

Li-ion Battery Simulation for Charging and Discharging using MATLAB Simulink

Prof. Sagar S. Kawade¹, Praduemna A. Deosthale², Shivsharan N. Giram³,
Suraj T. Mali⁴, Jyotiram A. Bedage⁵

Assistant Professor, Department of Electrical Engineering¹

Student, Department of Electrical Engineering^{2,3,4,5}

SVERI's College of engineering, Gopalpur, Pandharpur, Maharashtra, India

Abstract: *In EV and HEV applications, battery optimization has increased. Lithium-ion batteries, in particular, are increasingly used as an energy storage system in green technology applications because of their high power and energy density. Drawbacks are seen in electric car applications during the storage system's charging interval period. Multi-state charging is seen to be the best option in these circumstances. The state charging of lithium-ion batteries and their criteria for charging and discharging for long battery life are discussed in this study using the MATLAB Simulink tool. The state-of-charge (SOC), which is measured and used to assess charging and discharging characteristics, is a crucial factor in determining a battery's performance. Therefore, accurate SOC estimate is required to safeguard the battery and avoid overcharging and undercharging it. Additionally, by doing this, the battery's lifespan will be extended. Multi-state charging is used for applications that demand greater efficiency.*

Keywords: MATLAB, Li-ion, state-of-charge, electric car

I. INTRODUCTION

Batteries are very useful in solar energy systems, EV, HEV, and other smart-grid systems. The "Primary Battery (PB)" and the "Secondary Battery (SB)" are the two most common battery kinds. Due to its chargeability, high energy to power ratio, and high power to energy ratio as compared to Lead acid and other Nickel Metal Hydride batteries, SB, especially Li-ion Battery, is highly used and preferred[1]. Designers consider battery behaviour for anticipating performance and optimising energy dispute. So, when building the circuit to achieve high power performance and efficiency, knowledge of the Li-ion battery's charging and draining is crucial. Battery behaviour is influenced by a number of factors, one of which is the battery's state-of-charge (SOC). The stored charges (Q) and integrated current (I) flowing through the battery affect the battery's state of charge. The SOC of a battery is defined as the proportion of Current Capacity to Nominal Capacity[2]. As the battery's SOC information reveals how its charge/discharge regulation is managed, the accurate reporting of SOC is crucial for hybrid electric vehicle applications. There is no sensor to measure the SOC's value, hence it cannot be determined. For the purpose of determining the SOC, which is given by: C. Park suggested an approach based on physical measurements.

$$SOC = 1 - (1 - 1/Q) \int_0^t i(t) dt$$

Some chemical techniques made use of electrolytes, such as non-sealed lead acid batteries, and calculated SOC using their specific gravity and pH. Utilizing the battery's discharge curve, the voltage technique was employed to translate battery voltage to SoC. However, the battery's voltage was impacted by the battery's current and temperature. This issue can be fixed by correcting the voltage with a correction term whose value is proportionate to the battery current. A strong tool based on MathWorks called MATLAB/Simulink was required in order to estimate SOC in charging, discharging, and multi-state charging states. It is a software/tool provided by MathWorks that aids in the design and analysis of a specific element and is built on the Python and C programming languages. It is a straightforward programme that has a small number of user-friendly toolboxes, libraries, simulation blocks, symbols, arithmetic and logical operation blocks, and batteries—which are crucial—among other features. This package includes battery models that are suggested in the Sim Power Systems library. Shepherd equation-based models developed here were unable to discern between the battery's described performance. Consequently, a better model was required for simulation results to be more accurate. A Simulink model based on a Li-ion battery is created using Simulink libraries' building

components for detailed information. The mean value of the RC Circuit parameter is used to simplify the model. The first LiFePO₄ battery Simulink model was presented by L.W. Yao. This model was eventually applied to various battery modules after being further validated for experimental outcomes forecasting the current and voltage performances.

