STUDY OF LITHIUM ION CHARGING & DISCHARGING CHARACTERISTICS

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ABSTRACT:- 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.

1. INTRODUCTION:- DETAILS OF LITHIUM ION BATTERY:- 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.

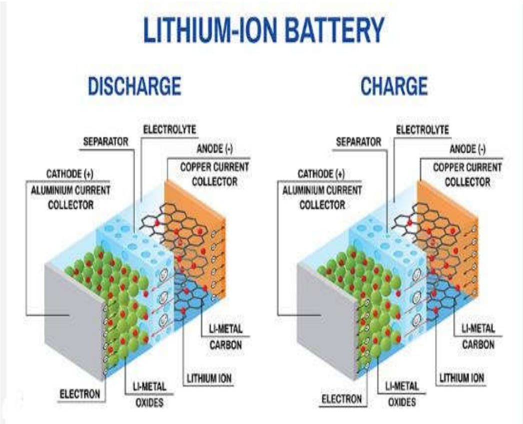


Figure1.1:-CHARGING AND DISCHARGING OF LITHIUM ION BATTERY

Lithium cells :-

Lithium Cells are Primary cells in which lithium acts as anode and cathode may differ. Lithium metal is used as anode because of its light weight, high standard oxidation potential(>3v) and good conductivity. As the reactivity of lithium in aqueous solution is more, Lithium cells use non aqueous solvents as electrolyte. Lithium cells are classified into two categories:
a) Lithium cells with solid cathodes
b) Lithium cells with liquid cathodes

a) Lithium cells with solid cathode:

The electrolyte in these systems is a solid electrolyte . The most widely used cell is Lithium-Manganese dioxide cell . MnO_2 should be heated to over 3000C to remove water before keeping it in the cathode, there by the efficiency of the cell is increased.
Anode: Lithium metal
Cathode: MnO_2 as an active material
Electrolyte: $LiBF_4$ salt in a solution of propylene carbonate and dimethoxy ethane.

Net reaction: $Li + MnO_2 \rightarrow LiMnO_2$

Reactions:
At Anode : $Li \rightarrow Li^+ + e^-$
At Cathode : $e^- + MnO_2 \rightarrow MnO_2^-$
Net reaction: $Li + MnO_2 \rightarrow LiMnO_2$
Applications:

1) The coin type cells are used in watches and calculators.
2) Cylindrical cells are used in fully automatic cameras.

(b) Lithium cells with Liquid cathode: Lithium- Sulphur dioxide cell is an example of liquid cathode. The co-solvents used are acrylonitrile or propylene carbonate (or) mixture of the two with SO_2 in 50% by volume.

Cell reaction: $2Li + 2SO_2 \rightarrow LiS_2O_4$
Uses: 1) They are used for military and space application.
2) In Medicinal devices like neuro-stimulators drug delivery system lithium batteries are widely used.
3) They are also used in electric circuit boards for supplying fixed voltage for memory protection and standby functions.

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.

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

Simscape:

Simulink is a graphical programming environment for modelling, simulating and analysis of dynamic systems where as Simscape is a Physical modelling part in simulink environment. It 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.

1.3 Battery Performance Parameters:-

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

1.3.1 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.

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

1.3.3 Charging and Discharging rates: - 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.

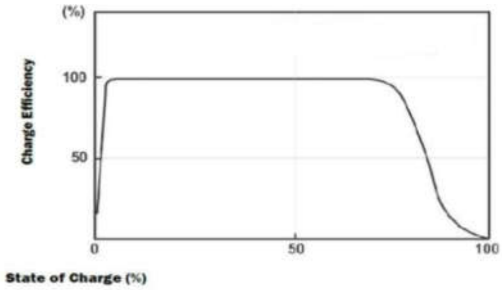


Figure 1.2 :- Graph between State of charge and charge Efficiency

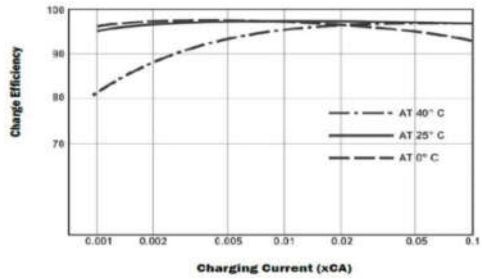


Figure 1.3:- Graph between Charging current & Charge Efficiency

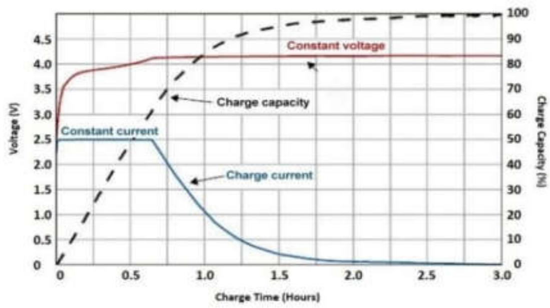


Figure 1.4 :- Charge curve of Lithium –Ion Battery

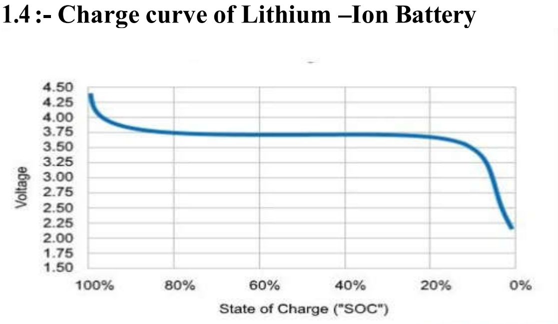


Figure 1.5:- Discharge curve of Lithium–Ion Battery

2. 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.

