

STUDY OF INTERMIXING OF LEAD ACID - LITHIUM ION CHARGING & DISCHARGING CHARACTERISTICS

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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 now days 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 forcasting the characteristics nature in regards to charging and discharging regimes i.e. state of charge and current nature hood during these period is enviable. 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.

1.INTRODUCTION:- 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.

Lithium-Ion Battery Life:-

Lithium ion battery should last between 300 and 500 charge/discharge cycles.

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.

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. Lead Acid batteries are widely used in automobiles, inverters, backup power systems etc. Unlike tubular and maintenance free batteries, Lead Acid batteries require proper care and maintenance to prolong its life. The Lead Acid battery consists of a series of plates kept immersed in sulphuric acid solution. The plates have grids on which the active material is attached. The plates are divided into positive and negative plates. The positive plates hold pure lead as the active material while lead oxide is attached on the negative plates. A completely charged battery can discharge its current when connected to a load. During the process of discharge, the sulphuric acid combines with the active materials on the positive and negative plates resulting in the formation of Lead sulphate. Water is the single most important step in maintaining a Lead Acid battery. The frequency of water depends on usage, charge method and operating temperature. During process, the hydrogen atoms from the sulphuric acid react with oxygen to form water. This results in the release of electrons from the positive plates which will be accepted by the negative plates. This leads to the formation of an electric potential across the battery. The electrolyte in the Lead Acid battery is a mixture of Sulphuric acid and water which has a specific gravity. Specific gravity is the weight of

the acid-water mixture compared to equal volume of water. The specific gravity of pure ions free water is 1.

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.

Advantages:- Lead acid batteries are used for supplying current to railways, hospitals, automobiles, power stations, telephone exchange, Ups (stand-by supplies). Other advantages are its recharge ability, portability and Its relatively constant potential & low cost.

Disadvantages: Use of Conc.H₂SO₄ is dangerous; Use of lead battery is fragile.

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 platform 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.

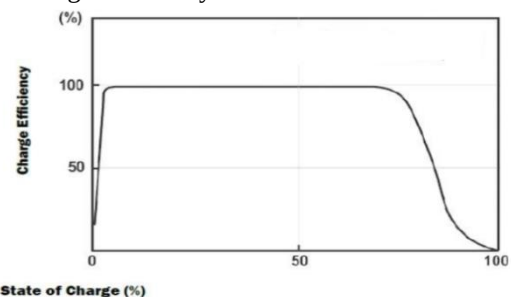


Figure 1.2 :- Graph between State of charge and charge Efficiency

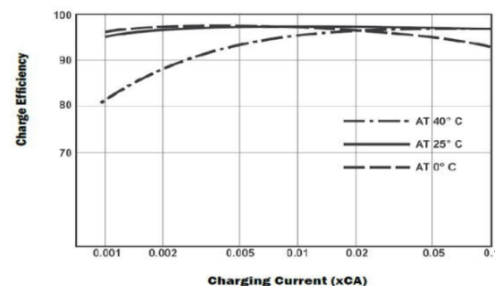


Figure 1.3:- Graph between Charging current & Charge Efficiency

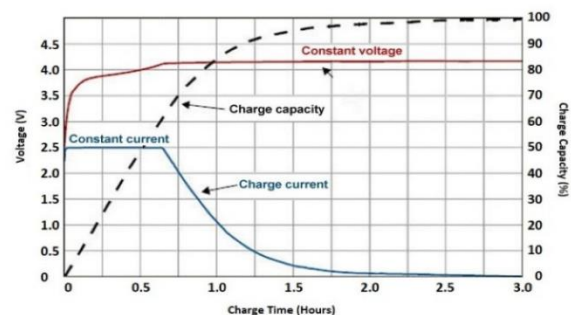


Figure 1.4:- Charge curve of Lithium -Ion Battery

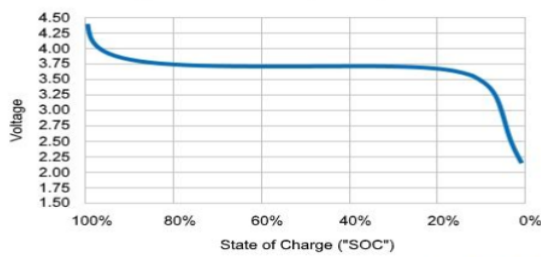


Figure 1.5:- Discharge curve of Lithium-Ion Battery

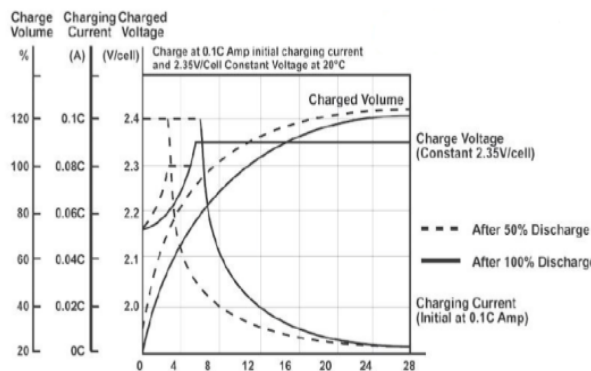


Figure 1.4:-Lead Acid battery charge characteristics taking case that charging is non continuous and peak voltage higher.

