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MATLAB/Simulink Based Study on Battery Management System

Dhanashri Pokharkar, Shubham Rawool, Sachin Gore, J.V. Satre

Student, Department of Electrical Engineering, Trinity College of Engineering and Research, Pune, India

Associate Professor, Department of Electrical Engineering, Trinity College of Engineering and Research, Pune, India

ABSTRACT: The rapid growth of electric vehicles (EVs) has brought significant attention to the critical role of Battery Management Systems (BMS) in optimizing battery performance and ensuring safety. As EVs become increasingly prevalent in the automotive industry, the demand for efficient and reliable BMS technology continues to rise. This paper aims to provide a comprehensive overview of the importance of BMS in EV batteries, exploring various aspects such as state-of-charge estimation, cell balancing, thermal management, and fault diagnosis. By examining existing literature and industry practices, this paper identifies key challenges and opportunities in BMS design and implementation, while also discussing emerging trends and future directions for advancing BMS technology. Battery Management Systems play a crucial role in maximizing the efficiency and lifespan of EV batteries. One of the primary functions of a BMS is state-of-charge estimation, which involves accurately determining the amount of charge remaining in the battery. This information is essential for drivers to monitor their vehicle's range and plan their journeys accordingly. Additionally, state-of-charge estimation helps prevent overcharging or deep discharging, which can degrade battery health and reduce its lifespan.

I. INTRODUCTION

The Battery Management System (BMS) is a specialized technology overseeing a battery pack, comprising cells organized in a matrix configuration. It incorporates both software and hardware, aiming to optimize discharge cycles and maximize battery lifespan for a targeted range of voltage and current delivery under various load scenarios. Battery Management System (BMS) is a management technique that monitors and calculates various parameters of rechargeable batteries. It can be classified as simple or complex. A simple BMS regulates voltage and limits current flow when predefined thresholds are reached. On the other hand, a complex BMS monitors multiple battery parameters to enhance battery life and efficiency. MATLAB/Simulink is commonly used for simulating and supervising lithium-ion battery systems

