COMPARISON ON STUDY OF LITHIUM ION SERIES & LEAD ACID SERIES CHARGING & DISCHARGING CHARACTERISTICS

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ABSTRACT:-

Lead acid batteries are strings of 2 volt cells connected in series, commonly 2, 3, 4 or 6 cells per battery. Strings of lead acid batteries, up to 48 volts and higher, may be charged in series safely and efficiently. However, as the number of batteries in series increases, so does the possibility of slight differences in capacity. These differences can result from age, storage history, temperature variations or abuse .Fully charged batteries should never be mixed with discharged batteries when charging batteries in series. The discharged batteries should be charged before connection .When a single constant voltage charger is connected across an entire high voltage string, the same current flows through all cells in the string. Depending on the characteristics of the individual batteries , some may overcharge while other remain in a slightly undercharged condition .To minimize the effect of individual battery differences , use batteries of the same age , manufacturer , amp hour , and history and , if possible ,charge in strings of no greater than 24 or 48 volts .

On the other hand it is highly recommended to charge lithium batteries in series with a multi-bank charger. This means each battery is charged at the same time but completely independent of the other. Charging properly a lithium-ion battery requires 2 steps: Constant Current (CC) followed by Constant Voltage (CV) charging. A CC charge is first applied to bring the voltage up to the end-of-charge voltage level. One might even decide to reduce the target voltage to preserve the electrode.

Li-ion does not need to be fully charged as is the case with lead acid, nor is it desirable to do so. In fact, it is better not to fully charge because a high voltage stresses the battery. In a lithium-ion battery, overcharging can create unstable conditions inside the battery, increase pressure, and cause thermal runaway. Lithium-ion battery packs are required to have a protection circuit to prevent excessive pressure build-up and cut off the flow of ions when the temperature is too high. A partial charge and discharge will reduce stress and prolong battery life. It is recommended to avoid full cycles and stay between 100% and 50% DOD (0-50% SoC).

1. INTRODUCTION:-

Strings of lead acid batteries, up to 48 volts and higher, may be charged in series safely and efficiently. However, as the number of batteries in series increases, so does the possibility of slight differences in capacity. These differences can result from age, storage history, temperature variations or abuse. Batteries that are only in series keep the same capacity and increase their voltage. Combining the two provides the best of both worlds; increasing both voltage and amperage. For example connecting two 6Volt 10Ah batteries together in series but one cannot connect one 6V 10Ah battery with one 12V 20Ah battery. To connect a group of batteries in series , one connect the negative terminal of one battery to the positive terminal of another and so on until all batteries are connected . Batteries connected in series strings can also be recharged by a single charger having the same nominal charging voltage output as the nominal battery pack voltage.

Linking 12 Volt batteries in series is an easy way to create higher voltage 24V, 36V and 48V battery systems. Before linking batteries in series however it is helpful to first charge each battery individually. This is called balancing batteries in series, also known as voltage matching. The batteries can be charged at the same time by connecting to the end of the system in 12 volt mode or one at a time by connecting a battery charger to each battery individually also in 12-volt mode. A typical charge or use cycle for a lithium-ion battery is 8 hours of use, 1 hour to charge and another 8 hours of use. No cool down period is needed. This allows the battery to be used continuously throughout a 24-hour shift, with downtime occurring only during short periods of opportunity charging. Li-ion does not need to be fully charged as is the case with lead acid, nor is it desirable to do so. In fact, it is better not to fully charge because a high voltage stresses the battery. In a lithium-ion battery, overcharging can create unstable conditions inside the battery, increase pressure, and cause thermal runaway. Lithium-ion battery packs are required to have a protection circuit to prevent excessive pressure build-up and cut off the flow of ions when the temperature is too high. A Lithium-Ion battery's average life span is 2 to 3 years or 300 to 500 charge cycles, whichever comes first. At present, the industry has formed a three-stage strategy for charging lithium-ion batteries: precharge, constant current charging, and constant voltage charging. Lithium-ion and lithium-polymer batteries should be kept at charge levels between 30 and 70 % at all times. Full charge/discharge cycles should be avoided if possible. Exceptions to this can be made occasionally to readjust the charge controller and battery capacity meter. A partial charge and discharge will reduce stress and prolong battery life. It is recommended to avoid full cycles and stay between 100% and 50% DOD (0-50% SoC).

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.