PROBLEM STATEMENT-

To observe the SOC and charging current of Lead acid & Lithium ion 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.

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

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

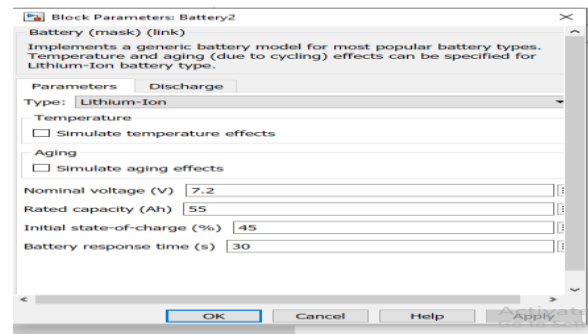


Figure 2.1:- DETAIL SPECIFICATION OF LITHIUM ION BATTERY CONNECTED IN SERIES WITH LEAD ACID BATTERY

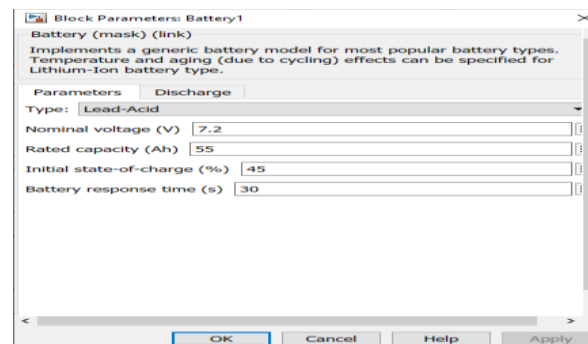


Figure2.2:- DETAIL SPECIFICATION OF LEAD ACID BATTERY CONNECTED IN SERIES WITH LITHIUM ION BATTERY

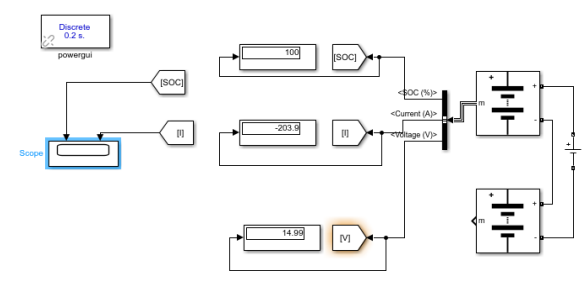


Figure 2.3:-CIRCUIT DIAGRAM OF LEAD ACID BATTERY CONNECTED IN SERIES WITH LITHIUM ION BATTERY FOR 1 HOUR

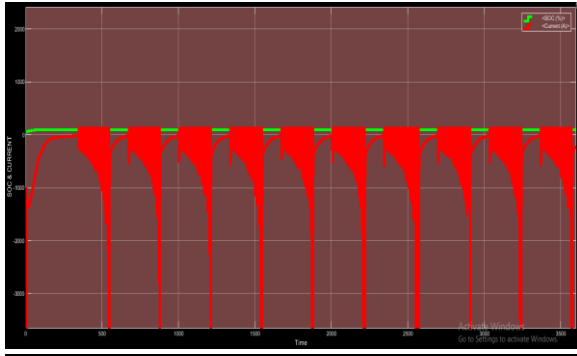


Figure 2.4:-SOC & CURRENT WAVEFORM OF LEAD ACID BATTERY CONNECTED SERIES WITH LITHIUM ION BATTERY FOR 1 HOUR

3. LEAD ACID-LITHIUM ION BATTERY PARALLEL CHARGING:

Combination of Lead Acid-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 .

