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EV BMS with Charging Monitoring & Fire Protection

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Abstract: This paper presents the design and implementation of an Electric Vehicle (EV) Battery Management System (BMS) with integrated charge monitoring and fire protection. The increasing adoption of EVs has highlighted the need for advanced battery safety and performance systems, particularly for lithium-ion battery packs which are highly sensitive to electrical and thermal stresses.

The proposed system continuously monitors key parameters such as voltage, current, temperature, and state of charge (SOC) using a microcontroller-based architecture.

Advanced algorithms are implemented for charge estimation and cell balancing to ensure uniform energy distribution across battery cells. Additionally, thermal management is enhanced through temperature sensing and fire detection modules that identify abnormal conditions such as overheating or gas emission.In hazardous situations, the system activates protection mechanisms including relay-based isolation, alarm systems, and emergency shutdown.

The system also supports real-time display and optional IoT-based remote monitoring for improved user awareness and control.Experimental results demonstrate improved safety,efficient charge utilization, and reliable performance under various operating conditions. The proposed BMS provides a scalable and cost-effective solution for next-generation EV battery systems.

Index Terms: Electric Vehicle, Battery Management System, Charge Monitoring, Fire Protection, Thermal Runaway, Lithium-ion Battery

I. INTRODUCTION

Electric vehicles (EVs) are rapidly transforming the transportation industry due to their environmental benefits and energy efficiency. At the core of EV technology lies the lithium-ion battery, which serves as the primary energy storage system. However, these batteries are highly sensitive to operational conditions such as overcharging, deep discharging, excessive current flow, and temperature variations.Failure to manage these parameters can lead to performance degradation, reduced lifespan, and serious safety hazards including thermal runaway and fire.

Therefore, an efficient Battery Management System (BMS) is essential for monitoring and controlling battery operation.Charge monitoring plays a crucial role in maintaining optimal battery performance by ensuring that charging and discharging occur within safe limits. It also helps in estimating the State of Charge (SOC), which is critical for determining the remaining battery capacity.

In addition to electrical parameters, thermal management is equally important. Elevated temperatures can accelerate chemical reactions inside the battery, increasing the risk of fire. Hence, integrating fire protection mechanisms such as temperature sensing and gas detection enhances system safety.

This paper proposes a comprehensive EV BMS with charge monitoring and fire protection features. The system combines real-time monitoring, intelligent control, and safety mechanisms to ensure reliable and efficient battery operation.

II. LITERATURE SURVEY

Battery management systems have been extensively studied to improve the safety and efficiency of EV batteries. Plett **(2015)** introduced advanced battery modeling and state estimation techniques, which form the foundation for SOC and State of Health (SOH) calculations. Hannan et al. **(2017)** reviewed various energy management strategies in EVs and emphasized the importance of accurate monitoring systems for improving battery efficiency and lifespan. Their work highlighted the role of intelligent BMS in optimizing energy utilization**.**

Pesaran**(2001)** discussed battery thermal management systems and their significance in maintaining safe operating temperatures. The study demonstrated that proper thermal control can significantly reduce the risk of battery failure.

Feng et al. **(2018)** analyzed thermal runaway mechanisms in lithium-ion batteries and proposed early detection techniques to prevent catastrophic failures. Their research emphasized the importance of integrating thermal sensors and protective systems in BMS design.

Recent advancements include IoT-based monitoring systems, which enable real-time tracking of battery parameters and remote diagnostics. These systems improve user accessibility and predictive maintenance capabilities.

The proposed system builds upon these studies by integrating charge monitoring with fire protection mechanisms, providing a comprehensive safety solution.