3. LITHIUM ION BATTERY CHARGING:

Circuit diagram of Lead Acid battery charging is shown in figure and design parameters are also shown below .Simulation results are shown both in display and waveform basis.

. DC Voltage Source = 12 Volt
. Lead acid nominal voltage:- 7.2 volt
. Rated capacity:- 55 Ah
. Initial state of charge:- 45%
. Battery response time:- 30 seconds

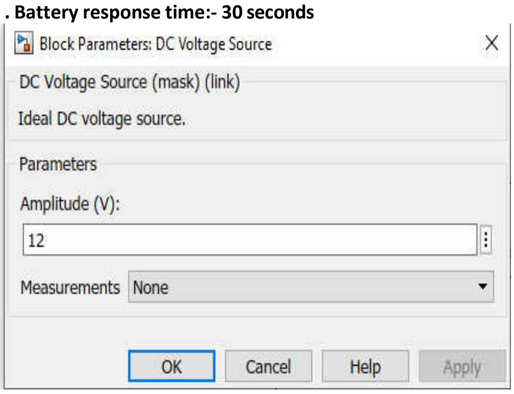


Figure 3.1. :-
<u>DC VOLTAGE SOURCE FOR LITHIUM ION BATTERY CHARGING</u>

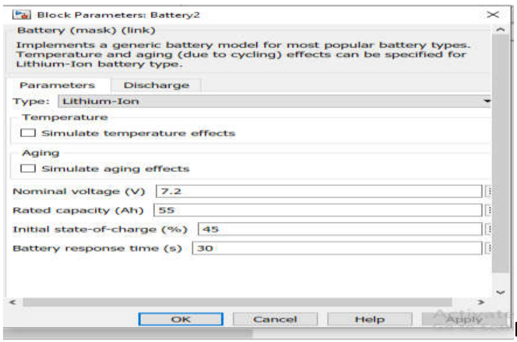


Figure 3.2:-
DETAIL SPECIFICATION OF LITHIUM ION BATTERY

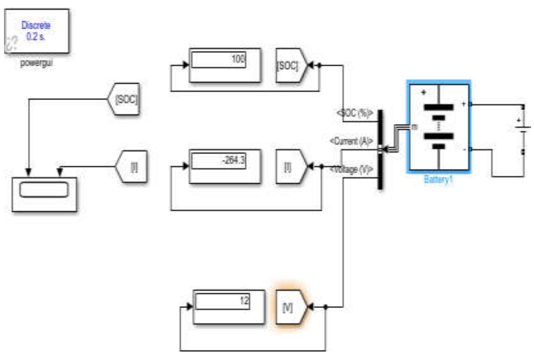


Figure 3.2.3 :- CIRCUIT DIAGRAM OF LITHIUM ION BATTERY CHARGING FOR 425 SECONDS

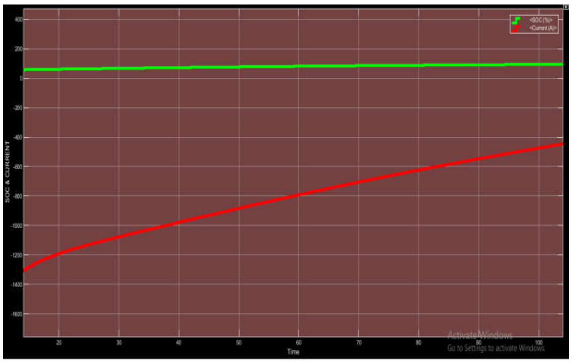


Figure 3.2.4:- SOC & CURRENT WAVEFORM OF LITHIUM ION BATTERY CHARGING FOR 135 SECONDS IS CAPTURED AND DISPLAYED FOR BETTER OBSERVATION

4. SERIES COMBINATION OF LITHIUM ION-LEAD ACID BATTERIES CHARGING :

Series combination of Lithium Ion-Lead Acid battery charging is shown in figure and design parameters are also shown below .Simulation results are shown both in display and waveform basis .