II. BMS DIAGRAM & OVERVIEW

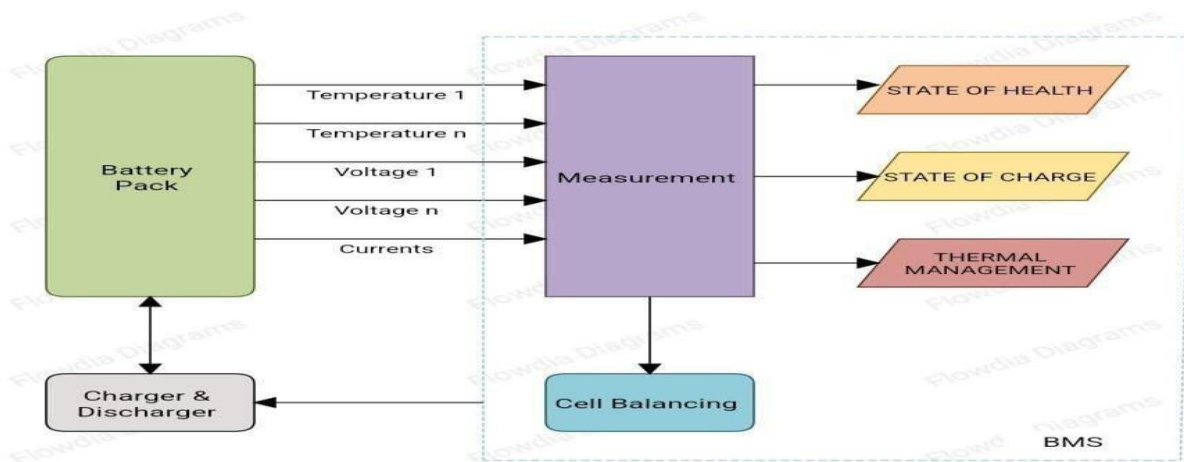


Figure 1 :- Block diagram of Battery Management System

- Cell Balancing: Cells within a battery pack can have slight differences in capacity or performance, leading to imbalances. The BMS ensures that each cell is charged and discharged evenly to prevent overcharging or over-discharging of individual cells, thus maximizing the overall pack performance and lifespan
- Cell Monitoring: The BMS monitors individual cells within the battery pack. This includes measuring voltage, temperature, and sometimes current for each cell.
- Thermal Management: Managing the temperature of the battery pack is critical for its safety and longevity. The BMS monitors cell temperatures and may control cooling/heating systems to maintain optimal operating conditions
- State of Health (SOH) Monitoring: The BMS tracks the health of the battery pack over time. It analyses factors such as charge/discharge cycles, temperature, and internal resistance to assess the battery's health.
- State of Charge (SOC) Estimation: Using the data collected from cell monitoring, the BMS estimates the state of charge of the battery pack. SOC estimation is crucial for accurately determining the available energy.
- Safety Features: BMS incorporates safety features to prevent overcharging, over-discharging, short circuits, and overheating. It may also include features like cell isolation and insulation monitoring to mitigate the risk of electrical hazard.
- Fault Detection and Diagnostics: The BMS continuously monitors the battery pack for faults or abnormalities. It diagnoses issues and may provide alerts or shut down the system to prevent damage or hazards.
- Energy Management: In applications like EVs or renewable energy systems, the BMS may optimize energy usage for better performance, efficiency, and longevity.
- Communication Interface: BMS often includes communication interfaces (e.g., CAN, UART) to communicate with external systems like vehicle controllers, chargers, or monitoring software.
- Control Algorithm: The BMS utilizes a control algorithm to determine the amount of energy that needs to be transferred between cells to achieve balance. Factors such as cell voltages, temperatures, and charge/discharge rates are considered in this calculation.
- User Interface: Some BMSs feature a user interface for displaying battery parameters, diagnostics, and status indicators, either integrated into the device or accessible remotely through software.
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III. CELL BALANCING

Balancing is a process which equalizes the amount of charge present in each cell of a battery. Individual cells operating at different levels of charge in a battery could lead to overcharging or over discharging which may be harmful to both the battery and its operator, and must be avoided.

There are two common types of battery balancing.

Active balancing: -

Active balancing involves actively transferring energy between cells to equalize their SOC. This is achieved by utilizing charge storing elements like capacitors and inductors. This is typically achieved using electronic components such as, MOSFET & IGBT switches, switched capacitor networks, or other power electronics. Switched capacitor network use capacitors to store and transfer energy between cells. By selectively connecting capacitors to cells, energy can be redistributed to achieve balance. Active balancing can be more efficient than passive balancing and is capable of balancing cells quickly and effectively, even under high-current conditions. However, it tends to be more complex and costly due to the additional electronic components and control algorithms required. Active balancing may be performed continuously or intermittently during charging or discharging cycles to maintain balance over the entire lifespan of the battery pack.

Passive balancing: -

Passive balancing methods dissipate excess energy from cells with higher state of charge (SOC) to cells with lower SOC through resistive elements, such as resistors or diodes. This method is relatively simple and cost-effective, as it doesn't require active electronics or energy transfer components. However, it can be less efficient than active balancing, especially for large imbalances or high-current applications.

IV. THERMAL MANAGEMENT

Temperature affects battery performance, with optimal performance typically achieved within a specific temperature range. Proper thermal management ensures that batteries operate within this range, maximizing efficiency and power output. Excessive heat can lead to thermal runaway, where the battery generates more heat than it can dissipate, potentially resulting in fires or explosions. Effective thermal management helps prevent such hazards; High temperatures accelerate battery degradation, reducing lifespan and capacity over time. Maintaining the battery within a suitable temperature range helps extend its lifespan

