IOT Based Electrical Vehicle Battery Management System with Charge Monitor and Fire Protection

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ABSTRACT

The rapid adoption of electric vehicles (EVs) has increased the need for efficient battery management systems to ensure safety, performance, and longevity. Conventional EV battery monitoring systems often lack remote accessibility and real-time protection mechanisms. This research presents an IoT-based Battery Management System (BMS) integrating an ESP8266 microcontroller, solar panel, battery, current sensor, IoT cloud, and fire detection sensors. The system continuously monitors battery voltage, current, and temperature, providing real-time data to a cloud platform for remote monitoring. A fire detection module is integrated to trigger alarms and prevent catastrophic battery failures. The ESP8266 serves as the central controller, processing sensor inputs and managing charge cycles. Solar panel integration enables renewable energy monitoring and partial charging. Data is transmitted to the IoT cloud for visualization and alert notifications. The system employs intelligent thresholds for overcharge, discharge, and temperature limits. Experimental results demonstrate that the proposed system enhances battery efficiency and safety. It offers real-time monitoring capabilities accessible via smartphones or web interfaces. Alerts for abnormal conditions prevent fire hazards and battery degradation. The architecture supports scalability for multiple EV battery packs. The IoT platform enables historical data analysis for predictive maintenance.

The system reduces human intervention while increasing operational reliability. Energy consumption is optimized through intelligent charge monitoring. The proposed method is cost-effective and easy to implement. Overall, the project demonstrates a reliable, smart, and secure solution for EV battery management.

INTRODUCTION

Electric vehicles are increasingly used worldwide due to environmental concerns and rising fossil fuel costs. Efficient battery management is crucial for extending battery life, ensuring safety, and maintaining vehicle performance. Traditional battery monitoring methods rely on manual inspection or centralized systems that cannot provide real-time alerts. IoT-based systems offer a solution by enabling remote monitoring, automatic control, and real-time notifications. In this project, an ESP8266 microcontroller is utilized to interface with sensors and manage data processing. The battery pack is monitored through voltage, current, and temperature sensors. A solar panel is integrated to support renewable energy charging and enhance energy efficiency. Fire sensors are included to detect overheating and prevent potential fire hazards. Data collected from the sensors is transmitted to the IoT cloud, enabling real-time monitoring on smartphones or computers. Threshold-based alarms are implemented to notify users of abnormal conditions. The system optimizes battery charging cycles, avoiding overcharge and deep discharge situations. Using IoT cloud services ensures historical data logging for analysis and maintenance planning. The proposed BMS is scalable and can be adapted for multiple EV battery configurations. It enhances safety, reduces operational risks, and provides actionable insights for users. Renewable energy integration improves sustainability. The system is user-friendly and cost-effective. It leverages modern IoT technologies for smart vehicle applications. The combination of sensors, microcontroller, and cloud ensures robust performance. The project demonstrates an innovative approach to EV battery management. Overall, it bridges the gap between safety, efficiency, and real-time monitoring for EV users.

LITERATURE SURVEY

Battery Management Systems (BMS) are vital for the safe and efficient operation of electric vehicles. Early research focused on basic voltage and current monitoring using wired systems. These systems lacked intelligence and remote monitoring capabilities. With the advent of IoT, researchers began integrating microcontrollers and wireless communication modules for real-time monitoring. Studies using ESP8266 and Arduino have shown that low-cost microcontrollers can efficiently collect sensor data and transmit it to cloud platforms. Several works have explored the integration of renewable energy sources, such as solar panels, to support EV charging. This reduces dependency on grid power and improves sustainability. Fire detection in EVs has been studied extensively to prevent catastrophic battery failures caused by thermal runaway. Current sensor-based monitoring ensures accurate detection of overcurrent or short circuits, enhancing battery protection. Machine learning algorithms have also been incorporated in some systems to predict battery health and life expectancy. IoT cloud platforms such as ThingSpeak, Blynk, and AWS IoT have been used for remote data visualization and alert notifications. Research shows that combining sensor data with cloud computing improves operational reliability. Safety measures, including automatic cutoff in case of abnormal readings, have been widely discussed. Some works have focused on multi-cell battery management, addressing balancing issues among cells. Communication protocols like MQTT and HTTP are frequently used for lightweight IoT data transfer. Energy efficiency studies show that intelligent charge-discharge cycles extend battery life. Overcharge and deep discharge are major concerns that are mitigated through threshold-based control. Historical data logging allows predictive maintenance and reduces unexpected failures. Fire and temperature sensors provide an additional layer of safety for high-capacity batteries. Many studies highlight the cost-effectiveness of ESP8266-based solutions for small-scale EVs. Battery monitoring systems integrated with mobile applications improve user accessibility. Researchers emphasize the need for real-time alerts to prevent safety hazards. Cloud-based monitoring allows multiple EVs to be managed simultaneously. Solar-assisted charging reduces overall operational costs. Fire hazard prevention improves user confidence and reliability. Sensor calibration and proper threshold setting are critical for accurate monitoring. Data visualization enhances decision-making for fleet operators. Modern BMS designs focus on scalability, safety, and integration with renewable energy. Overall, literature confirms that IoT-enabled BMS systems are the future for smart EV battery management.

