



EV BMS with Charge Monitor and Fire Protection

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Abstract- An Electric Vehicle (EV) Battery Management System (BMS) that combines charge-discharge monitoring with a predictive fire-protection mechanism is simulated in this study using MATLAB/Simulink. To guarantee steady energy management in dynamic circumstances, the model monitors changes in voltage, current, and State of Charge (SOC). Transitions between charging and discharging are controlled by a dual-mode controller, and dangerous voltage, current, or temperature levels are detected by a protection unit. The simulation results show consistent current tracking, voltage control around 48–50 V, and dependable SOC regulation between 51.8% and 51.95%. By successfully preventing overcharge or deep-discharge situations, the system improves operational safety. The suggested framework offers a useful method for simulating EV BMS safety and dependability prior to hardware deployment.

Keywords- Battery Management System (BMS), Electric Vehicle (EV), State of Charge (SOC), Fire Protection.

I. INTRODUCTION

An essential part of electric vehicles (EVs) are battery management systems (BMS), which guarantee the energy storage system operates safely, effectively, and dependably. Battery monitoring, estimating the State of Charge (SOC) and State of Health (SOH), controlling temperature, and guarding against thermal or electrical failures are just a few of the crucial duties that a BMS manages. Together, these features increase charging effectiveness, prolong battery life, and protect passenger safety. However, issues like heat buildup, overcharging, and thermal runaway have become more noticeable as battery energy density and power demand continue to increase. These safety issues emphasize how crucial it is to incorporate fault detection and predictive protection into contemporary BMS architectures in order to stop dangerous failures like fires and explosions.

A simulation model based on MATLAB/Simulink is created in this study to examine the dynamic behavior of a BMS when it is charging and discharging. With the implementation of a protective logic that reacts to anomalous electrical or thermal states, the framework is intended to continually regulate voltage, current, and SOC levels in real time. Designing a BMS simulation that faithfully simulates charge-discharge functions, putting fault-prevention algorithms into practice to reduce any thermal or electrical hazards, and assessing system stability using SOC, voltage, and current responses are the primary goals of this research. This study minimizes experimental complexity, prevents possible hardware damage, and permits early validation of fire-safe management mechanisms for upcoming EV battery systems by using a simulation-based methodology.

II. LITERATURE REVIEW

Many studies have been conducted on the development of Battery Management Systems (BMS) for Electric Vehicles (EVs) in an effort to enhance operating performance, safety, and energy efficiency. A thorough review of BMS topologies that incorporate thermal management systems, SOC and SOH estimates, and hardware monitoring was given by Kurkin, A. (2025) [1]. The author underlined that in order to guarantee dependability under dynamic load situations, a contemporary BMS has to effectively control both energy flow and protective activities. A thorough analysis of State-of-Charge (SOC) estimate techniques, including Kalman filters, Coulomb counting, equivalent circuit modeling, and machine learning-based hybrid approaches, was provided by Pisani Orta, M. A. (2025) [2]. The study came to the conclusion that SOC accuracy and robustness in real-time EV applications are greatly increased by integrating model-based and data-driven estimate methodologies. Liu, W. (2022) [3] explained how monitoring, balancing, and protection algorithms work together to provide safe and reliable EV operation by examining the relationships between battery chemistry, module setup, and BMS functions. The foundation for creating integrated frameworks for safety and charge monitoring is provided by this study. For EV systems, fire safety is still a major concern. According to Sun, P. (2020) [4], thermal runaway was the primary source of ignition, propagation, and post-fire dangers in their analysis of EV battery fire occurrences. The author underlined that thermal fault prediction and BMS-based cutoff systems are essential for reducing the hazards associated with fire. By comparing the thermal stability of lithium-ion and sodium-ion batteries, Boozula, A. R. (2025) [5] showed that variations in material composition result in different failure thresholds and fire behaviors. The significance of chemistry-specific protective logic in BMS design is underscored by these findings. In a similar vein, Chow, W. K. (2022) [6] investigated EV fire risks related to charging stations, parking lots, and collision situations, demonstrating how BMS cooperation with infrastructure-level security improves overall security. In addition, Huhn, E. (2025) [7] looked at active cooling and suppression strategies such as heat sinks and water-based systems to stop the spread of thermal runaway. According to the study, combining mechanical or thermal countermeasures with early BMS detection signals speed up reaction failures.



III. BLOCK DIAGRAM

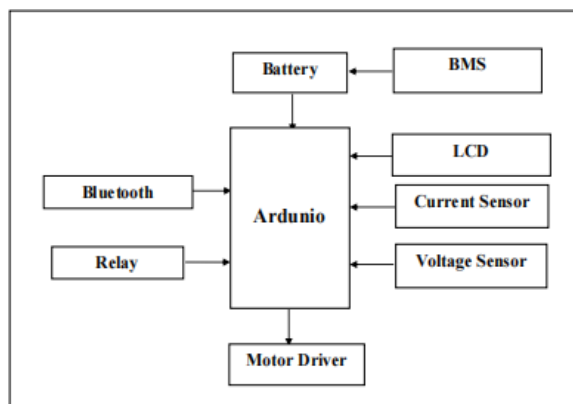


Fig.1. Block Diagram of EV BMS with charge monitor and fire protection

The suggested method creates a dependable Battery Management System (BMS) for Electric Vehicles (EVs) by fusing hardware and simulation principles. While the Arduino-based framework offers a workable implementation for real-time monitoring and protection, the MATLAB/Simulink model replicates the charge-discharge dynamics of a lithium-ion battery. This dual approach lowers hardware complexity and experimental risk during early validation while allowing for reliable performance evaluation under various load circumstances.