V. SIMULATION OF BATTERY MANAGEMENT SYSTEM (BMS)

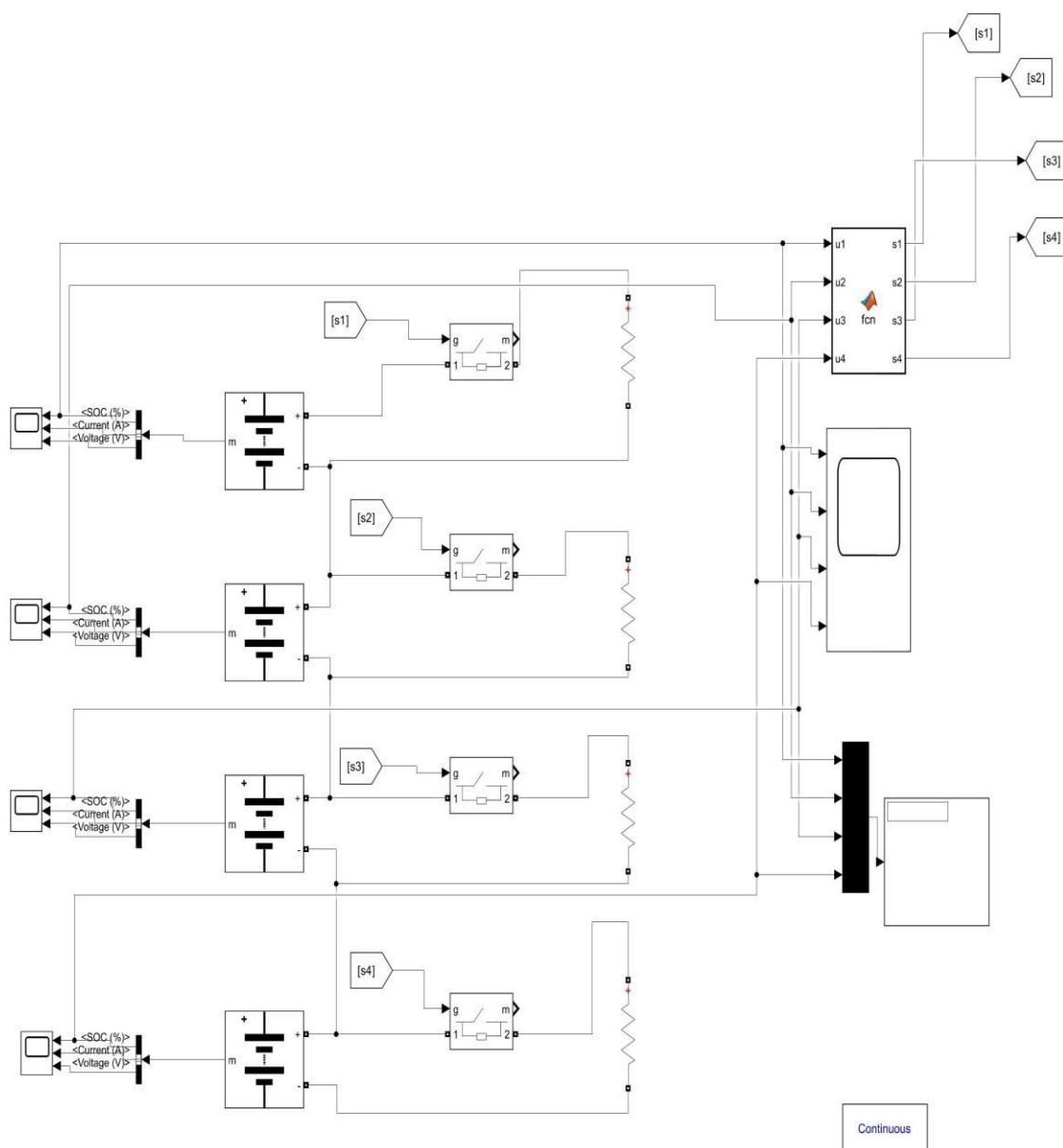


Fig - 1. Simulation For Passive Balancing (4 cells)