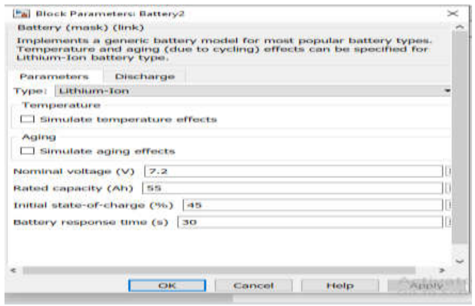


Figure 4.1:- DETAIL SPECIFICATION OF LITHIUM ION BATTERY CONNECTED IN SERIES WITH LEAD ACID BATTERY

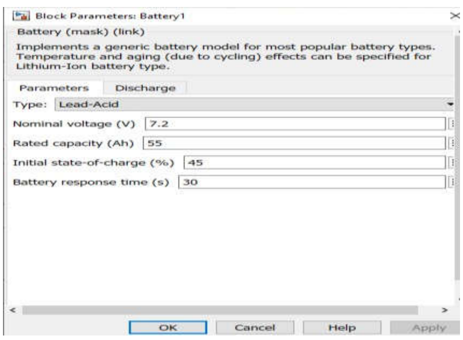


Figure 4.2:- DETAIL SPECIFICATION OF LEAD ACID BATTERY CONNECTED IN SERIES WITH LITHIUM ION BATTERY

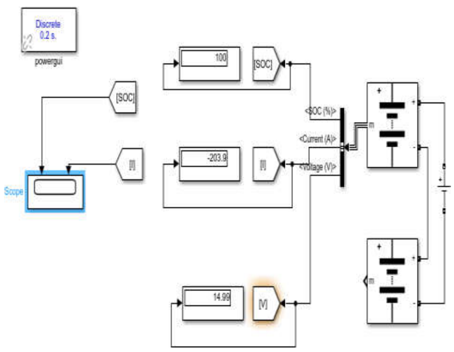


Figure 4.3:-CIRCUIT DIAGRAM OF LEAD ACID BATTERY CONNECTED IN SERIES WITH LITHIUM ION BATTERY FOR 1 HOUR

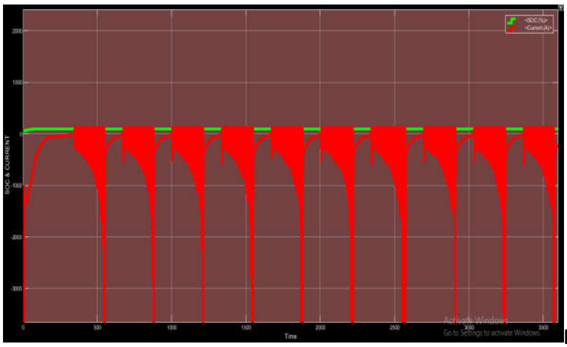
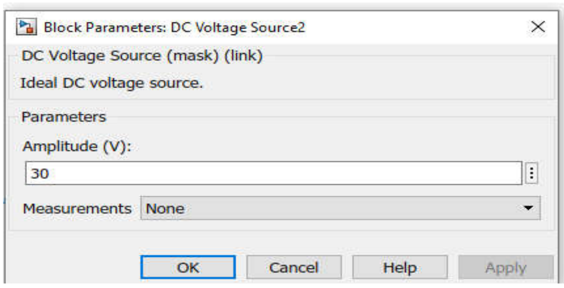


Figure 4.4:-SOC & CURRENT WAVEFORM OF LEAD ACID BATTERY CONNECTED SERIESWITHLITHIUM ION BATTERY FOR 1 HOUR

5. LITHIUM ION-LITHIUM ION SERIES CHARGING:

Series combination of Lithium Ion-Lithium-Ion battery charging is shown in figure and design parameters are also shown below .Simulation results are shown both in display and waveform basis .


Block Parameters: DC Voltage Source2

DC Voltage Source (mask) (link)

Ideal DC voltage source.

Parameters

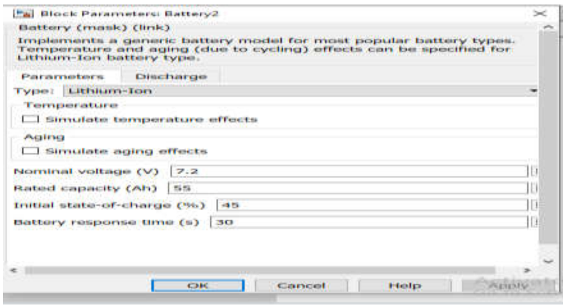
Amplitude (V):

30

Measurements None

OK Cancel Help Apply

Figure 5.1:- DC VOLTAGE SOURCE DETAIL FOR LITHIUM ION BATTERY SERIES CHARGING


Block Parameters: Battery2

Battery (mask) (link)

Implements a generic battery model for most popular battery types. Temperature and aging (due to cycling) effects can be specified for Lithium-Ion battery type.