The strong demand for battery technology in EV applications led to an increase in battery technology usage. This study uses the MATLAB-Simulink tool to model the SOC of a lithium-ion battery, which is then tested and used to assess the battery's charge/discharge. To guarantee high power and efficiency of the battery with the introduction of multistate currents, multiple charging and battery life optimization designed circuits were put into use. The paper is organised according to the following structure: The second segment features a presentation of literature. The methodology and process for estimating the battery are covered in the third portion of this essay. The simulation's Results/Outcomes and how they are perceived are covered in the following session. The Summary and Future Work of this Simulation are highlighted in the final section.

II. HOW CAN BATTERY LIFE BE INCREASED?

Battery life reduces when used outside of or above its limits, hence extending battery life BMS plays a significant role because it manages all the limits. As an illustration, consider temperature during use and numerous other characteristics.

Therefore, we can lengthen the battery life by taking the following actions:

- **Active balancing and Cell switching:**-A good and effective code and circuit should be created for the battery pack since active balancing and cell switching are controlled by the BMS.
- **Through optimized partial charging:**-Because of deterioration, batteries have a finite lifespan. Utilizing strategies for optimal partial charging can lower this. These days, a lot of electrical products have this feature. The consumer must use an expensive way to completely replace the battery unit due to its short lifespan. We can use a partial charging method that is optimised to lessen this degradation. The battery is charged to a particular point and is also discharged up to a set limit when using the optimal charging technique. The battery can only be fully charged when a person is travelling a longer distance, which is also known as the next day prediction. In this method, we also have another method in which we charge according to the usage of the battery. For instance, if a person travels only 50 km per day, the battery can only be charged up to 75 to 80%. The battery's sophisticated BMS assists in making all of this happen. By using this technique, battery performance and life are improved.
- **Avoid charging to 100%:** -Never charge the battery to 100 percent or full capacity. When the battery is fully charged, it will produce a greater float voltage, which will harm the battery and reduce its performance. One should use a battery that operates on a lower float voltage, such as li-ion phosphate cells, if they desire a battery that is always fully charged. They often operate at a lower float voltage than li-ion batteries, which are more comparable. Sometimes overcharging happens if there is no way to stop at 100%, which will hasten the ageing process of the batteries.
- **Limiting battery temperature:** -Limiting the battery's operating temperature extends its life and improves performance. For instance, we shouldn't charge or discharge batteries in extremely cold or extremely hot temperatures. The battery must be maintained at a specific temperature. Metal plating results from charging below 0 degrees Celsius. Additionally, the anode is showing signs of metal plating, which will eventually cause an internal short to develop and produce heat. All of this will make it unstable and difficult to handle. Many modern devices have a feature that prevents charging and discharging after a certain temperature is achieved.
- **Avoid the high charge and discharge rate:** Large charging and discharging rates will cause the battery to produce more heat, which will shorten the battery's life and decrease its efficiency. In batteries, a higher current rate is directly correlated with a higher stress rate.
- **Avoiding deep discharging:**- Deep discharging will quickly or irreparably harm the battery. As was already established, thorough discharge will cause metal plating and a short circuit. Because of this, handling the

battery is difficult, and an explosion is a possibility. According to it, many BMS are created in which discharging stops at a specific moment.

- **Selecting the proper charge termination method:** -In this, we chose a charge rate or charger with a minimum termination need for the present charge. Which will prolong the battery's life by preventing a full charge? For instance, terminating the cycle when the current falls to $c/5$. This is comparable to or same to lowering the float voltage to 4.1 V since, in both situations, the battery is not fully charged, extending battery life.