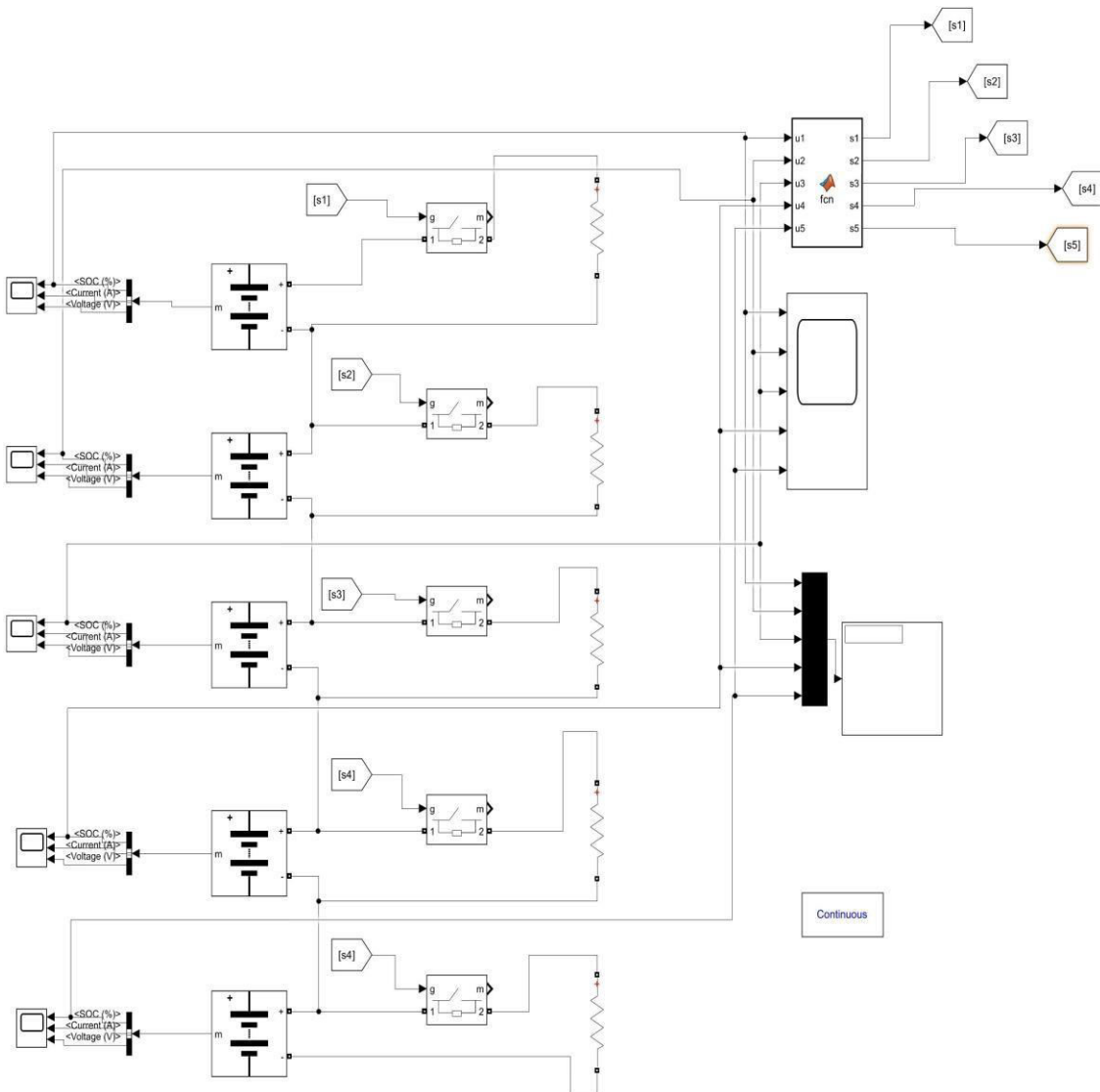


Fig - 2. Simulation for Passive Balancing (5 cells)

VI. EXPERIMENTAL RESULTS

- 1) The Fig (1). we have used different rating of battery cell, given different nominal voltage to each cell. In this passive cell balancing simulation, it observed output of cell is same. The state of charge of all cell are remain same. The input voltage is same as output voltage in results but after some time voltage and current comes into the same state of charge.
- 2) The initial state of charge is different for all cells but the output of each cell is remaining same, a minor difference in output is observed in simulation. Fig (2)
- 3) If we change the initial state of charge nominal voltage and rated capacity of the cell it is observed input and output then input output nominal voltage and rated capacity is remaining same.
- 4) In Fig (3) if we change the rated capacity of cell then also output remaining same.

