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Analysis and Simulation of Battery Charging and Discharging in Ev's Using Matlab Simulink

Dimple B N¹, Krithika P Ramesh², Chinmayi B K³, Ms. Kruthi Jayaram⁴

Department of Electrical and Electronics Engineering, BNMIT, Bengaluru, India^[1]

Department of Electrical and Electronics Engineering, BNMIT, Bengaluru, India^[2]

Department of Electrical and Electronics Engineering, BNMIT, Bengaluru, India^[3]

Department of Electrical and Electronics Engineering, BNMIT, Bengaluru, India^[4]

ABSTRACT: The paper deals with modelling and simulation of the battery. It needs to know the mathematical relationship between battery input and output parameters and simulator by using MATLAB. Electric vehicles are set to be the dominant form of transportation in the future and Lithium-based rechargeable battery packs have been widely adopted in them. Battery packs need to be constantly monitored and managed in order to maintain the safety, efficiency and reliability of the overall electric vehicle system. A battery management system consists of a battery fuel gauge, optimal charging algorithm, and cell/thermal balancing circuitry. It uses three non-invasive measurements from the battery, voltage, current and temperature, in order to estimate crucial states and parameters of the battery system, such as battery impedance, battery capacity, state of charge, state of health, power fade, and remaining useful life. These estimates are important for the proper functioning of optimal charging algorithms, charge and thermal balancing strategies, and battery safety mechanisms. Approach to robust battery management consists of accurate characterization and optimal battery control strategies. In this paper we analyse batteries by process of charging and discharging on after the other and then circuit is built up having same mechanism to conduct simulation and to study the characteristics parameters by using the MATLAB software.

KEYWORDS: Battery charging, discharging, MATLAB, Types of Battery, Applications

I. INTRODUCTION

With rapid development of economy and continuous improvement of people's quality of life vehicles gradually become the means of transportation for people to travel everyday. The continuous consumption of fossil energy gradually results in the increasingly shortage of energy. Petrol or diesel vehicles are highly polluting and are being quickly replaced by electric vehicles. Electric vehicles (EV) have zero tailpipe emissions and are much better for the environment. Using more energy efficient vehicles like electric vehicles supports the economy and helps diversify the transportation fleet. The multiple fuel sources used to generate electricity results in a more secure energy source for the electrified portion of the transportation sector.

The energy storage system in electric vehicle comes in the form of a battery. Current battery technology is designed for extended life. There are four main kinds of batteries used in EVs: lithium-ion, nickel-metal hydride, lead-acid, and ultracapacitors. The most common type of battery used in electric vehicle is the lithium-ion battery. These batteries are used in most portable electronics, including cell phones and computers. Nowadays, batteries based on lithium-ion (Li-Ion) seems to be the most suitable for traction, especially nickel-manganese-cobalt (NMC) and nickel-cobalt-aluminium (NCA). An appropriate model of these batteries is fundamental for the simulation of several processes inside an EV, such as the state of charge (SoC) estimation, capacity and power fade analysis, lifetime calculus, or for developing control and optimization strategies. Driving range is closely related to the energy capacity of the battery. Battery with high energy capacity will result in longer driving distance.

Although there are other alternatives such as hydrogen storage, a battery is also required for DC bus voltage stabilization and switching on of other essential or auxiliary devices of the fuel cell system. High capital costs, limited

lifetime, and relatively poor performance at low temperatures are the most important issues in EVs [2–5]. Therefore, the development of efficient storage technologies is an essential part for electromobility

WORKING PRINCIPLE

Battery, in electricity and electrochemistry, any of a class of devices that convert chemical energy directly into electrical energy. They are a collection of one or more cells whose chemical reactions create a flow of electrons in a circuit. All batteries are made up of three basic components: an anode (the '-' side), a cathode (the '+' side), and some kind of electrolyte (a substance that chemically reacts with the anode and cathode).

