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Research Article

IoT – Based Battery Management System for EVs

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ABSTRACT

Electric Vehicles (EVs) are gaining widespread adoption due to their positive impact on the environment and cost-effectiveness. Despite these advantages, they still face critical issues such as sudden battery drain and, in rare cases, battery fires, which can affect their reliability and safety. To help mitigate these problems, we have developed a smart Battery Management System (BMS) based on the ESP32 microcontroller and Internet of Things (IoT) technology. This system enables continuous monitoring of essential battery parameters like voltage, current, and temperature in real time. The setup incorporates various sensors, including a B25 voltage sensor, ACS712 current sensor, a flame sensor, MQ2 smoke sensor, and a temperature sensor. These components are connected to the ESP32, which collects and processes the data. The processed information is then transmitted to a mobile application created using MIT App Inventor. Through this app, users can view real-time readings such as voltage, current, and temperature, along with instant alerts in case of smoke or flame detection. The prototype successfully demonstrates remote battery condition monitoring and early fault detection, providing timely notifications of abnormal activity. This solution not only supports better battery performance and lifespan but also greatly enhances the safety of electric vehicles by offering early warning systems and real-time diagnostics

Keywors: diagnostics, temperature, MIT, lifespan

INTRODUCTION

The global shift from traditional fossil fuel vehicles to Electric Vehicles (EVs) is rapidly gaining momentum, driven by increased environmental awareness and the need for cleaner, more sustainable modes of transportation. Although EVs provide several key benefits—including reduced greenhouse gas emissions, lower running costs, and higher energy efficiency—they also bring forth new technical challenges, especially in terms of ensuring battery safety and maintaining optimal performance.

One of the most pressing concerns in EV technology is the unpredictable nature of battery behavior. EV users often experience faster-than-expected battery drainage, and in some extreme cases, battery overheating or fires have been reported. These issues not only pose risks to user safety but also impact the reliability and lifespan of the vehicle. Traditional Battery Management Systems (BMS) are typically limited to localized control and diagnostics, lacking remote monitoring capabilities that can offer real-time insights or early warnings.

To overcome the mentioned challenges, this project introduces an IoT-enabled Battery Management System (BMS) utilizing the ESP32 microcontroller for real-time tracking of vital battery metrics such as voltage, current, temperature, smoke presence, and flame detection. The system employs a combination of sensors, including the B25 voltage sensor, ACS712 current sensor, MQ2 smoke detector, flame sensor, and a temperature sensor. Together, these components form a smart and responsive BMS capable of identifying irregularities early and mitigating potential risks.

The data collected from the sensors is processed by the ESP32 and wirelessly transmitted to a dedicated mobile application, designed using MIT App Inventor. This application features an intuitive interface that allows users to monitor the battery's condition in real time, access remote diagnostics, and receive instant alerts and visual feedback on any abnormal behavior.

This approach aims to improve EV battery efficiency, enhance safety, and empower users with actionable insights through IoT integration. The prototype demonstrates the viability of this system and its potential impact on future

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EV technology, where smart monitoring and early detection play a crucial role in overall vehicle performance and safety.

METHODS

The developed system is an IoT-based Battery Management System (BMS) for Electric Vehicles (EVs), designed to enhance battery safety, performance, and real-time monitoring using the ESP32 microcontroller. The battery in this setup is connected to an L298N motor driver, which powers a 12V DC motor acting as the load. To monitor the battery voltage, a B25 voltage sensor is used. This sensor provides analog voltage readings to the ESP32. If the battery voltage falls below 12V, the system interprets this as a low-power condition and sends a signal to the motor driver to turn off the motor, thus protecting the battery from over-discharge. Once the voltage rises above 12V, the motor is automatically turned back on, resuming normal operation.

To monitor the current flowing through the battery to the motor, an ACS712 current sensor is integrated. This sensor helps track how much current the load is drawing, allowing analysis of battery load behavior over time. Temperature is monitored using the DS18B20 digital temperature sensor, which provides accurate temperature readings to the ESP32 via the 1-Wire protocol. If the battery temperature exceeds 31°C, the system activates a cooling fan connected to a digital output of the ESP32. The fan remains on until the temperature drops below 31°C, ensuring that the battery remains within a safe thermal range.