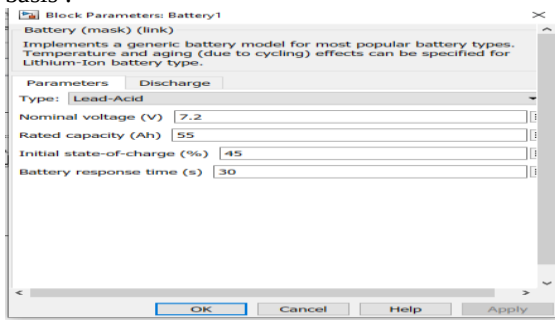


Figure3.1:- DETAIL SPECIFICATION OF LEAD ACID BATTERY

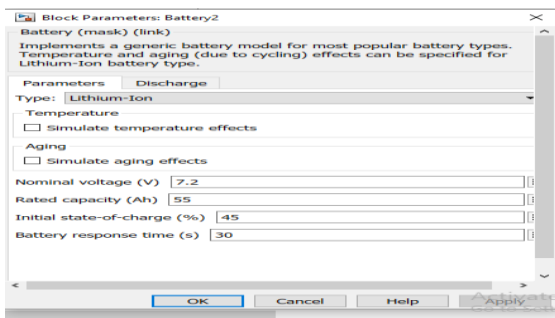


Figure 3.2:- DETAIL SPECIFICATION OF LITHIUM ION BATTERY

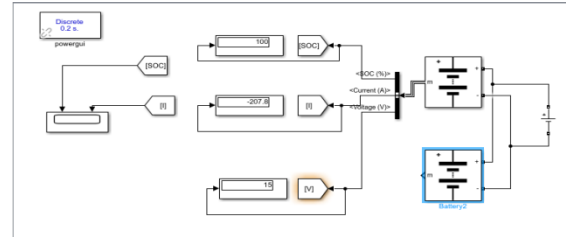


Figure 3.3:-CIRCUIT DIAGRAM OF LEAD ACID BATTERY & LITHIUM ION BATTERY PARALLEL CHARGING FOR 1 HOUR

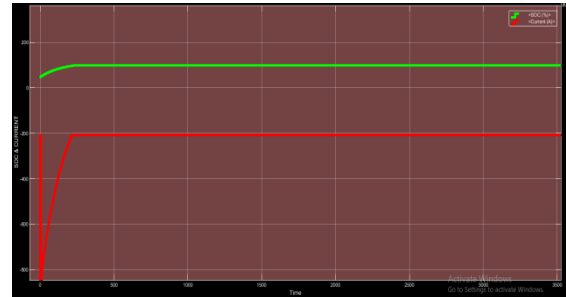


Figure 3.4:-SOC & CURRENT WAVEFORM OF LEAD ACID BATTERY & LITHIUM ION BATTERY FOR PARALLEL CHARGING FOR 1 HOUR

4. LEAD ACID-LITHIUM ION SERIES BATTERY DISCHARGE:

Circuit diagram of Lead Acid-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 .

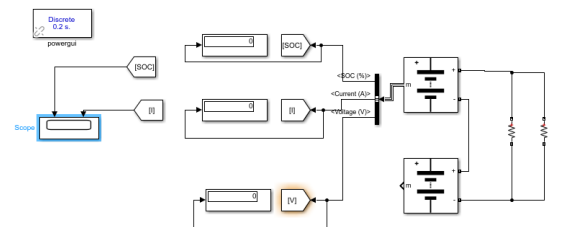


Figure 4.1:- CIRCUIT DIAGRAM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