When the anode and cathode of a battery is connected to a circuit, a chemical reaction takes place between the anode and the electrolyte. This reaction causes electrons to flow through the circuit and back into the cathode where another chemical reaction takes place. When the material in the cathode or anode is consumed or no longer able to be used in the reaction, the battery is unable to produce electricity. At that point, your battery is "dead." Batteries that must be thrown away after use are known as **primary batteries**. Batteries that can be recharged are called **secondary batteries**.

Maintaining the Integrity of the Specifications

Li-ion batteries

Firstly, a Lithium-ion battery was developed by Akira Yoshino in 1985. The positive electrode (cathode) is made of lithium cobalt oxide and the negative electrode (anode) is made of graphite. Lithium salt as an organic solvent is used as an electrolyte. A separator is used to separate electrodes.

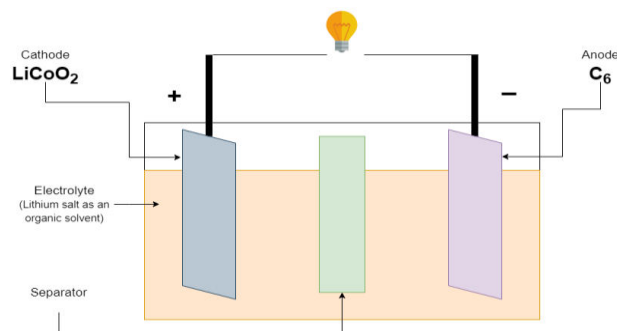


Fig.1: Structure of Li-ion battery

The battery has a discharge/charge cycle is about 400 – 1200 cycles. This depends upon various factors, how you are charging or discharging the battery. The nominal voltage of the lithium-ion battery is 3.60V. When the battery is in full charge the voltage is about 4.2 V. when the battery is fully discharged the voltage is about 3.0V. Li-ion battery comes in different sizes and shapes, the capacity is also available as requirements.

DISCHARGING OF LITHIUM ION BATTERY:

At the time of discharge of the battery, the Load is connected to the terminal battery. The lithium-ion is released from the negative electrode and travels to the electrolyte. A positive electrode absorbs this lithium-ion. The negative electrode also releases the electrons, which travel through an external wire to the positive electrode. This provides us with an electric current to our circuit.

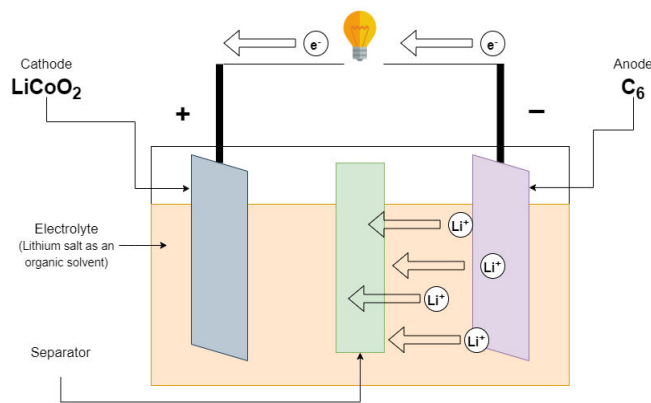
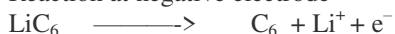


Fig.2: Discharging of Li-ion battery

(Discharging of Li-ion battery)

Reaction at negative electrode



Reaction at positive electrode



Overall reaction



Li-ion battery can discharge at the rate of 10C (where C is the capacity of the battery). If the battery can provide 1000mAh then the discharge rate will be $10 \times 1000 = 10000\text{mAh}$.

CHARGING OF LITHIUM ION BATTERY:

At the time of charging the Li-ion battery, the battery is connected to the charger. The Positive electrode losses a negatively charged electron. To maintain this charge balance at the negative electrode, an equal number of positively charged ions are dissolved into the electrolyte solution. These lithium-ion travel over to the positive electrode, where they are absorbed within the graphite. This absorption reaction also deposits electrons into the graphite anode to 'tie' up the lithium-ion.