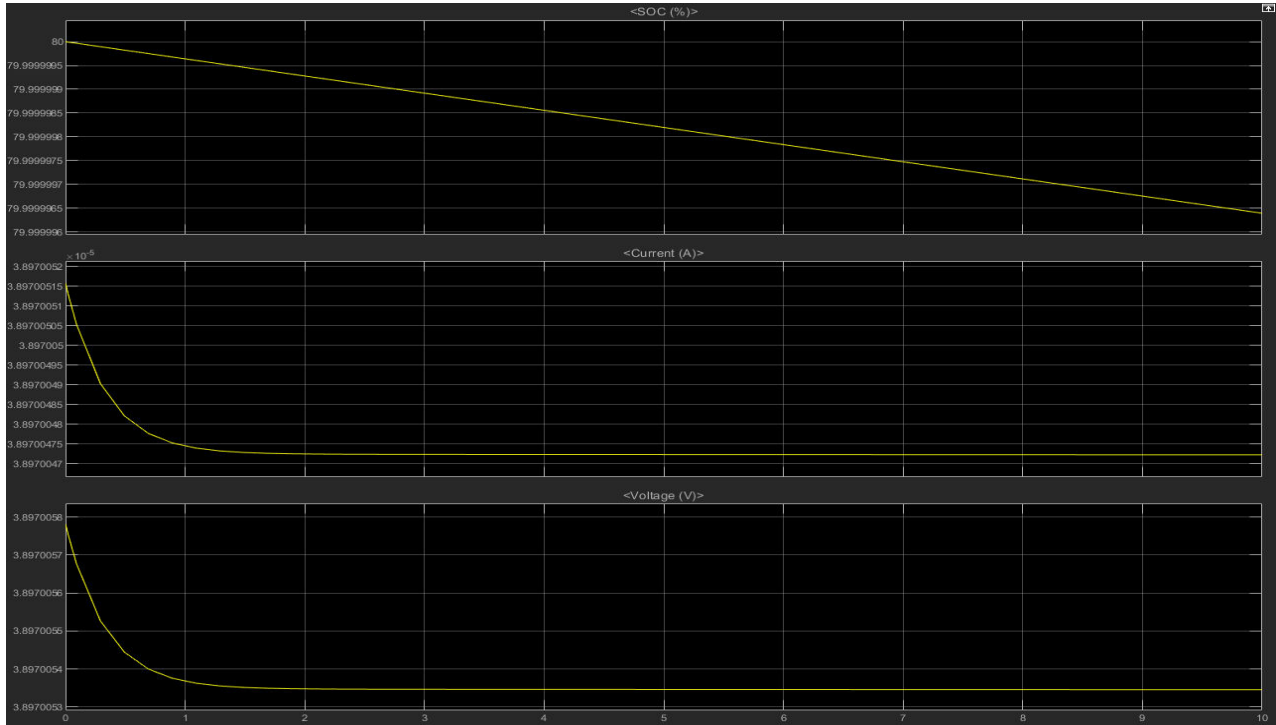


Fig No.3

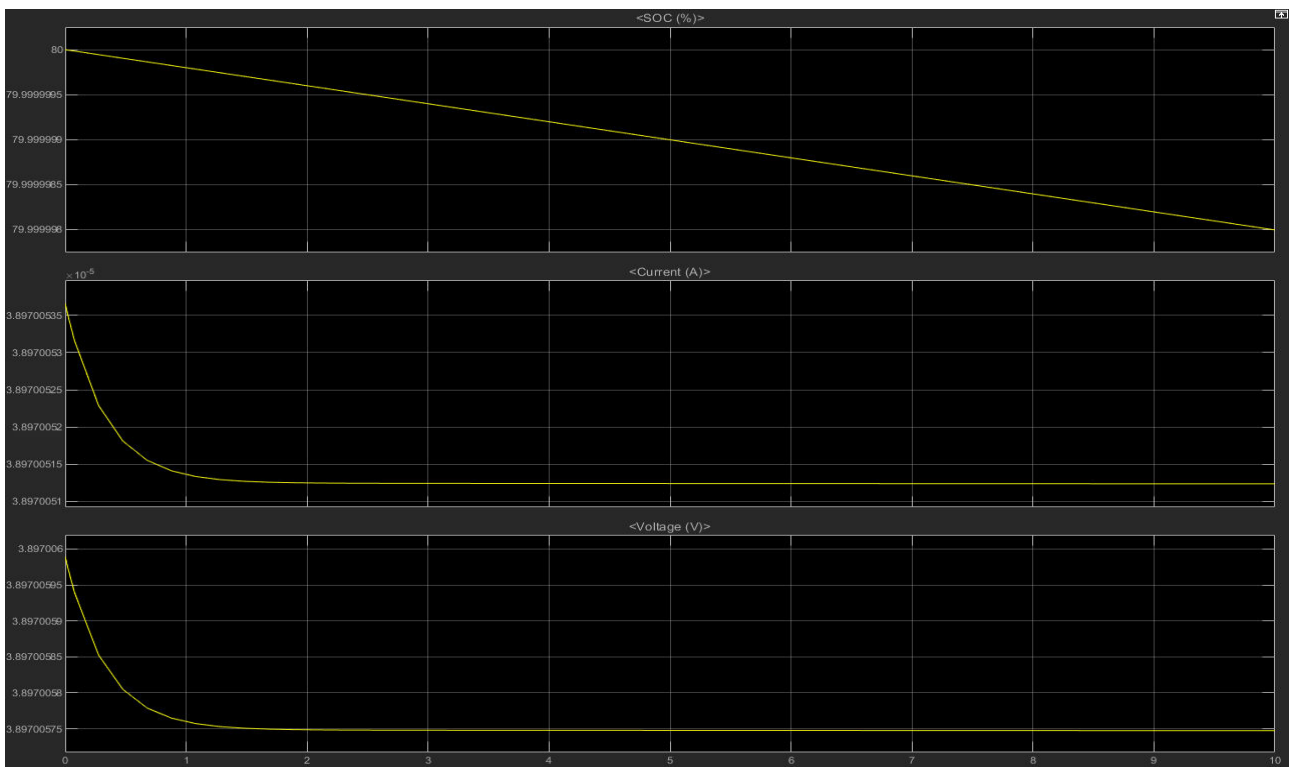


Fig No.4