Parameters Discharge

Type: Lithium-Ion

Temperature

Simulate temperature effects

Aging

Simulate aging effects

Nominal voltage (V) 7.2

Rated capacity (Ah) 55

Initial state-of-charge (%) 45

Battery response time (s) 30

OK Cancel Help Apply

Figure 5.2:-DETAIL SPECIFICATION OF BOTH LITHIUM ION BATTERY FOR SERIES CHARGING

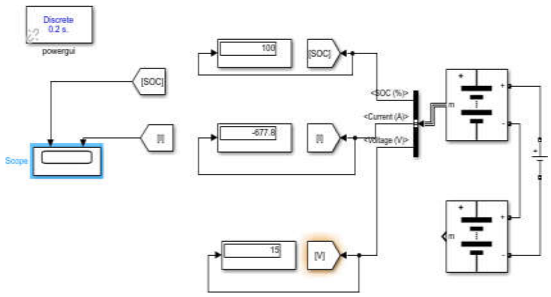


Figure 5.3:-CIRCUIT DIAGRAM OF LITHIUM ION BATTERY CONNECTED IN SERIES WITH LITHIUM ION BATTERY FOR 1 HOUR

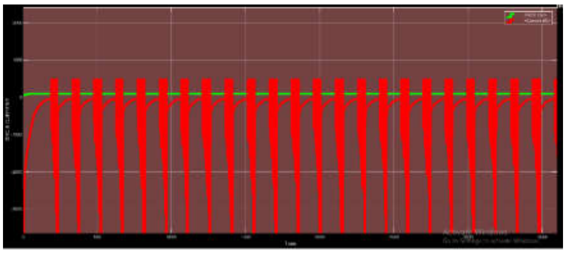


Figure5.4:-SOC & CURRENT WAVEFORM OF LITHIUM ION BATTERY CONNECTED IN SERIES WITHLITHIUM ION BATTERY FOR 1 HOUR

6. LITHIUM ION-LEAD ACID BATTERY PARALLEL CHARGING:

Parallel combination of Lithium Ion-Lead acid battery Parallel charging is shown in figure and design parameters are also shown below .Simulation results are shown both in display and waveform basis .

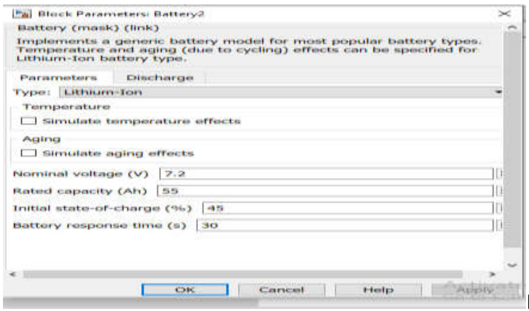


Figure 6.1:- <u>DETAIL SPECIFICATION OF LITHIUM ION BATTERY</u>

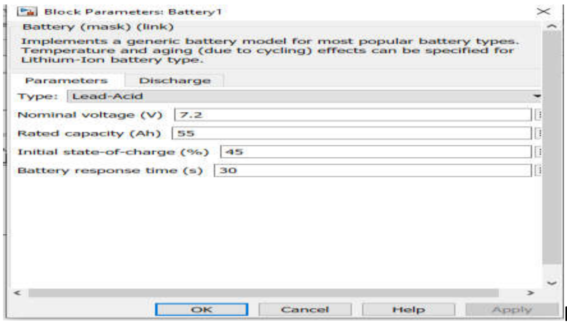


Figure 6.2:-<u>DETAIL SPECIFICATION OF LEAD ACID BATTERY</u>

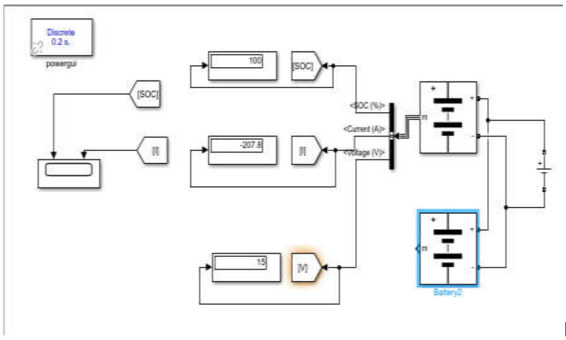


Figure 6.3:<u>-CIRCUIT DIAGRAM OF LITHIUM ION BATTERY & LEAD ACID BATTERY PARALLEL CHARGING FOR I HOUR</u>

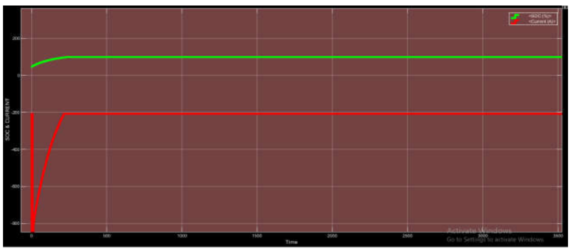


Figure 6.4:-<u>SOC & CURRENT WAVEFORM OF LITHIUM ION BATTERY & LEAD ACID BATTERY PARALLEL CHARGING FOR 1 HOUR</u>

7. <u>LITHIUM ION-LITHIUM ION BATTERY PARALLEL CHARGING:</u>

Combination of Lithium Ion-Lithium Ion battery Parallel charging is shown in figure and design parameters are also shown below .Simulation results are shown both in display and waveform basis.

