Battery Management System (BMS) Simulation

Internship Organization: Codec Technologies

Intern Name: Prabath M

B.E Electrical and Electronics Engineering (EEE)

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Abstract
This project, carried out as part of my internship at Codec Technologies, focuses on the simulation of a Battery Management System (BMS) for Electric Vehicles (EVs). The BMS plays a crucial role in ensuring battery safety, efficiency, and reliability by monitoring key parameters such as State of Charge (SOC), State of Health (SOH), cell voltage, and temperature. In this project, MATLAB/Simulink was used to model and simulate the behavior of a lithium-ion battery pack under various operating conditions.

The system integrates SOC estimation using Coulomb counting and Extended Kalman Filter (EKF), SOH estimation based on capacity fade and resistance growth, as well as a thermal management subsystem. Protection mechanisms such as overvoltage, undervoltage, overcurrent, and overtemperature were also modeled to demonstrate safe battery operation. The results show accurate estimation of SOC and SOH under dynamic load conditions, effective temperature tracking, and proper activation of protection logic, making the system highly relevant to EV applications.

1. Introduction
The growing demand for Electric Vehicles (EVs) has made battery performance and safety increasingly important. A Battery Management System (BMS) is essential to maximize battery life, prevent unsafe operating conditions, and ensure efficient energy usage. This project focuses on simulating a BMS for lithium-ion batteries using MATLAB/Simulink. The simulation includes modules for estimating SOC, SOH, temperature, and implementing protection mechanisms.

2. BMS Functional Design
The BMS designed in this project performs the following key functions:
- State of Charge (SOC) estimation using Coulomb Counting and EKF.
- State of Health (SOH) estimation based on capacity degradation and internal resistance increase.
- Thermal monitoring using a lumped thermal model to simulate temperature rise.
- Protection logic to safeguard against overvoltage, undervoltage, overcurrent, and overtemperature.
- Optional balancing algorithms for multi-cell packs to maintain equal cell SOC levels.

3. Simulation Setup
The simulation was built in MATLAB/Simulink using drag-and-drop blocks and custom MATLAB functions:
1. Battery Model: 1-RC Thevenin equivalent circuit with OCV-SOC lookup table.
2. SOC Estimator: Coulomb counting with OCV reset and an Extended Kalman Filter for accuracy.

3. SOH Estimator: Capacity fade modeled over cycles; resistance growth estimated from voltage-current pulses.
4. Thermal Model: Heat generation from I^2R losses and dissipation via ambient cooling.
5. Protection System: Logic for detecting unsafe voltage, current, and temperature conditions.
Simulation drive cycles (constant current, dynamic load profiles) were applied to evaluate system behavior.

4. Results and Analysis

Simulation results demonstrated the effectiveness of the BMS in managing battery performance:
- SOC tracking closely matched actual SOC, with EKF reducing estimation errors.
- SOH values decreased gradually with simulated aging cycles, reflecting capacity fade and resistance growth.
- Thermal modeling showed temperature rise under heavy load conditions, with safe limits enforced by protection logic.
- Protection events (overvoltage, undervoltage, overcurrent, and overtemperature) triggered as expected, preventing unsafe operation.

Graphs for SOC vs. time, SOH vs. cycles, and temperature vs. time can be added to strengthen the analysis section.

5. Applications

The simulated BMS has several applications in both academic and industrial contexts:
- Electric Vehicles (EVs) for safe and efficient battery management.
- Renewable energy storage systems such as solar and wind battery banks.
- Consumer electronics requiring advanced battery monitoring.
- Research and development of advanced algorithms for SOC/SOH estimation.

6. Conclusion

This internship project successfully developed a simulation model for a Battery Management System (BMS). The system was capable of accurately estimating SOC and SOH, monitoring thermal behavior, and enforcing protection limits to ensure battery safety. The project highlights the importance of BMS in electric mobility and energy storage applications. Future work may include extending the model to multi-cell packs, implementing active cell balancing, and integrating AI-based estimation techniques.

7. References

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