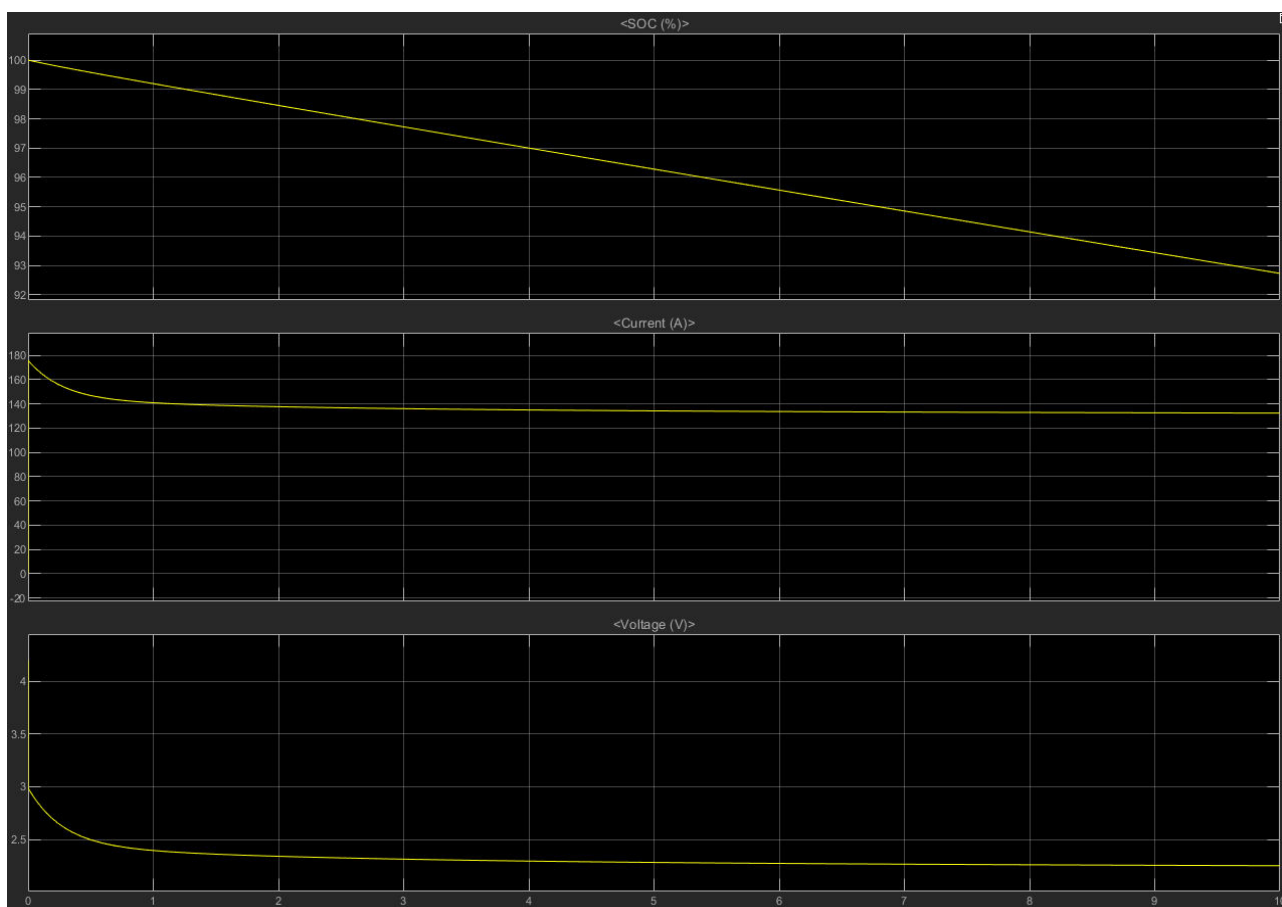


Fig No.5

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