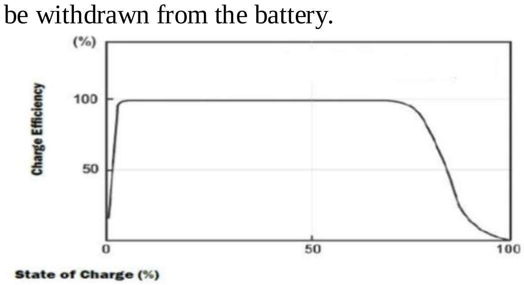

Figure 1.1 :- Graph between State of charge and charge Efficiency

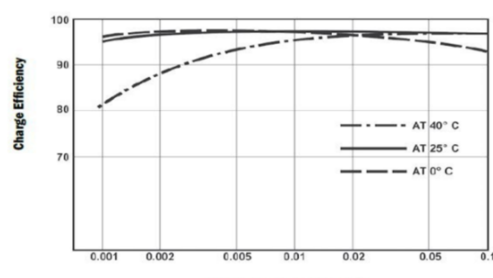

Figure 1.2:- Graph between Charging current & ChargeEfficiency

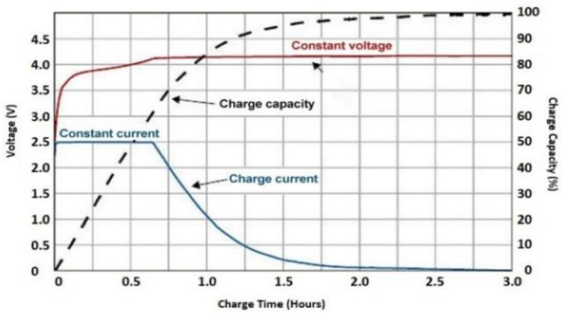

Figure 1.3:- Charge curve of Lithium –Ion Battery

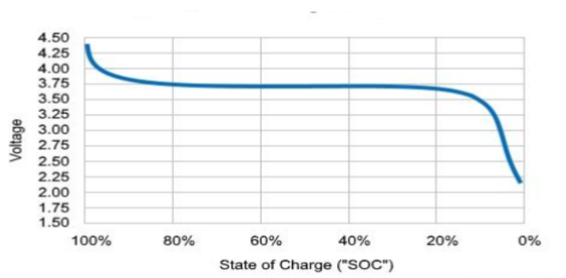

Figure 1.4:- Discharge curve of Lithium–Ion Battery

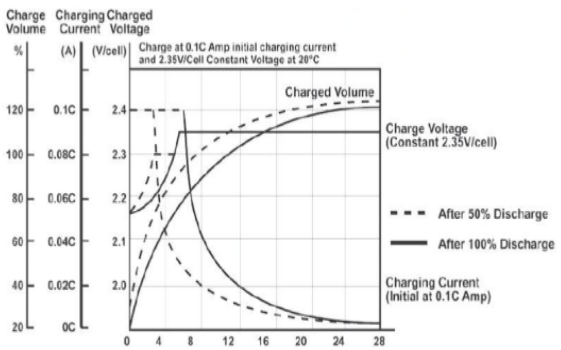

Figure 1.5:-Lead Acid battery charge characteristics taking case that charging is non continuous and peak voltage higher.

2. PROBLEM STATEMENT-

To observe the SOC and charging current of Lithium ion series and Lead acid series batteries 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-LITHIUM ION SERIES CHARGING:

Series combination of Lithium Ion-Lithium-Ion & Lead acid-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 .