III. METHODOLOGY

3.1 Steps for Charging Circuit

Put Sims cape's electrical cord in there (this will be included in library it has components like battery, MOSFET, RLC unit etc.) Additionally, add a DC power source and a Li-ion battery from the library. (Set your voltage and amp-hours.) Set the resistance and inductance values after inserting the RLC unit and choosing the RL type. Connect the RL unit's positive terminal to it. Put in two MOSFET, branch them together, and connect to the opposite end of the RL unit. An RC unit's values are set once a resistive load is added. Connect the MOSFET, RC circuit, and resistor in parallel. Add the perfect switch. (Join it with a constant block.) Set the charging voltage and connect the ideal switch at one end and the resistor at the other. SOC, current, and voltage can be selected using a bus selector. Connect it to the power source. Add three Go TO tags with the names SOC, Current, and Voltage to the Bus selection. Include tags for MOSFETs 1 and 2. Then, we must build a charging subsystem, therefore we must first connect the PID controller and PWM generator. Using a not gate in between, the MOSFET 1 tag connects it to the PWD branch and the MOSFET 2 tag. Connect the PID controller to an add operator (change it to +-). Connect to the - of the add block's constant block (which is the reference current) and set the necessary value. Connect the + of the add block to the Current tag. (This is how we cry.) Make connections for SOC, current, and voltage to the scope and add it to the output-checking setup. Li-ion battery charging circuit is shown in Figure.

3.2 Steps for Discharging Circuit

incorporate a continuous power GUI. Li-ion battery addition using the library option. Attach a bus selector to it. Choose the SOC (%) element there, link it to a GOTO tag, branch the connection, and add a display to the newly-branched link. Connect a scope to the SOC GOTO tag and use it. Connect two perfect switches to the battery's negative and positive ends (with initial state 0). To finish the circuit, add a DC source voltage and link it to the optimum switches. In order to link two distinct ideal switches, branch the connection between the battery terminals and the ideal switches (initial state 0). Complete the circuit by connecting a load resistance in series with the switches. Create two statement blocks in the chart, one for statement 1 (charge entry: pulse=1) and the other for statement 2 (discharge entry: pulse=0). Provide it with the conditions $SOC > 85$ in condition 1 and SOC tag as output to chart in condition 2. We'll design a timer circuit right now. A relation operator ($>$) is connected to a clock and a constant block both of which have the value 10. Next, include a second clock and a block of constants with the value 200, and connect them to the relation operator ($>$). Connect a product1 block to both relation operators. Include one more product block. Connect the discharge tag to the product block after connecting the not gate and product 1 to it. Next, attach the two pulse tags to the ideal switch and ideal switch1, respectively two v discharge tags connected to ideal switches 2 and 3.

Li-ion battery from the library, please. Select SOC, Current, and Voltage, and then connect a scope to the bus selector after connecting the battery. Branch the voltage connection and attach it directly to a unit. Add a switch block (with a > 0 condition) and connect the output of the unit delay to the switch block's input 2 (condition). Connect input 1 of the switch block with the constant block CS-CC you've added, with the value 60. Add a further CS-TC constant block with the value 30 and input 3. Link the output of the unit delay to the input 2 (condition) of switch 1, connect the output of the switch to the input 3 of switch 1, add a constant block CS-CV with a value of 15, and then add another switch1 block (> 0 condition). it to switch 1's input 1. Include a source of regulated current. Also include the library's standard blocks for measuring current and voltage. Connect the regulated current source's input to the output of switch 1, then scope 1 and the display. The battery's positive terminal is now connected to the positive terminal of the voltage measuring block, and the negative terminals are now connected to ground. Connect a display2 and a scope1 to the

voltage measurement's output. Connect the negative terminal of the current measurement to the branch point where the positive terminals of the battery and the voltage metre are connected. Join the positive terminals of the current source and the current measurement. Next, link scope 1 and display 1d to the output of the current measurement.

