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ELECTRICAL VEHICLE BMS WITH CHARGE MONITOR &FIRE PROTECTION USING STM-32

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ABSTRACT:

The rapid growth of electric vehicles (EVs) has increased the demand for efficient and safe battery management systems (BMS). This paper presents the design and implementation of an EV battery management system with integrated charge monitoring and fire protection using an STM32 microcontroller. The system continuously monitors battery parameters such as voltage, current, and temperature to ensure safe operation. A temperature sensor is used for real-time thermal monitoring, and protective actions are triggered when unsafe conditions occur. The system supports both fast and slow charging modes, optimizing performance while maintaining safety. In case of overheating, the system activates a relay-based isolation mechanism and alerts the user through a buzzer. Experimental results demonstrate accurate monitoring, efficient charge control, and reliable fire protection. The proposed system offers a cost-effective and scalable solution for EV battery safety and management.

KEYWORDS:

BATTERY MANAGEMENT SYSTEM (BMS), ELECTRIC VEHICLES (EV), STM32, CHARGE MONITORING, FIRE PROTECTION, LITHIUM-ION BATTERY, EMBEDDED SYSTEMS.

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INTRODUCTION

The global transition toward sustainable and eco-friendly transportation has significantly accelerated the adoption of electric vehicles (EVs) as an alternative to conventional internal combustion engine vehicles [1]. Governments and organizations worldwide are promoting EVs to reduce greenhouse gas emissions and dependence on fossil fuels [2]. At the core of every electric vehicle lies a rechargeable battery system, most commonly lithium-ion batteries, which offer high energy density and long cycle life [3]. However, these batteries are highly sensitive to operating conditions such as voltage, current, and temperature, making proper management essential for safe and efficient operation [4].

A Battery Management System (BMS) is a critical component in EVs that ensures the safe operation, performance optimization, and longevity of the battery pack [5]. The BMS continuously monitors key parameters such as voltage, current, and temperature, and prevents unsafe conditions like overcharging, deep discharging, and overheating [6]. In addition to safety, it also improves battery efficiency and provides accurate information about the battery status to the user [7]. Without an effective BMS, battery systems can degrade rapidly and may pose serious safety risks, including thermal runaway and fire hazards [8].

Charge monitoring is one of the fundamental functions of a BMS, as it helps in determining the charging state and controlling energy flow within the battery system [9]. Modern BMS designs incorporate both fast and slow charging modes to balance charging speed and battery safety. Fast charging enables quick energy replenishment but may increase temperature, whereas slow charging ensures stable and safer operation. Accurate monitoring of these charging modes is essential to maintain optimal performance and prevent damage to the battery [10].

In addition to charge monitoring, fire protection has become a critical requirement in EV battery systems due to the increasing incidents of battery-related hazards. Elevated temperatures can lead to thermal runaway, resulting in catastrophic failures if not addressed promptly. Therefore, integrating temperature sensing, automatic disconnection mechanisms, and alert systems is essential for enhancing battery safety. In this work, an STM32-based BMS is proposed, which combines real-time monitoring, intelligent charge control, and an effective fire protection mechanism, providing a reliable and cost-effective solution for electric vehicle applications

MATERIALS AND METHODS:

The proposed system is developed using key hardware components including an STM32 microcontroller, voltage sensor, current sensor, temperature sensor (DHT11), relay module, LCD display, and buzzer. The STM32 microcontroller acts as the central control unit, processing sensor data and executing control algorithms. The voltage and current sensors measure battery parameters, while the temperature sensor monitors thermal conditions. The relay is used to disconnect the battery during unsafe conditions, and the LCD provides real-time display of system parameters.

The methodology involves continuous monitoring of battery parameters and intelligent decision-making based on predefined thresholds. The system collects voltage, current, and temperature data and processes it using embedded software. Based on these inputs, the system identifies charging modes (fast or slow) and ensures optimal energy transfer. During charging, the system adjusts operation to maintain safe conditions, while during discharging, it regulates load to prevent excessive stress on the battery.

A fire protection mechanism is integrated into the system to enhance safety. When the temperature exceeds a critical threshold, the system triggers an alert using a buzzer and disconnects the battery through a relay. The embedded software ensures real-time response and reliable operation. This integrated hardware-software approach enables efficient battery management, improved safety, and enhanced system performance.

RESULTS:

The proposed Battery Management System (BMS) was tested under different operating conditions to evaluate its performance in monitoring and protecting the battery. The system continuously measured key parameters such as voltage, current, and temperature using appropriate sensors integrated with the STM32 microcontroller. The results showed that the system was able to accurately track battery conditions in real time and display them on the LCD interface. This enabled effective monitoring of the battery status during both charging and discharging operations, ensuring improved reliability and user awareness.