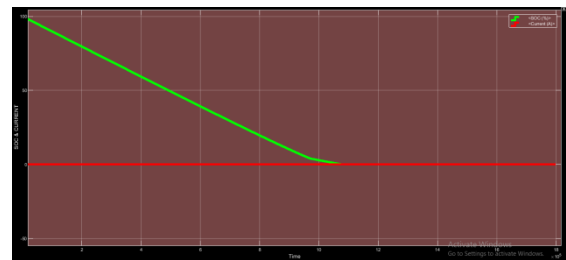


Figure 4.2:- WAVEFORM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

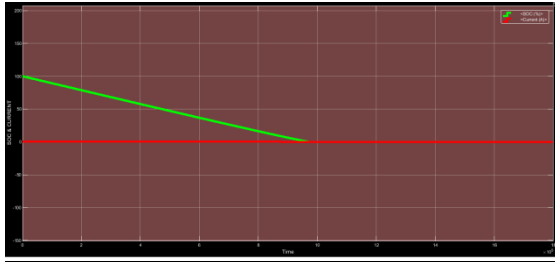


Figure 4.3:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL FOR 500 HOURS

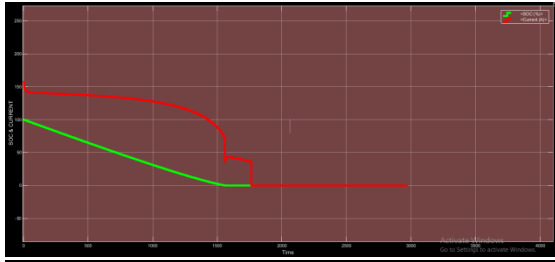


Figure 4.4:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 500 HOURS

5. LEAD ACID-LITHIUM ION BATTERY PARALLEL DISCHARGE: Combination 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 .

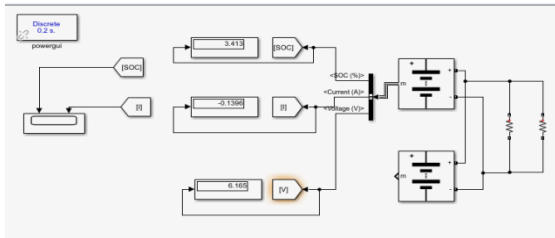


Figure 5.1:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD RESISTANCE 72 OHMS FOR 470 HOURS

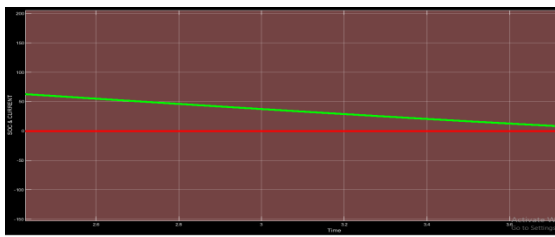


Figure 5.2:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD RESISTANCE 72 OHMS FOR 470 HOURS

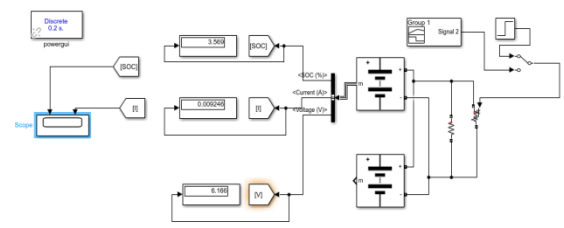


Figure 5.3:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 140 HOURS

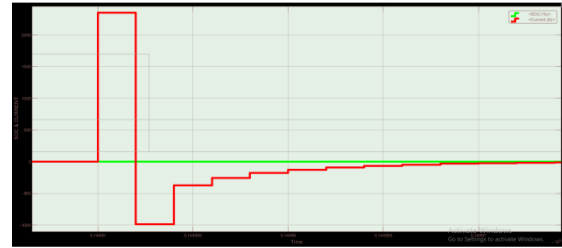


Figure 5.4:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL FOR 140 HOURS

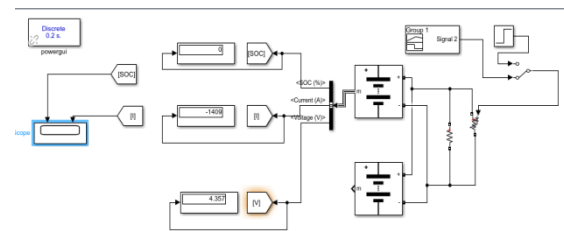


Figure 5.5:- CIRCUIT DIAGRAM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 200 HOURS

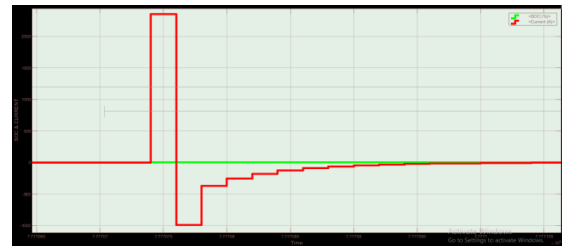


Figure 5.6:- SOC & CURRENT WAVEFORM OF DISCHARGE OF PARALLEL CONNECTED LEAD ACID-LITHIUM ION BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 200 HOURS

6. ANALYSIS:-

6.1 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 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 .

6.2 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 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 .

6.3 ANALYSIS OF LEAD ACID-LITHIUM ION SERIES DISCHARGE:-

The SOC reduces from 100% to 0% within a period of 300 hours & current remains constant throughout for 72 ohms resistance at load .For step , the SOC reduces to 0% in 250 hours & current constant throughout . For step, the SOC reduces to 0% in 250 hours and current constant throughout .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 .

6.4 ANALYSIS OF LEAD ACID –LITHIUM ION PARALLEL DISCHARGE:-

The SOC reduces to 3.413% in 470 hours and current remains low constant throughout 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.

7. TABLE

7.1 SIMULATION RESULT OF BATTERY CHARGING

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

7.2 SIMULATION RESULT OF BATTERY DISCHARGING

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

8.

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:-

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 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 nature hood 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.

9. 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 Interrupted 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 secures our future challenging needs.

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