III. SYSTEM OVERVIEW

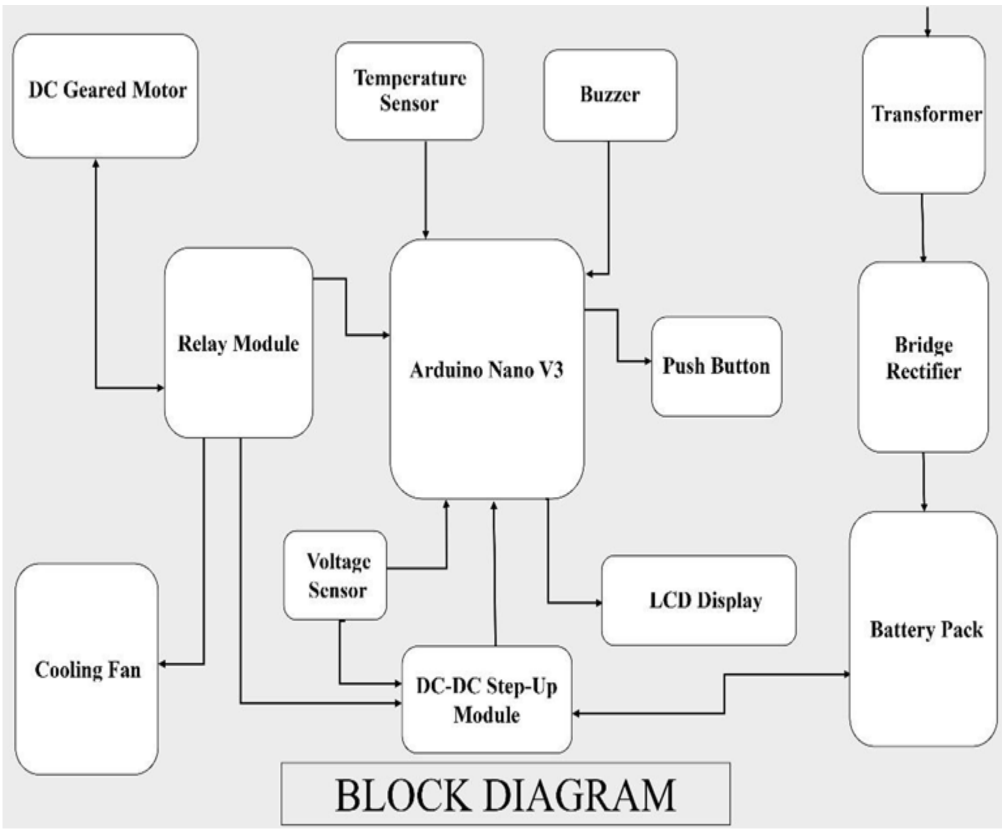

Fig 1: Block diagram

The proposed system consists of the following major components:

- Lithium-ion battery pack
- Sensing unit (voltage, current, temperature
- sensors)
- Microcontroller-based control unit
- Fire detection and protection system
- Relay-based isolation circuit
- Display and monitoring interface

The battery pack serves as the energy source, while sensors continuously measure key parameters. The microcontroller processes sensor data and calculates SOC using predefined algorithms.

The fire protection system includes temperature and gas sensors to detect abnormal conditions. If unsafe conditions are detected, the control unit triggers relays to disconnect the battery and activates alarms.

A display unit provides real-time monitoring, and optional IoT modules enable remote supervision through mobile or web applications

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IV. METHODOLOGY

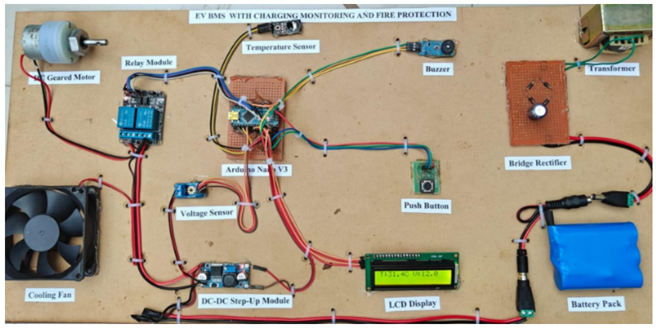

Fig. 2. System photo

1) Lithium-Ion Battery Pack

A multi-cell configuration (3S/4S) is used to achieve the required voltage and capacity. Proper cell balancing is necessary to ensure uniform performance.

2) Battery Management System (BMS)

The BMS monitors individual cell voltages, current flow, and temperature. It ensures safe operation by implementing protection against:

- Overcharging
- Over-discharging
- Overcurrent
- Short circuit

3) State of Charge (SOC) Estimation

SOC is calculated using voltage-based and current integration (coulomb counting) methods. This helps in determining battery capacity and remaining energy.

4) Voltage and Current Sensors

Sensors such as voltage dividers and current sensors (ACS712) are used for accurate measurements. These inputs are fed into the microcontroller for processing.

5) Temperature Monitoring

Temperature sensors (NTC thermistor or LM35) continuously monitor battery temperature. If temperature exceeds safe limits (typically 35°C), protective actions are initiated.

6) Microcontroller Unit

Arduino NAVO V3is used as the control unit. It processes sensor data, executes algorithms, and controls relays and alarms.

7) Protection Mechanism

Relay modules disconnect the battery during unsafe conditions. Buzzers and LEDs provide alerts to users.

8) Display Interface

A 16×2 LCD or OLED display shows real-time data such as:

- Voltage
- Current
- Temperature
- SOC percentage.

V. RESULT

The system was tested under various operating conditions to evaluate performance.