DETAIL SPECIFICATION OF BATTERIES FOR SERIES CHARGING:-

DCvoltage source=30 volt

Nominal voltage of both batteries=7.2 volt

Rated capacity=55Ah

Initial state of charge=55%

Battery response time=30 second

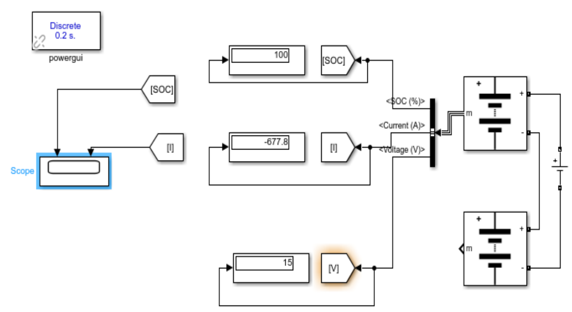

Figure 2.1:-CIRCUIT DIAGRAM OF BOTH BATTERY CONNECTED IN SERIES WITH LITHIUM FOR 1 HOUR

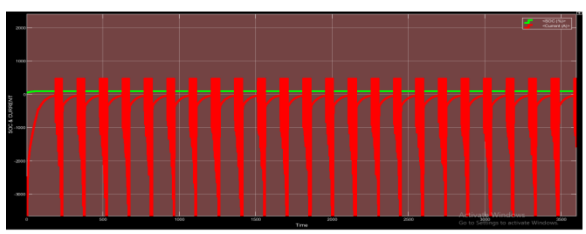

Figure2.2:-SOC & CURRENT WAVEFORM OF LITHIUM ION BATTERY CONNECTED IN SERIES WITHLITHIUM ION BATTERY FOR 1 HOUR

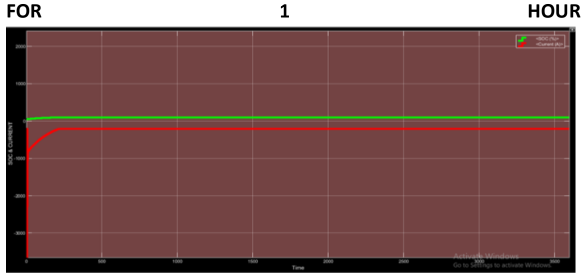

Figure2.3:- SOC & CURRENT WAVEFORMM OF LEAD ACID & LEAD ACID BATTERY SERIES CHARGING

4. ANALYSIS OF SERIES BATTERY CHARGING

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 .

ANALYSIS OF LEAD ACID –LEAD ACID SERIES BATTERY CHARGING: - Initially the SOC & nominal voltage of both Lead Acid batteries 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 30 volt DC source for charging lead acid battery of initial voltage of 7.2 volt , the charging current becomes constant.

5. BATTERY DISCHARGE:

Battery series 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 .

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 .

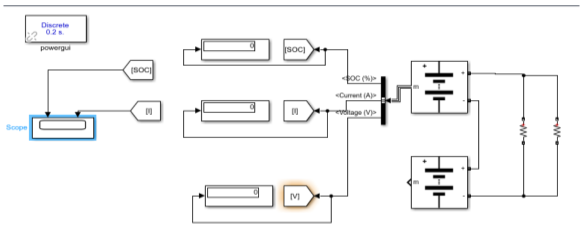

Figure5.1:- CIRCUIT DIAGRAM OF DISCHARGE OF SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

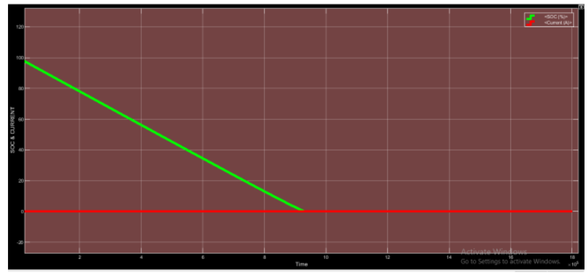

Figure 5.2:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

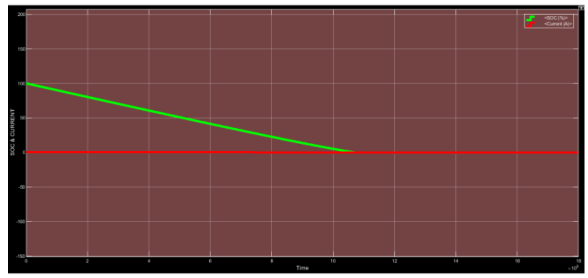

Figure5.3:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID-LEAD ACID SERIES BATTERY CONNECTED TO LOAD RESISTANCE OF 72 OHMS FOR 500 HOURS

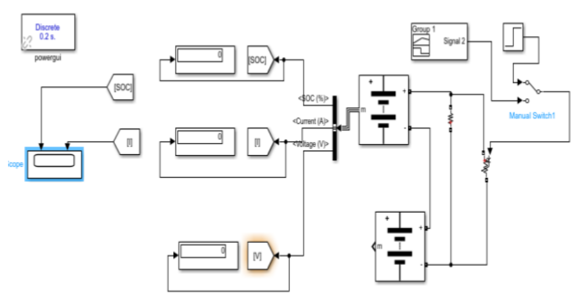

Figure5.4:- CIRCUIT DIAGRAM OF DISCHARGE OF SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 500 HOURS