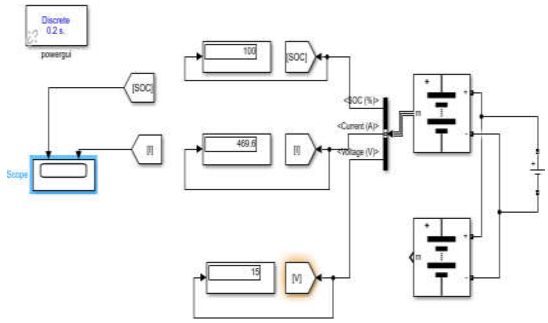


Figure 7.1:-<u>CIRCUIT DIAGRAM OF LITHIUM ION BATTERY & LITHIUM ION BATTERY PARALLEL CHARGING FOR I HOUR</u>

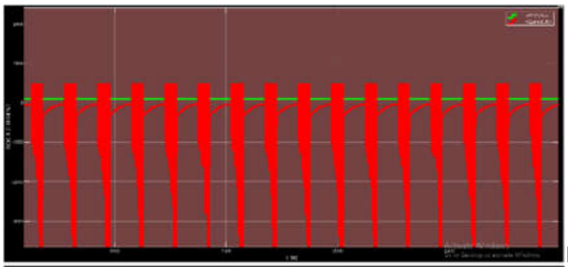
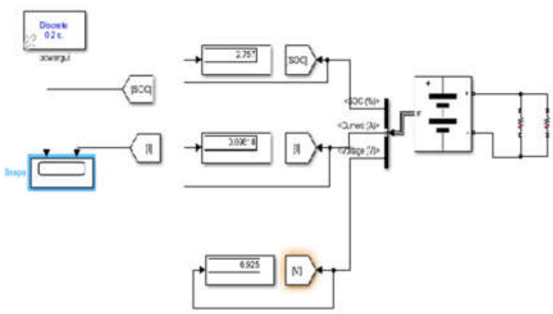


Figure 7.2:-<u>SOC & CURRENT WAVEFORM OF LITHIUM ION BATTERY & LITHIUM ION BATTERY FOR PARALLEL CHARGING FOR 1 HOUR</u>

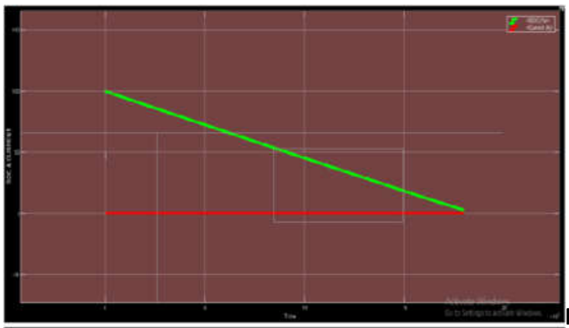
8. <u>LITHIUM ION BATTERY DISCHARGE:</u>

Lithium Ion battery discharge is shown in figure and design parameters are also shown below .Simulation results are shown both in display and waveform basis .Initially the battery charging is taken as 100% and nominal voltage of battery is taken as 7.2 volt .



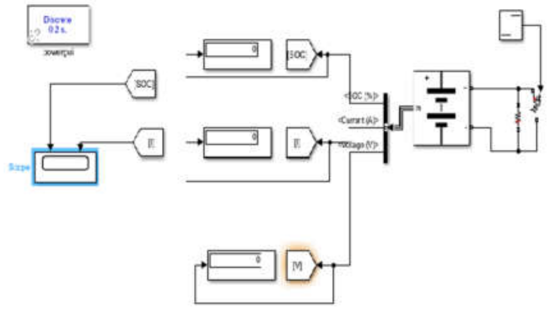
Figure

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



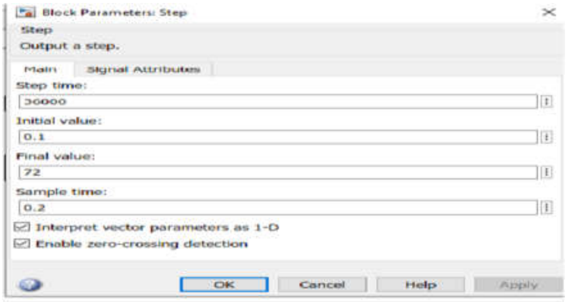
Figure

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



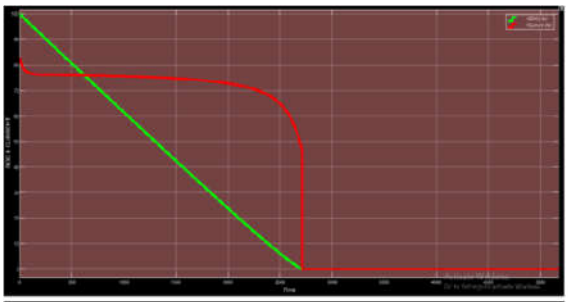
Figure

8.3 :- CIRCUIT DIAGRAM OF DISCHARGE OF LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 25 HOURS