In addition to voltage, current, and temperature monitoring, the system includes safety sensors to detect potential hazards. A flame sensor is used to detect any presence of open flame or spark near the battery area, acting as an early fire detection mechanism. Alongside it, the MQ2 smoke sensor monitors the presence of gases like smoke, LPG, and methane, which can be indicators of overheating or internal cell damage in the battery. These safety sensors provide essential data to prevent dangerous scenarios like battery fires or explosions.

All sensor data—voltage, current, temperature, flame, and smoke—is continuously collected by the ESP32 and transmitted wirelessly to a custom mobile application developed using MIT App Inventor. The app provides real-time display of sensor values and system status (such as motor ON/OFF and fan ON/OFF). It also serves as an alert system, notifying the user if any parameter goes beyond the safe threshold, such as low voltage, high temperature, smoke presence, or flame detection. This real-time monitoring and alert system allow EV users to remotely observe the condition of their battery and take preventive actions promptly, making the vehicle more reliable, efficient, and safer.

RESULTS

The working of this IoT-based Battery Management System revolves around real-time monitoring and intelligent control of various battery parameters using the ESP32 microcontroller. When the system is powered on, the ESP32 begins collecting data from all connected sensors. The B25 voltage sensor constantly measures the battery voltage, providing analog input to the ESP32. Based on the voltage readings, if the voltage falls below 12V, the ESP32 triggers the L298N motor driver to turn off the 12V DC motor, effectively disconnecting the load to prevent battery over-discharge. When the voltage returns to a safe level (above 12V), the motor is turned back on, allowing normal operation to resume.

Simultaneously, the ACS712 current sensor measures the current being drawn by the motor. This data helps monitor the load on the battery, offering insights into energy usage and potential abnormal power consumption. The DS18B20 temperature sensor continuously reads the temperature around the battery area. If the temperature exceeds 31°C, the ESP32 activates a cooling fan to reduce heat. The fan automatically turns off once the temperature drops below the threshold, maintaining optimal battery temperature.

For enhanced safety, the system is equipped with a flame sensor and an MQ2 smoke sensor. The flame sensor detects any presence of fire or spark, and the MQ2 sensor detects smoke or gas emissions such as methane or LPG, which could indicate overheating or internal damage in the battery. If any of these hazards are detected, the ESP32 can trigger alerts and take safety actions.

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All sensor data is transmitted via the ESP32's built-in Wi-Fi module to a mobile application developed using MIT App Inventor. The app displays real-time values of voltage, current, temperature, smoke, and flame detection status. It also visually shows the status of the motor and the cooling fan, and issues alerts if any values go beyond defined safety limits. This system ensures that the user is constantly informed about the battery's health and environmental conditions, allowing proactive decisions to be made to avoid damage or hazards. Thus, the project effectively combines sensor-based monitoring, smart control logic, and IoT communication to create a reliable and intelligent battery management solution for electric vehicles.

DISCUSSION

In this project, an IoT-based Battery Management System for Electric Vehicles (EVs) has been successfully designed and implemented using the ESP32 microcontroller. The system continuously monitors critical battery parameters such as voltage, current, temperature, smoke, and flame, using sensors like the B25 voltage sensor, ACS712 current sensor, DS18B20 temperature sensor, MQ2 smoke sensor, and a flame sensor. Based on real-time sensor data, the system performs intelligent actions such as turning off the motor when voltage drops below 12V, activating a cooling fan when the temperature exceeds 31°C, and issuing alerts when potential safety threats like smoke or fire are detected.

All readings and system statuses are transmitted wirelessly to a custom mobile app, allowing users to remotely monitor their EV battery's health, performance, and safety. This enhances both efficiency and reliability, while also helping prevent dangerous situations such as battery overheating or failure. By using low-cost, readily available components and an open-source mobile platform, the system demonstrates a practical and scalable solution for EV battery monitoring. Overall, this smart BMS improves battery utilization, supports preventive maintenance, and contributes to the safer and more intelligent operation of electric vehicles.

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