Project Report: Thermal Modeling of the Battery Pack

1. Introduction

Lithium-ion batteries are widely used in various applications, including electric vehicles and portable electronics, due to their high energy density, long cycle life, and low self-discharge rate. However, the thermal management of these batteries is crucial to ensure safety, performance, and longevity. This project focuses on the thermal modeling of a 10-cell series lithium-ion battery pack, simulating the thermal effects, and comparing life cycle performance under various temperatures, charge, and discharge rates using MATLAB.

2. Objective

The primary objective of this project is to:

- Simulate the thermal behavior of a 10-cell series lithium-ion battery pack.
- Analyze the impact of different operating temperatures on the battery's State of Charge (SoC) and overall performance.
- Compare the life cycle performance at various temperatures ranging from 300K to 390K.

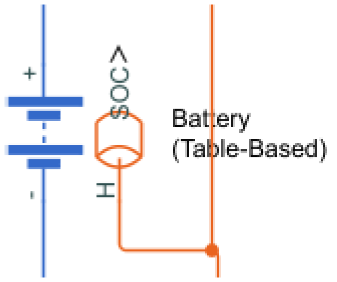
3. Methodology

3.1 Component Requirements

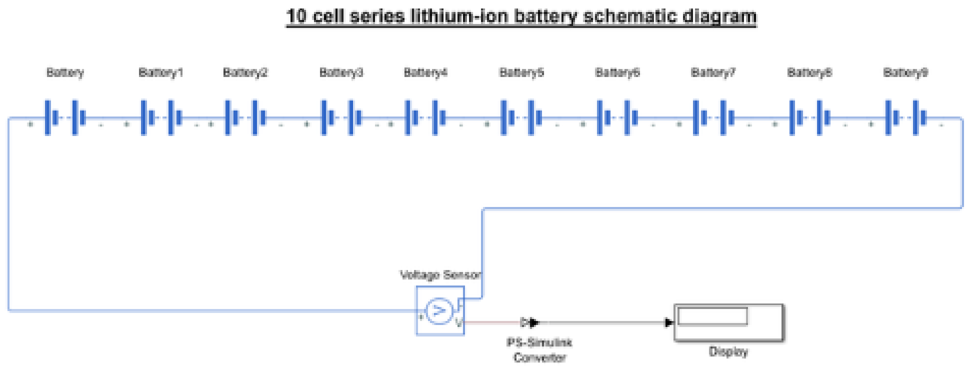
- **Battery (Table-Based)**: The battery block in MATLAB's Simscape is used, where the SoC and thermal properties are activated. The block choice is set to "Instrumented | Show thermal port."
- **Thermal Reference**: Acts as the reference point for the thermal circuit.
- **Temperature Sensor**: Measures the temperature of the battery cells.
- **Convective Heat Transfer**: Models the heat transfer between the battery and its surroundings.
- **PS-Simulink Converter**: Converts physical quantities into Simulink data for analysis.
- **Electrical Reference**: Provides a ground reference for the electrical circuit.
- **Solver Configuration**: Configures the solver for simulation.
- **Goto and From Blocks**: Used for organizing signals within the Simulink model.
- **Scope**: Displays the output waveform of various parameters such as temperature, SoC, and voltage.
- **Controlled Current Source**: Discharges the battery with a constant discharge current.

3.2 Schematic Diagram

1. Battery (Table-Based)



10 cell series lithium-ion battery schematic diagram:



A schematic diagram of the 10-cell series lithium-ion battery was developed using the components mentioned above. The model was designed to simulate the battery's behavior under different thermal conditions.

3.3 Simulation Setup

The simulation was conducted with the following parameters:

- **Operating Temperatures**: The battery was tested at temperatures of 300K, 330K, 360K, and 390K.
- **Discharge Current**: A constant discharge current was applied to evaluate the battery's performance at each temperature.