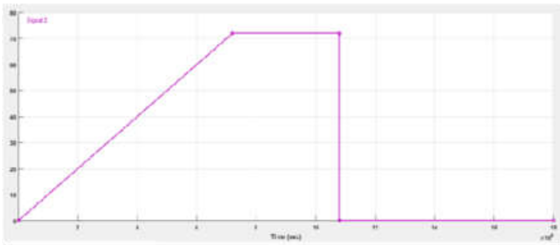
Figure

8.4:- IMAGE SHOWING DETAILS OF STEP SIGNAL



Figure

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



Figure

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

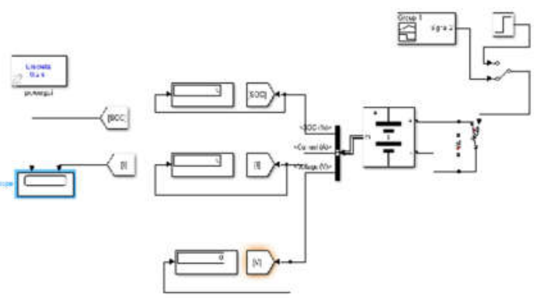


Figure 8.7:- CIRCUIT DIAGRAM OF DISCHARGE OF LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 20 HOURS

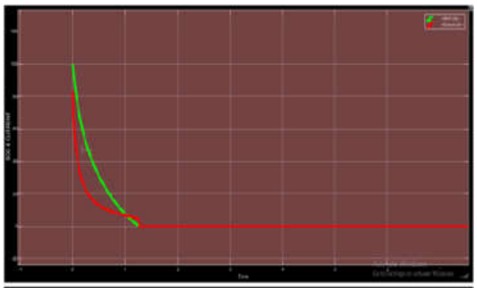


Figure 8.8:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION BATTERY CONNECTED TO LOAD AS STEP SIGNAL WITH RAMP START FOR 20 HOURS

9. LITHIUM ION-LEAD ACID SERIES BATTERY DISCHARGE:

Combination of Lithium Ion-Lead acid series battery discharge is shown in figure and design parameters are also shown below .Simulation results are shown both in display and waveform basis .

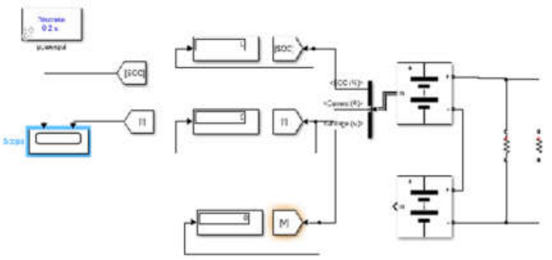


Figure 9.1 :- CIRCUIT DIAGRAM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

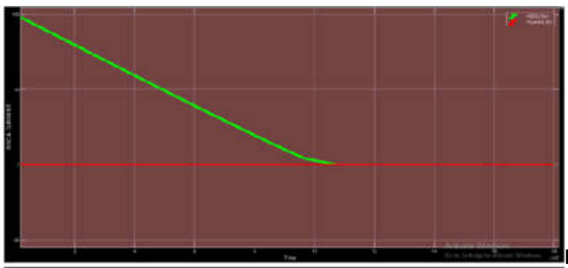


Figure 9.2:- WAVEFORM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

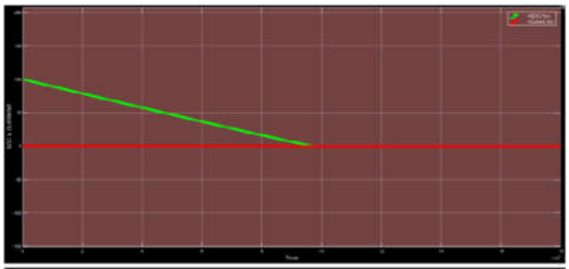


Figure 9.3:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL FOR 500 HOURS

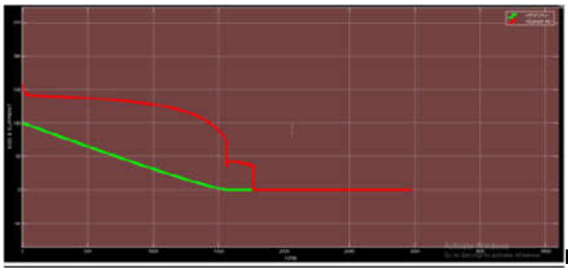


Figure 9.4:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 500 HOURS

10. LITHIUM ION-LITHIUM ION SERIES BATTERY DISCHARGE:

Combination of Lithium Ion-Lithium Ion Series battery discharge is shown in figure and design parameters are also shown below .Simulation results are shown both in display and waveform basis .