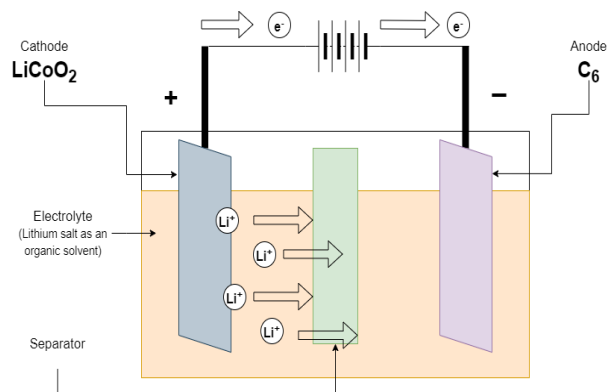
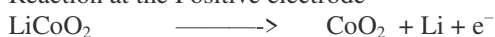
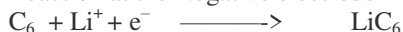


Fig.3: Charging of Li-ion battery

Reaction at the Positive electrode



Reaction at the Negative electrode



Overall Reaction



The Li-ion battery charging chemistries utilize constant current and constant voltage algorithms that can be broken into four parts.

- **Trickle Charge:-** When the battery is deeply discharged it is below 3.0 V per cell. the constant current of 0.1C maximum used to charge the battery is called trickle charge.
- **Constant Current:-** When voltage is above 3.0V per cell the constant current is applied in the range of 0.2 C to 1C to perform constant current charging.
- **Constant voltage:-** when voltage is reached at 4.2 V per cell from constant current charging. The constant voltage is applied till the current taken by the cell drop to zero, this maximizes the performance of the battery.

II. BATTERY CHARGING AND DISCHARGING CHARACTERISTICS

The key function of a battery in a PV system is to provide power when other generating sources are unavailable, and hence batteries in PV systems will experience continual charging and discharging cycles. All battery parameters are affected by battery charging and recharging cycle.

Battery state of charge (BSOC): A key parameter of a battery in use in a PV system is the battery state of charge (BSOC). The BSOC is defined as the fraction of the total energy or battery capacity that has been used over the total available from the battery. Battery state of charge (BSOC or SOC) gives the ratio of the amount of energy presently stored in the battery to the nominal rated capacity. For example, for a battery at 80% SOC and with a 500 Ah capacity, the energy stored in the battery is 400 Ah. A common way to measure the BSOC is to measure the voltage of the battery and compare this to the voltage of a fully charged battery. However, as the battery voltage depends on temperature as well as the state of charge of the battery, this measurement provides only a rough idea of battery state of charge.

Depth of Discharge (DOD):

In many types of batteries, the full energy stored in the battery cannot be withdrawn (in other words, the battery cannot be fully discharged) without causing serious, and often irreparable damage to the battery. The Depth of Discharge (DOD) of a battery determines the fraction of power that can be withdrawn from the battery. For example, if the DOD of a battery is given by the manufacturer as 25%, then only 25% of the battery capacity can be used by the load.

Nearly all batteries, particularly for renewable energy applications, are rated in terms of their capacity. However, the actual energy that can be extracted from the battery is often (particularly for lead acid batteries) significantly less than the rated capacity. This occurs since, particularly for lead acid batteries, extracting the full battery capacity from the battery dramatically reduced battery lifetime. The depth of discharge (DOD) is the fraction of battery capacity that can be used from the battery and will be specified by the manufacturer. For example, a battery 500 Ah with a DOD of 20% can only provide $500 \text{ Ah} \times 0.2 = 100 \text{ Ah}$.

Daily Depth of Discharge:

In addition to specifying the overall depth of discharge, a battery manufacturer will also typically specify a daily depth of discharge. The daily depth of discharge determines the maximum amount of energy that can be extracted from the battery in a 24-hour period. Typically in a larger scale PV system (such as that for a remote house), the battery bank is inherently sized such that the daily depth of discharge is not an additional constraint. However, in smaller systems that have a relatively few days storage, the daily depth of discharge may need to be calculated.