The Arduino microcontroller serves as the control center, as seen in Fig. 1, gathering information from voltage and current sensors to determine the State of Charge (SOC) and identify anomalies. The battery operates as the major energy source, while the BMS maintains safe voltage, current, and temperature limitations to prevent overcharging and thermal stress, keeping with the design concepts of Kurkin [1] and Liu [3]. According to Sun [4] and Boozula [5], the relay disconnects the load in atypical circumstances in order to prevent faults. In order to support the communication-based safety measures suggested by Chow [6] and Huhn [7], the motor driver regulates power delivery, and the LCD and Bluetooth modules allow for both local and wireless monitoring. The MATLAB/Simulink simulation verifies the charge-discharge process by incorporating SOC estimates, voltage monitoring, and protective logic. The accuracy and stability of the system were confirmed by maintaining a stable voltage at 48–50 V and a state of charge (SOC) between 51.8% and 51.95%. In accordance with Huhn [7] and Boozula [5].

The protection algorithm effectively separated errors under hazardous situations, guaranteeing thermal safety. All things considered, the integrated method shows improved fault avoidance, efficient charge monitoring, and a scalable basis for the development of future EV BMS hardware with fire safety features.

IV. SIMULATION DIAGRAM

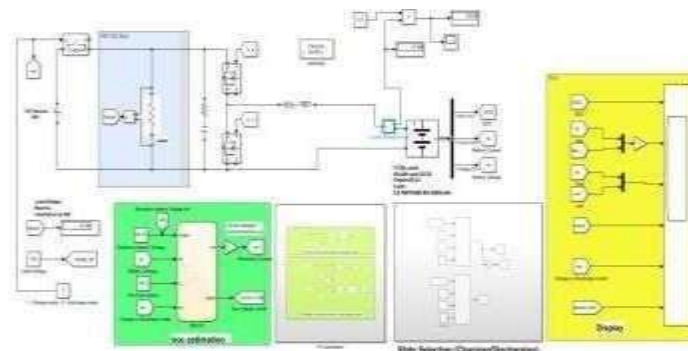


Fig.2 MATLAB/Simulink model of the proposed Battery Management System (BMS) for Electric Vehicles showing SOC estimation, charge/discharge control, and protection modules.

The general architecture of the suggested Battery Management System (BMS) for Electric Vehicles (EVs) is depicted in the MATLAB/Simulink model in Figure 2. Modules for fault prevention, charge-discharge control, SOC estimate, and display monitoring are all part of the system. It is intended to replicate how a battery would behave in real time under various load scenarios, guaranteeing dependable and safe functioning. The model lowers experimental risks and expenses by offering an effective platform for evaluating control schemes prior to hardware implementation.

The simulation is based on the battery and sensor subsystem, in which the lithium-ion battery block serves as the energy source and voltage and current sensors gather data in real time. Using the control techniques outlined by Kurkin [1] and Liu [3], the controller processes these inputs to keep voltage and current within safe working limits. In accordance with Pisani Orta's [2] estimation techniques, the SOC estimate block uses current integration with voltage feedback to provide reliable SOC values between 51.8% and 51.95%.

Whether the system is in charging or discharging mode is determined by the state selection and protection subsystem. When dangerous situations like overvoltage or overcurrent are detected, the model automatically triggers a relay protection system based on sensor data. This reflects the safety ideas put out by Sun [4] and Boozula [5] and guarantees safe battery isolation and avoids possible fire threats. The logic preserves system integrity and user safety by ensuring dependable functioning even in the event of a breakdown.

Data such as voltage, current, SOC, and system status are shown in real time in the display and monitoring area. According to simulation findings, current flow was well-regulated in both operating modes, and the voltage was constant between 48 and 50 V. The accuracy and safety dependability of the model were confirmed by the protection logic's effective response to anomalous situations. All things considered, the simulation confirms that the suggested architecture is a workable and safe BMS framework that complies with the contemporary EV safety measures mentioned by Chow [6] and Huhn [7].