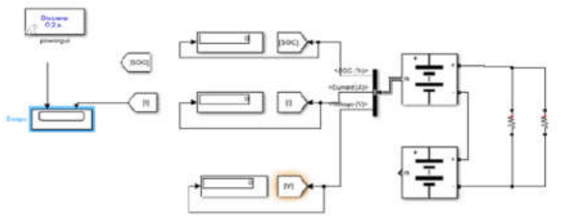


Figure10.1:- CIRCUIT DIAGRAM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

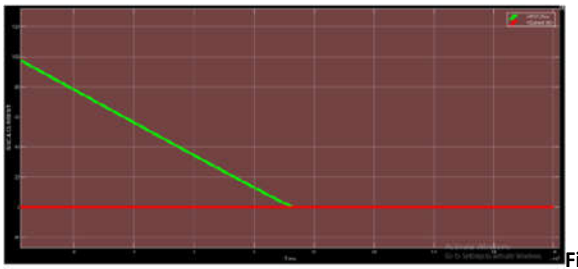


Figure 10.2:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

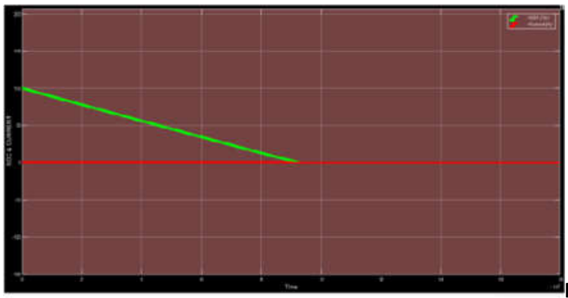


Figure 10.3:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL FOR 500 HOURS

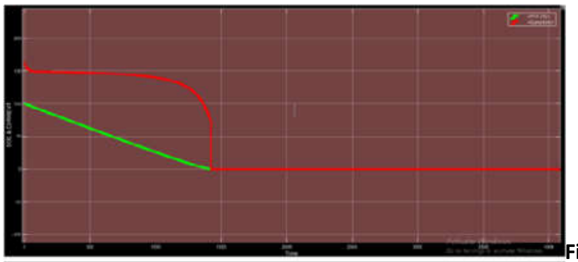


Figure 10.4:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 500 HOURS

11. LITHIUM ION-LEAD ACID BATTERY PARALLEL DISCHARGE:

Combinaation of Lead Acid- Lithium Ion battery parallel discharge is shown in figure and design parameters are also shown below .Simulation results are shown both in display and waveform basis.

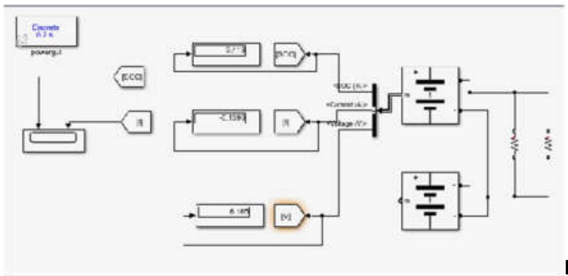


Figure 11.1:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD RESISTANCE 72 OHMS FOR 470 HOURS

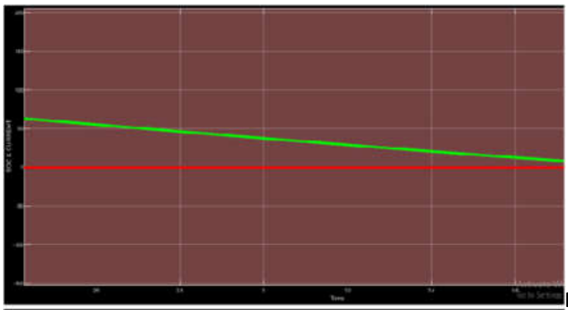


Figure 11.2 :- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD RESISTANCE 72 OHMS FOR 470 HOURS

