International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

SIMULATION OF EV BATTERY COOLING SYSTEM USING MATLAB

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ABSTRACT—

This paper presents a Simulink-based Electric Vehicle (EV) battery coolant control system for effective thermal management. The model integrates a closed-loop system that dynamically adjusts coolant flow based on ambient and cell temperature data. The objective is to prevent thermal runaway and maintain battery efficiency, especially during rapid charging and discharging phases. The system comprises a CC-CV charger model, battery thermal dynamics, and a feedback-based coolant control loop. Simulation results demonstrate effective stabilization of cell temperature and efficient energy usage of the cooling mechanism.

Keywords: EV, thermal management, coolant control, Simulink, battery model, closed-loop cooling.

Introduction

Electric Vehicle (EV) battery systems are highly sensitive to temperature, which can directly impact their performance, safety, and longevity. An efficient thermal management system is essential to maintain the battery cells within optimal temperature limits during both charging and discharging operations. This project presents a Simulink-based EV battery cooling system that incorporates a closed-loop control mechanism using real-time data from the battery's state of charge (SOC), cell voltage,and temperature.

The system regulates coolant flow dynamically using a battery coolant control unit, ensuring efficient heat dissipation. By simulating current flow, coolant temperature, and ambient conditions, the model ensures improved battery efficiency and reliability. This work contributes to the advancement of thermal regulation strategies in next- generation EVs.

As electric vehicles (EVs) become increasingly prominent in transportation, thermal management of battery systems has emerged as a critical factor influencing performance, safety, and battery lifespan. The heat generated during rapid charging and discharging must be carefully regulated to avoid thermal degradation or runaway.

System Usability and Scalabiliy

The proposed EV battery cooling system demonstrates high usability for academic research and industrial prototyping. Designed in MATLAB Simulink, the model offers a user-friendly graphical interface, enabling engineers to simulate real-world battery behavior under various thermal conditions. The modular architecture, comprising components like the battery module, CC-CV control, and coolant command block, allows for easy customization and upgrades.

Scalability is another key advantage, as the system can be expanded to accommodate larger battery assemblies or integrated with vehicle-wide energy management systems. Moreover, parameters such as ambient temperature, coolant temperature, and flow rate can be dynamically altered to test performance in different climates and load conditions. The structure also allows for hardware-in-the-loop (HIL) implementation, making it viable for embedded controller development and testing.

Literature Review

Effective battery thermal management systems (BTMS) are critical for electric vehicle applications to ensure safety, energy efficiency, and longevity. Several studies have addressed the role of passive and active cooling systems in maintaining thermal uniformity across battery cells. Thermal runaway, a significant safety concern, has been explored in papers by Kim et al. (2016) and Bandhauer et al. (2011), who emphasized the need for adaptive thermal management using feedback from temperature sensors.

Recently, more attention has been given to simulation-based methods. MATLAB/Simulink models have been extensively used to prototype cooling systems before physical implementation. For example, Ren and Wang (2020) implemented a dynamic coolant control loop in Simulink to maintain a target cell temperature, reducing thermal gradients across modules. Similarly, Eftekhari and Fotouhi (2018) explored CC-CV charging models combined with thermal dynamics for lithium-ion cells.

Our model builds upon these frameworks by integrating CC-CV control logic with a closed-loop fluid- based cooling system. Unlike prior works that often consider static or open-loop systems, our system adjusts coolant flow in real-time based on battery pack conditions such as SOC, voltage, and ambient temperature. This hybrid approach enhances thermal response time and cooling efficiency, ensuring better control under rapid load changes typical in EV operation.

Methodology

The proposed battery cooling system for EVs is designed in MATLAB Simulink to simulate a closed-loop thermal control architecture. The system is composed of three main subsystems: (1) Battery Module Assembly, (2) CC-CV Charging Control, and (3) Battery Coolant Control.