III. ANALYSIS OF BATTERY CHARGING AND DISCHARGING USING BATTERY

A. CONSTRUCTION

In the construction of the circuit, we have taken 2 lithium-ion batteries, naming Battery 1 and Battery 2. Battery 1 is connected to a resistive load along with the ideal switch in order to control battery and this connection is made to show the discharging characteristics of Battery 1. Battery 2 is connected to battery 1 along with the ideal switch. Battery 2 acts as a source of supply for battery 1. Scope and display connected to both the batteries in order to display graph and soc values.

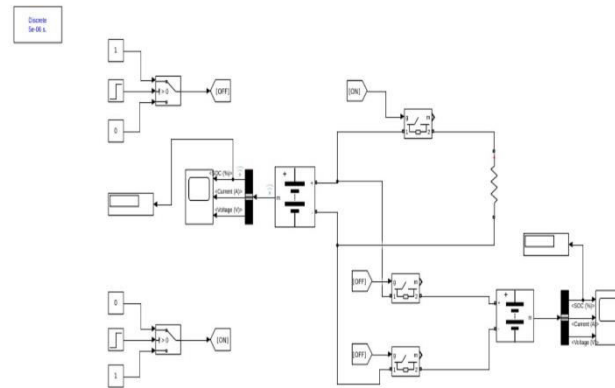


Fig.4: Circuit Design

B. METHODOLOGY

Initially, Battery 1 has the soc of 80% and Battery 2 has the initial soc as 100%. We have taken discrete time for the battery discharging, initially we have to increase the battery, charging and discharging of battery so we can differentiate between the batteries easily. We have taken a scope where the graph will be viewed of the parameters like Soc, current and voltage. There is ideal switch, Initially, when the supply is given to the load from battery 1, Soc of the battery1 gets reduced. The reducing time is set to 4sec at the beginning, the battery which is initially at 80% soc when the battery runs for 4 sec the battery runs down to 70% to 60%, and battery gets disconnected from load after 4 sec. The battery 1 has to get charged again. Now Battery 2 is connected to Battery 1 and charging of Battery 1 takes place and soc of battery 1 is increased to 80% to 85%. From this process we can analyze charging and discharging parameters of battery like State of charge, Current and Voltage.

This project shows the parameterization of the battery charging / discharging behavior by using MATLAB –Simulink and this project helps to study the dynamic characteristics of Lithium-ion battery. Each battery type has a particular set of restraints and conditions related to its charging and discharging regime, and many types of batteries require specific charging regimes or charge controllers. For example, nickel cadmium batteries should be nearly completely discharged before charging, while lead acid batteries should never be fully discharged. Furthermore, the voltage and current during the charge cycle will be different for each type of battery. Typically, a battery charger or charge controller designed for one type of battery cannot be used with another type. In this project the charging and discharging is shown with respect to soc and current and voltage characteristic during charging and discharging is explained practically using Simulink.

MATLAB programming based battery test system with consistent current source has been created and utilized for knowing battery limit and battery charging and releasing time for its various burdens. In a dynamic burden, the releasing current of the battery is kept steady and battery voltage is diminished by the heap. After Simulation the battery model, its output of battery parameters by the graphs represented here. The terminal voltage rises and falls during charging and discharging of batteries can be characterized by measurements of voltage under constant charge and discharge inputs.

C. ANALYSIS OF BATTERIES BASED ON CONSTRUCTION:

Stage1:

Function: Battery 1 having SOC of 80% is reduced to 79.95% in step time of 4sec.

This shows the discharging parameters of a battery 1. And ideal state characteristics of battery 2.

Analysis on battery during process stage 1:(from initial state to 4 sec)

Battery 1:

- Soc reduced from 80% to 79.95%.
- Current initially increased from 0 to 13A and runs constant throughout the discharge.
- Voltage is reduced slowly. (but variation is minimum).