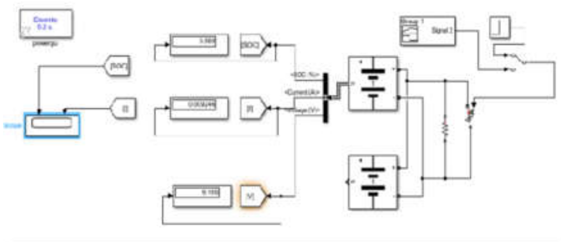


Figure 11.3 :- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 140 HOURS

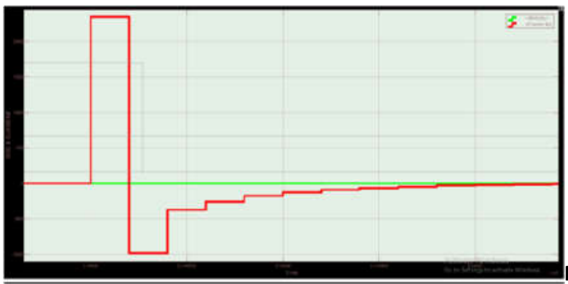


Figure 11.4 :- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 140 HOURS

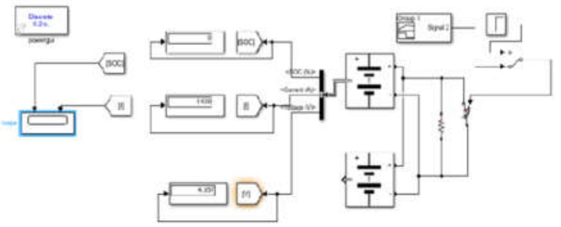


Figure 11.5:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 200 HOURS

Figure 11.6:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 200 HOURS

12. LITHIUM ION-LITHIUM ION BATTERY PARALLEL DISCHARGE:

Combination of Lithium Ion-Lithium Ion battery Parallel discharge is shown in figure and design parameters are also shown below .Simulation results are shown both in display and waveform basis .

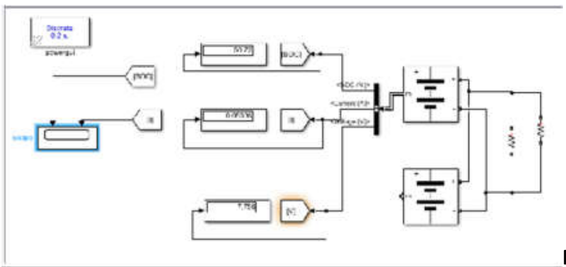


Figure 12.1:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS 72 OHMS FOR 500 HOURS

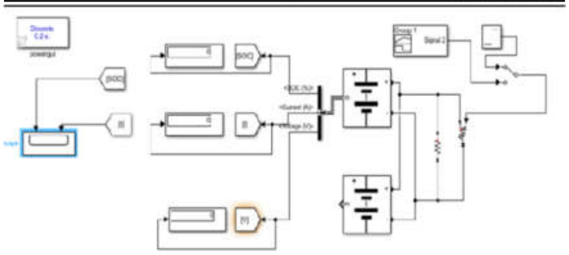


Figure 12.2:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS 72 OHMS FOR 500 HOURS

Figure 12.3:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 6 HOURS

Figure 12.4:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 6 HOURS

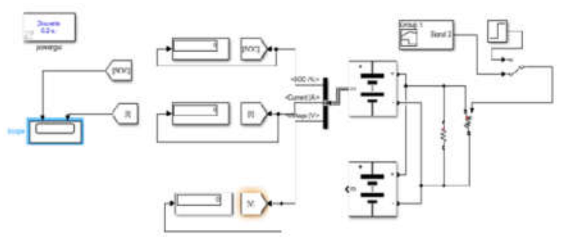


Figure 12.5:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 80 HOURS

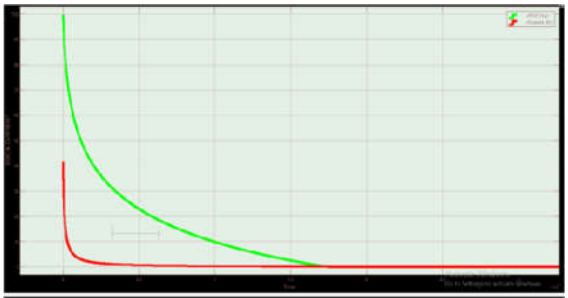


Figure 12.6:- **SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LITHIUM ION-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 80 HOURS**

13. ANALYSIS:-

13.2 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 mille 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.

13.2 ANALYSIS OF LITHIUM ION-LEAD ACID 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 mille 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 .

13.3 ANALYSIS OF LITHIUM ION –LITHIUM ION SERIES BATTERY CHARGING: - Initially the SOC & nominal voltage of both lithium ion batteries taken as 45% and 7.2 volt . The SOC reaches to 100% and charging current becomes -677.8 mille 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 .

13.4 ANALYSIS OF LITHIUM ION-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 mille 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 lead acid-lead acid parallel battery charging .

13.5 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 mille 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 .

13.6 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 .

13.7 ANALYSIS OF LITHIUM ION-LEAD ACID 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 .For 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 .

13.8 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 .

13.9 ANALYSIS OF LITHIUM ION-LEAD ACID 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 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

13.10 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 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.

14. SIMULATION RESULT OF BATTERY CHARGING

TABLE 14.1 SIMULATION RESULT OF BATTERY CHARGING

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

TABLE 14.2 SIMULATION RESULT OF BATTERY DISCHARGING

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

. **15. CONCLUSION:-** 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 is presented for comparison. These design concepts are validated through simulation in the Matlab and the results are presented for analysis of various batteries.

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.

The initial state of charge of Lithium-Ion battery set at 45% and it is found that 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 Lithium Ion Battery discharge to 2.757% in 500 hours with load resistance set at 72 ohms . In lithium-ion charging through simulation, it is seen that the charging current develops constant current pattern and it is observed that the current deduces to constant nature hood in a very short period of time duration .So it is seen in Lithium Ion also that discharging for 500 hours results to constancy in current characteristics .

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