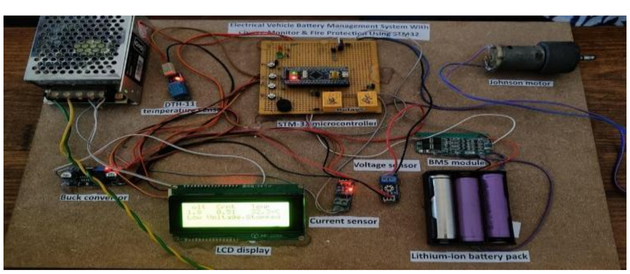

FIG. 1: COMPLETE CIRCUITS CHEMATIC OF THE PROPOSED BMS.

The charging performance of the system was analyzed under both fast charging and slow charging modes. During fast charging, the system allowed higher current flow for rapid energy replenishment while continuously monitoring temperature to prevent overheating. In slow charging mode, the system maintained a controlled and stable charging process with minimal thermal stress. The transition between charging modes was handled efficiently by the controller based on real-time sensor inputs. The system demonstrated stable operation in both modes, ensuring safe and optimized charging performance under varying conditions.

The fire protection mechanism was validated by testing the system under elevated temperature conditions. When the battery temperature exceeded the predefined threshold, the system successfully activated safety measures including triggering a buzzer alert and disconnecting the battery using a relay. This prevented further temperature rise and ensured system safety. Overall, the results confirmed that the proposed BMS provides accurate monitoring, efficient charge control, and reliable protection against overheating, making it suitable for electric vehicle and battery safety applications.

DISCUSSION:

The developed Battery Management System (BMS) prototype demonstrates an effective integration of hardware components for real-time monitoring and protection of lithium-ion batteries. As shown in the experimental setup, the system consists of an STM32 microcontroller, voltage and current sensors, a DHT11 temperature sensor, relay module, LCD display, and a lithium-ion battery pack. The coordinated operation of these components enables continuous monitoring of critical battery parameters, ensuring safe and efficient performance. The LCD display provides real-time visualization of voltage, current, state of charge (SoC), and temperature, improving user awareness and system transparency.

The charge monitoring functionality of the system performs reliably under different operating conditions. The integration of voltage and current sensors allows accurate measurement of battery parameters, which are processed by the STM32 microcontroller. Based on these inputs, the system effectively distinguishes between charging and discharging states and manages energy flow accordingly. The presence of both fast and slow charging control ensures flexibility in operation, balancing charging speed with battery safety. The inclusion of a DC power supply and controlled switching elements further enhances system stability during operation.

A key strength of the proposed system is its fire protection mechanism. The DHT11 temperature sensor continuously monitors battery temperature, and when it exceeds a predefined threshold, the system triggers protective actions such as activating a buzzer and disconnecting the battery using a relay. This rapid response helps prevent thermal runaway and potential hazards. The hardware implementation demonstrates that the system can reliably detect abnormal temperature conditions and respond in real time, ensuring enhanced safety for battery operation.

Overall, the prototype highlights a cost-effective and practical solution for EV battery management. The modular design allows easy integration and scalability for different battery configurations. However, the system can be further improved by incorporating more precise temperature sensors, advanced state estimation algorithms, and communication interfaces for remote monitoring. Despite these limitations, the proposed BMS successfully achieves its objectives of monitoring, control, and protection, making it suitable for small-scale EV and battery safety applications

CONCLUSIONS:

This work presents the design and implementation of an Electrical Vehicle Battery Management System (BMS) with charge monitoring and fire protection using an STM32 microcontroller. The system successfully integrates multiple sensors and control components to continuously monitor critical battery parameters such as voltage, current, and temperature. The real-time data acquisition and processing enable effective supervision of battery operation, ensuring safe and reliable performance.

The proposed system demonstrates efficient charge management by supporting both fast and slow charging modes. It maintains optimal operating conditions by regulating energy flow and preventing unsafe situations such as overcharging and excessive current. The inclusion of an LCD display enhances user interaction by providing real-time information about battery status, improving system transparency and usability.

A significant contribution of this work is the implementation of a fire protection mechanism. The system effectively detects abnormal temperature rise and responds immediately by disconnecting the battery and activating an alert system. This feature enhances safety by preventing thermal runaway and potential hazards associated with lithium-ion batteries.

Overall, the developed BMS offers a cost-effective, efficient, and reliable solution for battery monitoring and protection in electric vehicle applications. The system can be further enhanced by incorporating advanced algorithms, wireless communication, and improved sensing techniques, making it suitable for future smart and scalable EV systems

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