Battery 2 (battery 2 is not connected at stage 1):

- SOC remains constant at 100%

- 0 current
- Voltage 14v

Stage2:

Function: Battery 1 having SOC of 79.95% after discharging to load, now is under charging process. Battery 2 having 100% acts as source of supply to battery 1.

Soc of battery 2 reduced from 100% to 99.97% at a step of 4sec. This shows discharging characteristics of battery 2. SOC of battery 1 initially at stage 2 being 79.95% is now charged and increased to 80.41%. This shows the charging parameters of a battery 1.

Analysis on battery during process stage 2:(from time 4sec to 10 sec)

Battery 1 (charging)

- Soc increased from 79.95% to 81.41%.
- Current increases.
- Voltage is also increased

Battery 2 (discharging)

- SOC reduced from 100% to 99.57.
- Current almost constant.
- Voltage is reduced slowly. (But variation is minimum).

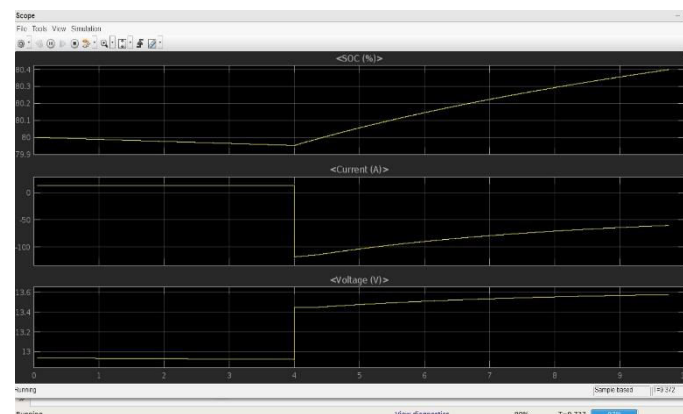


Fig.5: graph of functioning of battery1

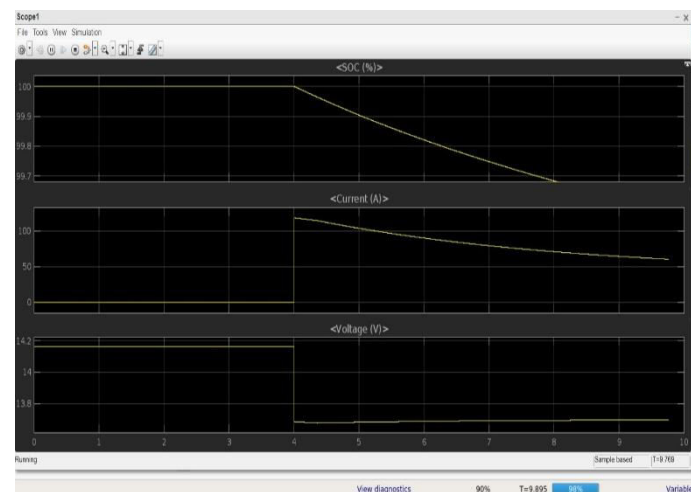


Fig.6: graph of functioning of battery2



IV. CONCLUSION

This paper proposes an optimal mechanism to protect the Lithium-ion storage devices from overcharging and undercharging which will enhance the battery performance and lifecycle in EV applications. The main goal was identified and achieved for the proposed BMS model. Therefore, a BMS model is developed for obtaining the efficient charging and discharging of the storage. Obtained result reveals that, proposed control strategy can significantly control the charging-discharging of battery storage system and thus save the energy and prolonged the battery life. So, the outcomes can be treated as the excellent performance for the proposed BMS model for the application in modern EV systems.

The Li-ion battery has good charging and discharging electrical characteristics. While charging, the charging capacity increases gradually with the charge voltage maintaining a constant current. When the voltage reaches a maximum, the current decreases exponentially. On the other hand, the capacity discharge maintains an almost constant voltage and current to the load, although there is a small decrease and increase in the voltage and current values, respectively, until the cell capacity reaches the minimum acceptable level, which is set by the manufacturer as an end-of-charge voltage.

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