IV. PROPOSED WORK

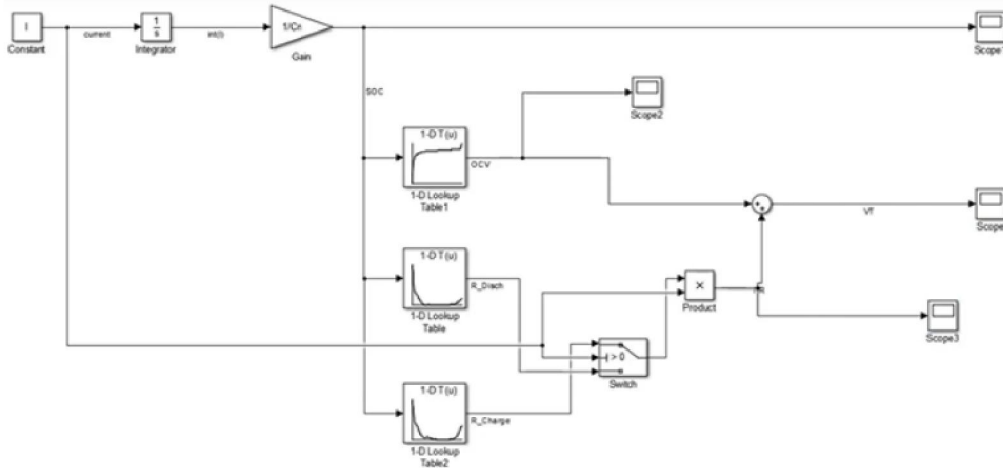


Figure: Complete model of Battery charging and discharging.

V. RESULT

Battery limit, battery charge, and release time for its varied burdens have been determined using a MATLAB programming based battery test system with consistent current supply. In a dynamic load, the battery's releasing current is maintained constant while the heap lowers the voltage of the battery. Following simulation of the battery model, the output of the battery parameters shown in Figures 1 and 2 can be visualised by plotting the following graphs:

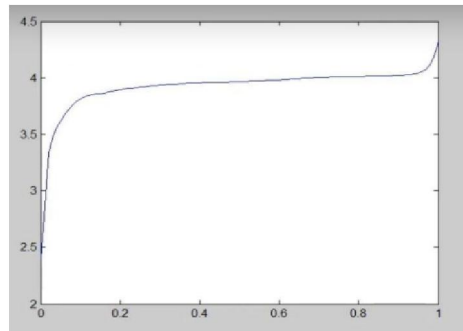


Figure: Output of SOC with OCV

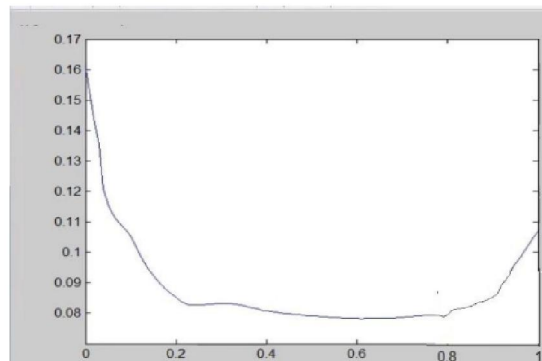


Figure: Output of charge resistance of battery

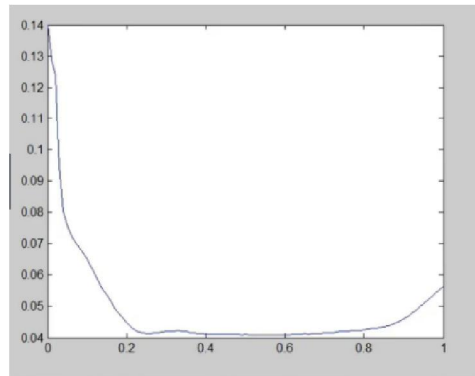


Figure: Output of Discharging resistance of battery

VI. CONCLUSION

For determining battery limit, battery charge, and release time for its varied burdens, a battery test system based on MATLAB programming and a reliable current supply has been developed. In a dynamic load, the battery's releasing current is maintained constant while the battery voltage is decreased by the heap. After running the battery model through simulation, the output of the battery parameters shown in Figs. 1 and 2 can be visualised by plotting the following graphs:

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