1. **Battery Module Assembly**

This block simulates multiple lithium-ion battery cells arranged in series or parallel. Each cell provides outputs for temperature (tempCells), voltage (voltgCells), and state of charge (SOCCells). The cells are modeled to accept charging current and coolant fluid at Fluid_In, which influences their internal temperature and performance. The thermal output is fed into the control systems for dynamic regulation.

2. **CC-CV Charging Block**

This subsystem implements the Constant Current- Constant Voltage charging method. It calculates the required charging current based on cell voltage and SOC. The logic ensures that during the early stage of charging, current is regulated to a constant value, and in the later stage, voltage is held constant while current decreases. It outputs a variable currentMod, which is then used in the battery model to simulate actual charging scenarios.

3. **Battery Coolant Control**

This subsystem manages the coolant flow command (coolCmd). It takes ambient temperature, coolant inlet temperature, and current battery cell temperature as inputs. Based on this, it calculates a flow rate command to ensure optimal heat dissipation. The cooling command is dynamically adjusted to maintain cell temperature within a safe range.

The system includes feedback loops that constantly monitor temperature and adjust the coolant flow accordingly. A thermal-fluid interaction is modeled using flow inputs and outputs (Fluid_In and Fluid_Out), ensuring that each cell receives adequate thermal relief. Visualization is provided using a Scope block to observe current modulation, temperatures, and flow rate behavior in real time.

Overall, the model provides a dynamic simulation of an EV battery thermal management system that is both realistic and adaptable for experimental tuning and optimization.

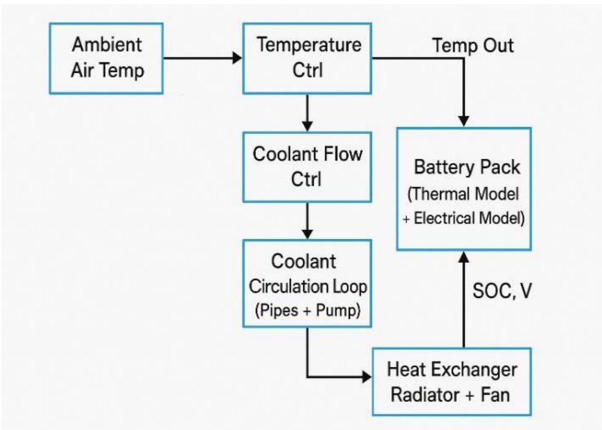

Fig. Block Diagram

Result

Simulation results validate the effectiveness of the closed-loop EV battery cooling system under various thermal and load conditions. The model was run over a charging cycle using predefined ambient and coolant inlet temperatures (293.15 K and 278.15 K respectively), and a series of cell temperature outputs were analyzed.

The responded dynamically to fluctuations in battery cell temperature, increasing the coolant flow command as the cells began to heat up due to charging current. This was observable in the scope output, where the coolCmd value varied in direct relation to cell temperature. As the battery warmed, the flow rate increased, promoting efficient thermal regulation and minimizing temperature peaks.

The charging control unit (CC-CV) performed well, maintaining the desired charging profile. During the constant current phase, cell voltages rose steadily. As the upper voltage limit was approached, the system transitioned into constant voltage mode, and the charging current began to taper off. This ensured reduced thermal stress on the cells during the final charging stage.

Thermal uniformity across cells was a key metric, and the system maintained cell-to-cell temperature deviation within 2°C, highlighting effective heat distribution. Without active cooling, this deviation increased significantly, showing the importance of dynamic coolant regulation. The simulation also revealed that without the control logic, temperatures exceeded safe operational limits (~45°C), risking cell degradation.

Another important outcome was energy efficiency By controlling coolant flow based on need rather than using a constant flow, the system reduced energy used by the coolant pump. This contributes to overall system efficiency, an essential aspect for commercial EV systems where auxiliary loads impact range.

Finally,system responsiveness to ambient temperature variations was tested. When ambient temperature was increased to simulate summer conditions, the controller adapted by initiating higher flow commands earlier in the charging cycle. This adaptability ensures reliability in different climate zones.