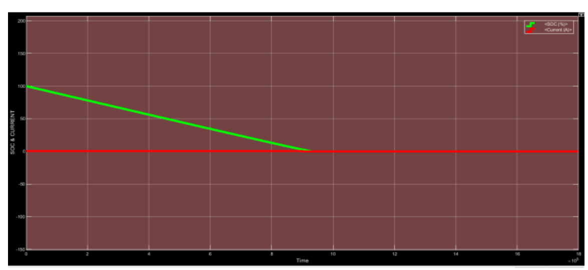

Figure 5.3:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL FOR 500 HOURS

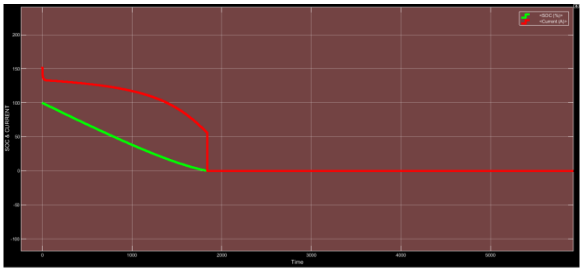

Figure5.4:-SOC & CURRENT WAVEFORM OF OF DISCHARGE OF LEAD ACID-LEAD ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 500 HOURS

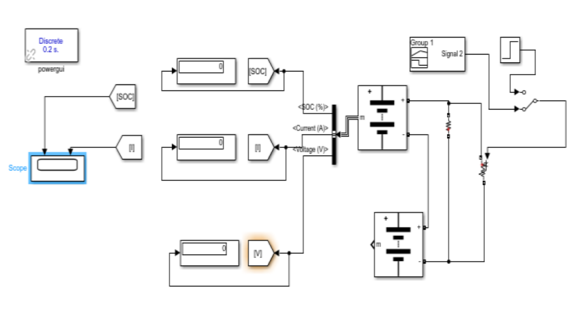

Figure5.5:- CIRCUIT DIAGRAM OF DISCHARGE OF SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START DEVELOPED BY SIGNAL BUILDER FOR 500 HOURS

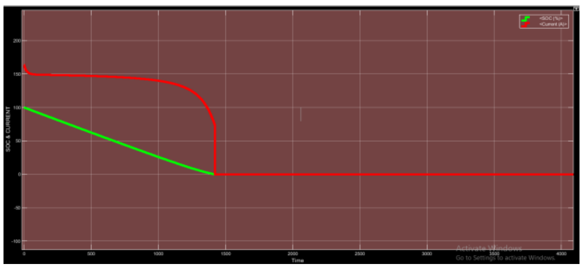

Figure5.6:- SOC & CURRENT WAVEFORM OF DISCHARGE OF LITHIUM ION-LITHIUM ION ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START FOR 500 HOURS

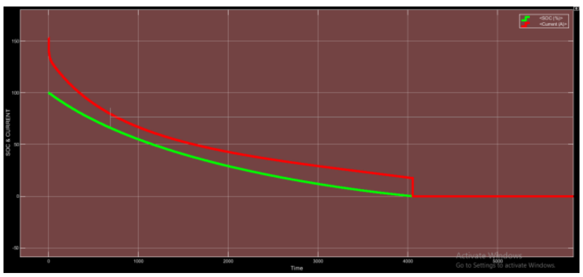

Figure5.7 :- SOC & CURRENT WAVEFORM OF DISCHARGE OF LEAD ACID-LEAD ACID SERIES BATTERY WITH LOAD AS STEP SIGNAL WITH RAMP START DEVELOPED BY SIGNAL BUILDER FOR 500 HOURS

6.ANALYSIS OF SERIES BATTERY DISCHARGE

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 .

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 .

7. SIMULATION RESULT OF SERIES BATTERY CHARGING

TABLE 7.1 SIMULATION RESULT OF BATTERY CHARGING

CHARGING OF BATTERIES WITH INITIAL STATE OF CHARGE = 45%		
SOC		TIME
LITHIUMION-LITHIUMION SERIES BATTERY CHARGING	60 SECONDS	100%
LEAD ACID-LEAD ACID SERIES BATTERY CHARGING	140 SECONDS	100%

TABLE 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-LITHIUMION SERIES BATTERY DISCHARGING	250 HOURS	0%
LEADACID-LEAD ACID SERIES BATTERY DISCHARGING	275 HOURS	0%

8. CONCLUSION:- When batteries are connected in series, the voltage increases. Wiring batteries in series provides a higher system voltage resulting in a lower system current. Low current indicates that one can use thinner wiring and suffer less voltage drop in the system. Connecting batteries in series increases voltage, but does not increase overall amp-hour capacity. All batteries in a series bank must have the same amp-hour rating.

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