3.4 Temperature Conversion

To relate the Kelvin (K) temperature values to Celsius (°C), the following formula was used:

y°C=xK−273.15\text{y°C} = \text{xK} - 273.15y°C=xK−273.15

K	degC
300	26.85

K	degC
330	56.85
360	86.85
390	116.85

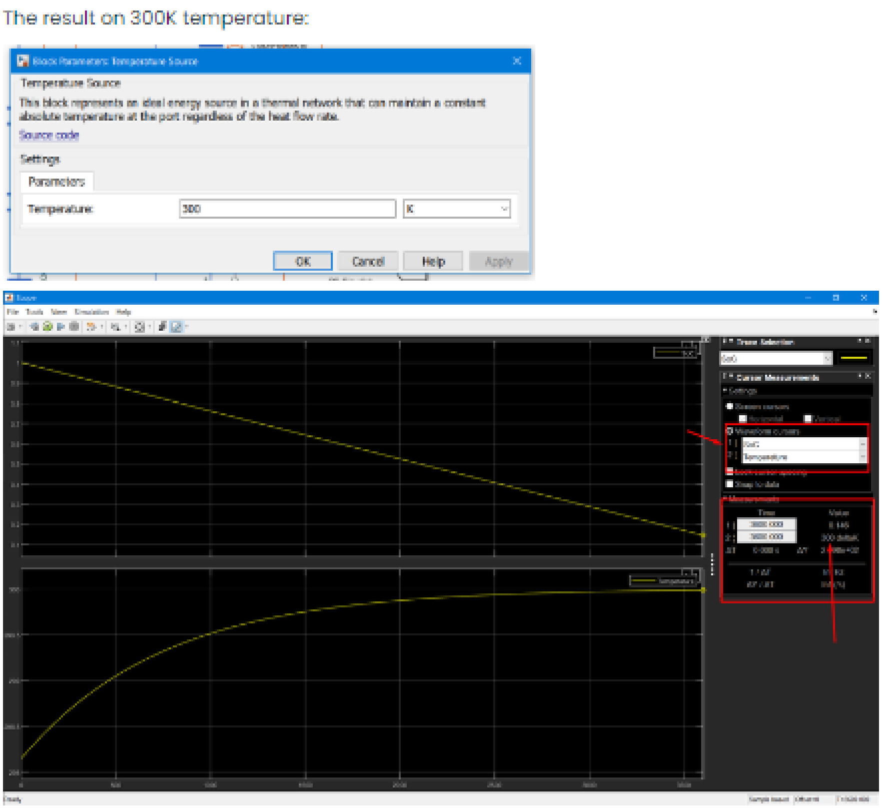
4. Results

The battery pack's performance was analyzed at each temperature, focusing on the SoC and its variation with temperature. The results were as follows:

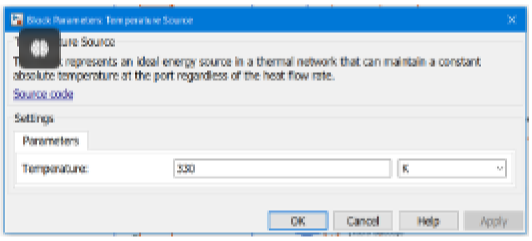
4.1 SoC at Different Temperatures

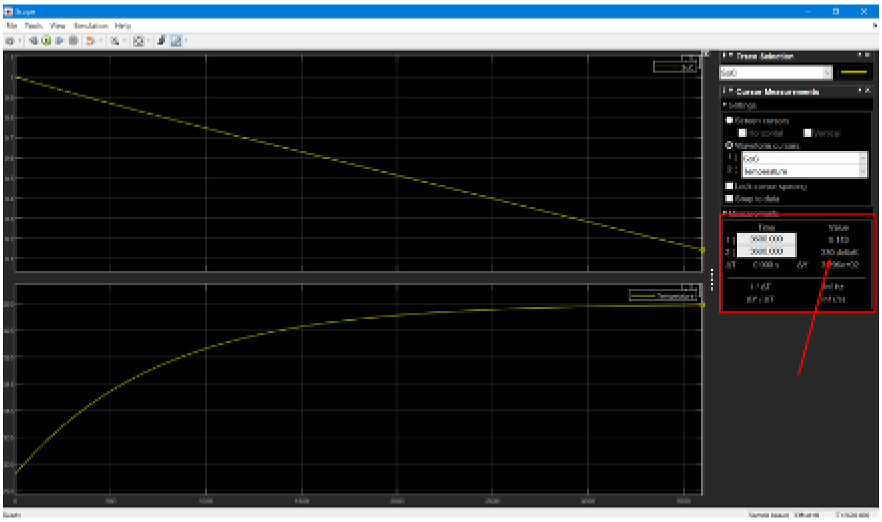
K	degC	SoC%
300	26.85	14.6%
330	56.85	14.3%
360	86.85	7.14%
390	116.85	2.38%

The result on 300K temperature:

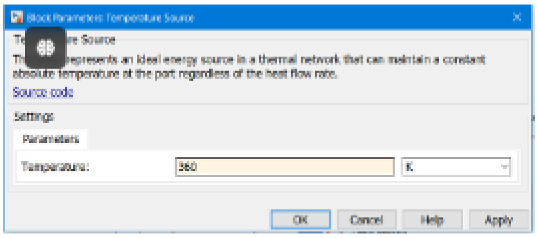


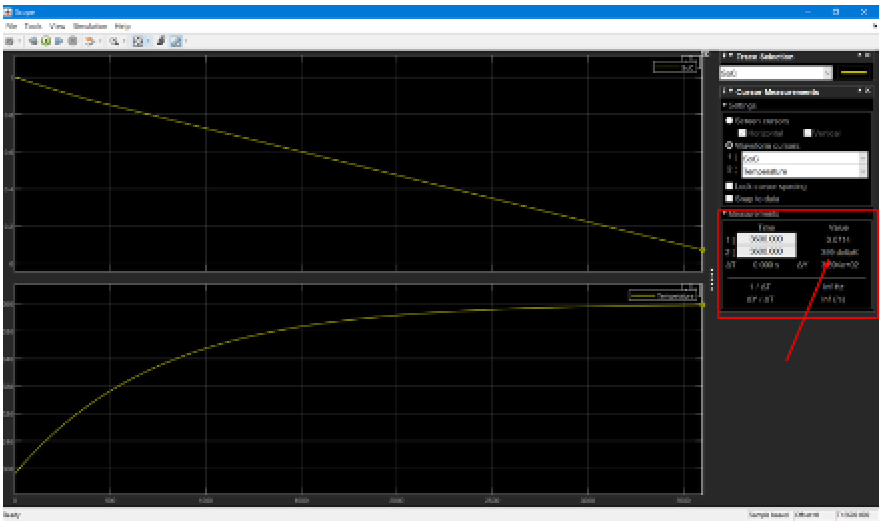
The result on 330K temperature:



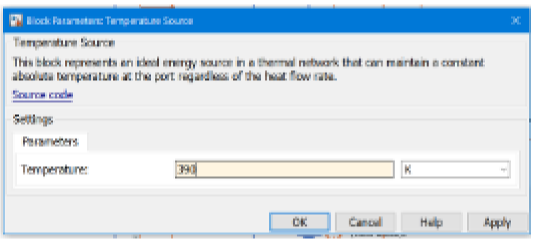


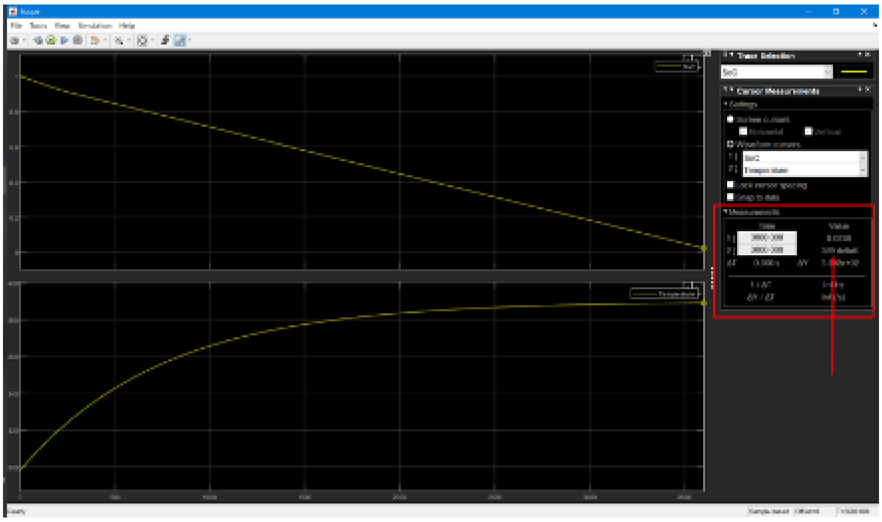
The result on 360K temperature:





The result on 390K temperature:





4.2 Analysis

As observed from the results, the SoC decreases as the temperature increases. This indicates that operating the battery at higher temperatures accelerates the discharge process, leading to a faster depletion of charge. Consequently, the life cycle of the battery is negatively impacted when it operates above the rated temperature.

5. Conclusion

This project successfully demonstrated the thermal effects on a 10-cell series lithium-ion battery pack. The simulation results confirmed that higher operating temperatures lead to a significant decrease in SoC, thereby reducing the battery's overall life cycle. Proper thermal management is, therefore, essential to maintain the performance and longevity of lithium-ion batteries in practical applications.