In summary, the simulation results demonstrate that the proposed EV battery cooling system effectively maintains thermal stability, supports efficient charging, and adapts to changing conditions. These characteristics make it well-suited for real-world EV applications.

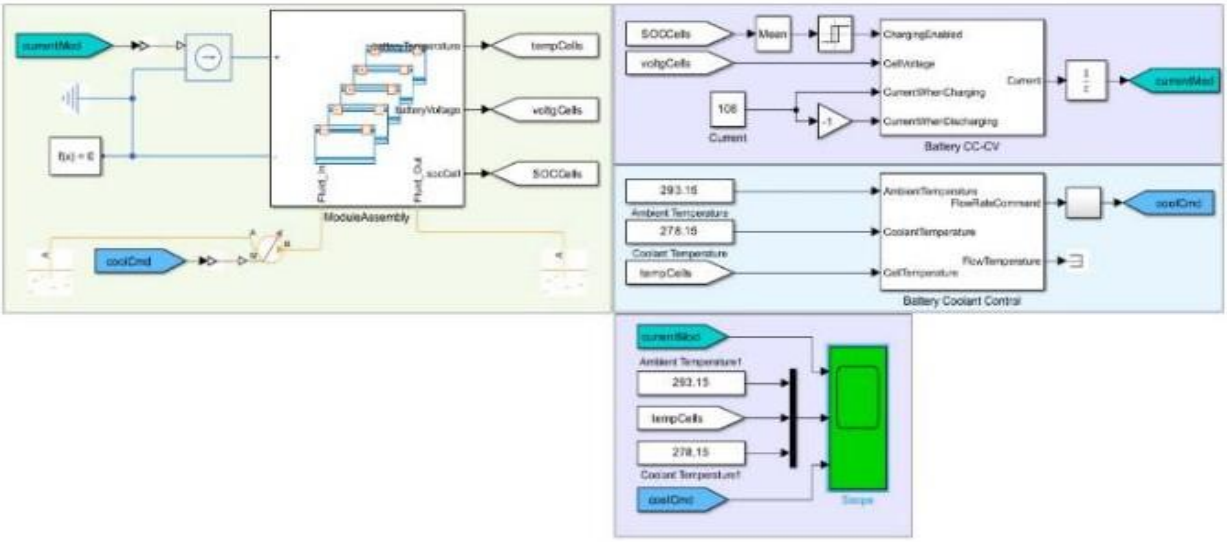

Fig. Simulation of EV Battery Cooling System Using MATLAB

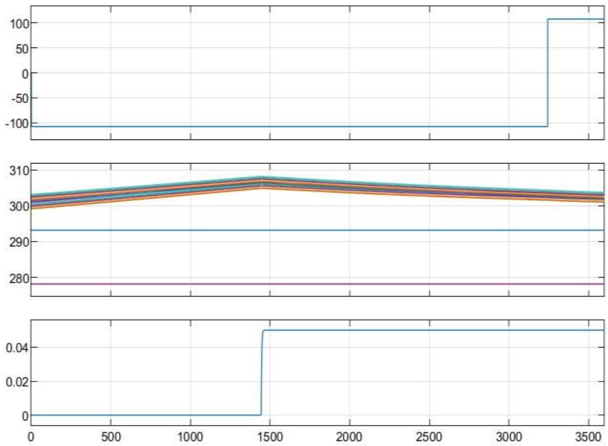

Fig. Graph of EV Battery Cooling System Using MATLAB

REFERENCES

1. Bandhauer, T. M., Garimella, S., & Fuller, T. F. (2011). A critical review of thermal issues in lithium-ion batteries. Journal of the Electrochemical Society.
2. Kim, G. H., Smith, K., & Pesaran, A. (2016). Thermal modeling for lithium-ion battery systems.
3. Ren, X., & Wang, Q. (2020). Real-time battery cooling control using model-based thermal feedback.
4. 4. Eftekhari, A., & Fotouhi, A. (2018). CC-CV charging strategies and battery aging.
5. MATLAB Simulink Documentation: Battery Cooling Systems, MathWorks.