Observations:

- Accurate monitoring of voltage (±1% error)
- Stable current measurement
- Reliable temperature detection
- Effective SOC estimation

- Immediate response to abnormal conditions

Performance Analysis:
- Overcharging conditions were successfully detected and prevented
- Temperature rise beyond threshold triggered automatic shutdown

VI. CONCLUSION

The proposed EV Battery Management System with Charge Monitoring and Fire Protection provides a robust solution for improving the safety and efficiency of lithium-ion battery systems.
By integrating electrical and thermal monitoring with intelligent control mechanisms, the system effectively prevents hazardous conditions such as overcharging and thermal runaway. The inclusion of fire detection features further enhances safety, making the system suitable for real-world EV applications.

VII. ACKNOWLEDGMENT

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We also thank all faculty members and laboratory staff for their assistance during the development and testing of this project

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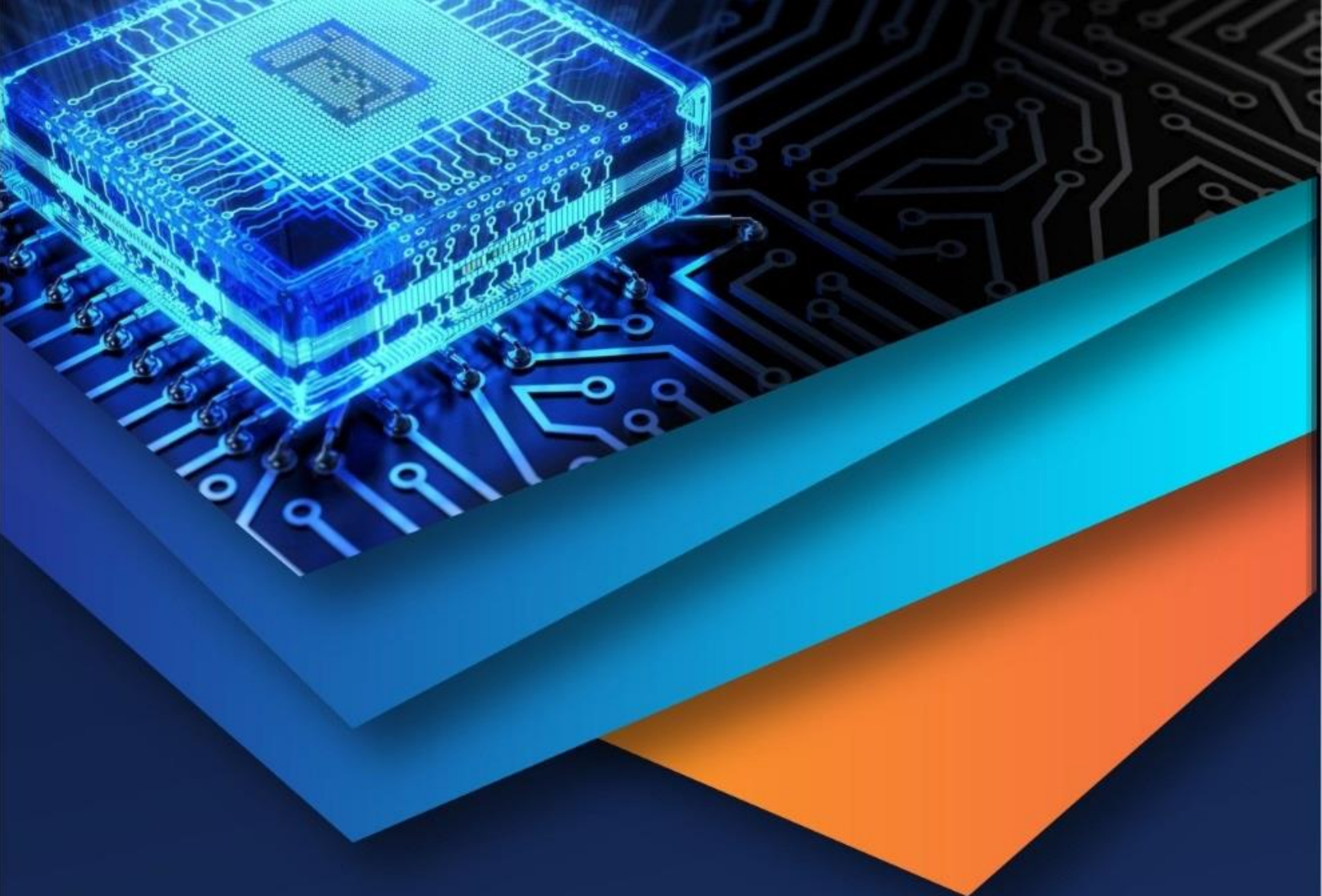

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