V. SIMULATION RESULT

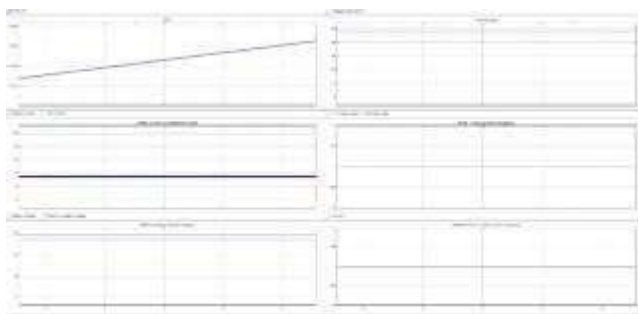


Fig.3. MATLAB simulation results showing charging characteristics of the proposed BMS including SOC, voltage, and current profiles.

Figure 3 shows the Battery Management System's (BMS) MATLAB/Simulink charging operation simulation, which demonstrates the system's capacity to maintain safe and regulated charging characteristics. The charge control algorithm successfully controls current flow into the battery without overshoot or instability, as seen by the State of Charge (SOC) graph's steady rise from 51.8% to 51.95%. The system prevented overvoltage and maintained steady functioning during the charging period, as evidenced by the voltage waveform's consistency between 48 and 50 V. The current waveform closely matched the reference signal, confirming the control loop's dependability and the charging algorithm's and load demand's correct synchronization.

The logic's capacity to continue operating without oscillations or inadvertent mode switching was confirmed by the mode selection block's stability during the charging phase. The process remained within specified voltage and current thresholds, as evidenced by the safety subsystem and relay not activating under typical charging conditions. This demonstrates how the BMS successfully avoids battery stress by preserving energy equilibrium and reducing heat production. This mode's accuracy and stability align with the charge-control and SOC estimate methods put forward by Kurkin [1] and Pisani Orta [2].

The outcomes further show that the MATLAB-based BMS effectively manages energy ingress while maintaining electrical and thermal safety. Accurate SOC tracking and voltage stability together demonstrate the system's ability to fend off deterioration and prolong battery life. The findings corroborate enhanced protection integration frameworks proposed by Huhn [7] and are in close agreement with Liu's description of real-time BMS behavior in EVs [3]. Therefore, the simulation validates the effective use of a strong, fire-safe charging algorithm that guarantees operational safety efficiency.



Fig.4. MATLAB simulation results showing discharging characteristics and protection response of the proposed BMS model.

Figure 4 shows the discharging process, which assesses the BMS's ability to preserve system stability and safeguard the battery while powering the load. As the SOC drops, the voltage measurement graph shows a steady reduction, which is indicative of typical energy output. The battery current nearly matched the reference current during the discharging phase, demonstrating the accuracy of the current control loop. Smooth power flow and effective load response were ensured by the system's successful maintenance of current within safe bounds. The model's capacity to efficiently control energy release under various load situations is demonstrated by the overall voltage and SOC behavior, which show predictable discharge dynamics.

Based on voltage and current thresholds, the state selection subsystem reliably identified changes between discharging and standby modes. The controller logic managed load variation without momentary spikes, as evidenced by the smooth switching response. During brief discharge cycles, the SOC value stayed constant, demonstrating good stability and efficiency. The safe discharge management strategies put forth by Boozula [5] and Sun [4], which stress the need to maintain constant voltage levels in order to prevent deep discharge or overcurrent situations, are compatible with this performance.

During this mode, overcurrent and fault scenarios were simulated in order to verify the protective logic. In order to prevent short circuits and potential fire occurrences, the relay was immediately triggered when the current over a certain threshold, isolating the battery from the load. This isolation verifies the model's efficient safety reaction, guaranteeing that the battery won't sustain any long-term harm. The electrical and thermal mitigation techniques covered by Chow [6] and Huhn [7] are consistent with the simulated protection. Overall, the discharge simulation confirms that the suggested BMS is a perfect framework for safe EV battery operation as it can distribute energy consistently, maintain system balance, and offer quick protective response in hazardous situations.



VI. CONCLUSION

A MATLAB/Simulink-based Battery Management System (BMS) for Electric Vehicles (EVs) with integrated charge monitoring and fire safety features was provided in this study. The created model demonstrated consistent voltage and current management, dependable State of Charge (SOC) prediction, and effective fault isolation while precisely simulating charging and discharging modes. The findings confirm that, in accordance with system-level safety strategies described by Kurkin [1] and Liu [3], the suggested BMS guarantees operational safety by preventing overcharge, overdischarge, and thermal instability.

An extra layer of security is provided by the fire prevention logic, which automatically isolates the circuit in the event of a malfunction or unusual temperature. In line with the thermal runaway prevention strategies covered by Sun [4] and Boozula [5], this process improves overall battery safety. As stressed in the previous research by Huhn [7], the simulation findings further verified that the BMS maintains a controlled charge-discharge profile, guaranteeing dependability, extended battery life, and protection from electrical problems.

The research establishes the foundation for future hardware implementation and real-world testing, even if its primary focus is simulation validation. To further improve system efficiency and safety, future research may include better cooling techniques, machine learning-based defect prediction, and Internet of Things-based remote diagnostics. In line with the path of next-generation sustainable electric transportation solutions, the study's findings advance safe and intelligent EV battery management frameworks.

VII. REFERENCES

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