charging times, greater flexibility and improved safety. Solid state batteries can have energy density of up to 350 watt-hours per kg and even higher as compared to 100-360 Whr/kg of conventional lithium ion batteries .So Solid state batteries can secure our future challenging needs .

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