RELATED WORK

Several researchers have proposed IoT-based solutions for EV battery monitoring using ESP8266 and Arduino platforms. Early designs focused on voltage and current sensing without remote monitoring. Later works integrated cloud platforms to allow real-time visualization and alerts. Some systems included solar-assisted charging for sustainable energy usage. Fire detection sensors were rarely incorporated in traditional setups. Modern approaches combine current, voltage, and temperature monitoring with cloud notifications. Machine learning has been explored for predictive maintenance. MQTT and HTTP protocols are commonly used for data transfer. Studies indicate that threshold-based alarm systems effectively prevent battery hazards. The proposed project improves on existing work by integrating fire protection, IoT cloud monitoring, and renewable energy support.

EXISTING SYSTEM

Traditional EV battery management systems monitor basic parameters like voltage and current using wired sensors. These systems often rely on manual observation or dashboard indicators. Many systems do not support remote monitoring or cloud-based alerts. Fire hazards are usually managed through general thermal fuses or circuit breakers. Battery overcharging or deep discharge issues are common due to lack of automated control. Renewable energy integration is minimal or absent. Most systems do not provide historical data analysis for predictive maintenance. User accessibility is limited, and maintenance requires physical inspection. Safety protocols are reactive rather than proactive. Charging modules are often unoptimized, causing energy wastage. Sensor integration is basic, lacking intelligence for decision-making. Communication with external devices is limited or absent. Energy efficiency is not actively managed in conventional systems. Threshold settings are fixed and non-adaptive. Overcurrent conditions may damage battery packs due to delayed alerts. Data visualization is either local or unavailable. Remote notifications are not supported. Solar-assisted or green charging options are not considered. Fire prevention measures are limited to hardware fuses. Overall, existing systems provide fundamental monitoring but lack intelligence, remote control, and safety enhancements.

PROPOSED SYSTEM

The proposed IoT-based EV Battery Management System integrates an ESP8266 microcontroller as the central controller. Voltage, current, and temperature sensors continuously monitor the battery pack. A fire sensor detects overheating and triggers an alarm through the microcontroller. A solar panel is connected to support renewable energy charging. Sensor data is processed by the

ESP8266 in real time. Thresholds for overcharge, overcurrent, and temperature are programmed into the controller. When a parameter exceeds safe limits, the system disconnects the battery to prevent damage. Data is transmitted to the IoT cloud for visualization and remote monitoring. Mobile and web applications display real-time battery status and alerts. Historical data is logged in the cloud for predictive maintenance. The charging module optimizes charge cycles to improve battery life. Alerts are sent via notifications to users for preventive action. The system reduces human intervention and increases reliability. Overcurrent and short-circuit conditions are managed automatically. Fire hazards are mitigated through early detection and cutoff mechanisms. IoT cloud integration allows monitoring of multiple EVs simultaneously. Data visualization includes charge percentage, voltage, current, and temperature trends. Solar-assisted charging reduces dependency on grid electricity. The methodology ensures scalable, safe, and efficient battery management. Overall, the system provides a smart and secure solution for modern EVs.

SYSTEM ARCHITECTURE

HARDWARE REQUIREMENT

ARDUNIO

The Arduino Uno is a popular open-source microcontroller board built around the ATmega328P microcontroller. It comes equipped with 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, and a USB interface for programming and power. Operating at 5V, it can be powered through a USB connection or an external power supply ranging from 7 to 12 volts. The board is favored for its simplicity, reliability, and flexibility, making it a go-to choice for beginners, hobbyists, and educational projects. Programming is done using the Arduino IDE, which employs a user-friendly version of C/C++. Additional features include onboard LEDs, a reset button, and pin headers for easy interfacing with sensors, modules, and shields.

Communication with external devices is supported via UART, SPI, and I2C protocols. Its extensive open-source ecosystem offers rich resources, tutorials, and libraries, enabling applications in IoT, automation, robotics, and interactive systems.

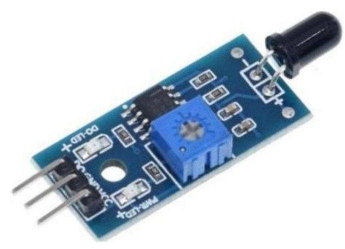
SOLAR PANEL

The solar panel serves as a renewable energy source to partially charge the EV battery, reducing dependency on the grid. It converts sunlight into electrical energy that is regulated and supplied to the battery pack. Integration with the BMS ensures safe and efficient charging without overloading the battery.

CURRENT SENSOR

The current sensor measures the flow of electrical current during battery charging and discharging. It provides crucial data to the microcontroller for monitoring overcurrent or short-circuit conditions. Accurate current measurement ensures safe operation and prevents damage to the battery system.

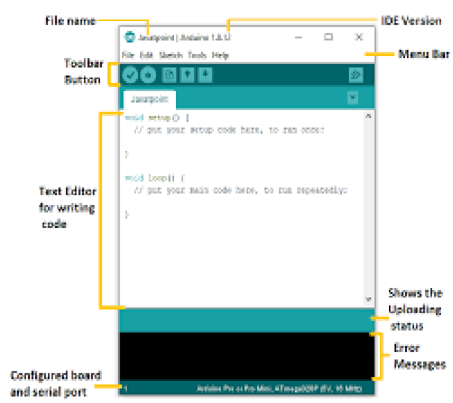
FIRE SENSOR



Fire sensors, also known as flame sensors or fire detectors, are devices designed to detect the presence of fire or flames. They play a critical role in fire prevention and safety systems, providing early warning to help mitigate potential damage. Different types of fire sensors employ various technologies to detect flames, smoke, or elevated temperatures. Below are details about some common types of fire sensors.

SOFTWARE REQUIREMENT

Arduino Software (IDE)



The Arduino IDE (Integrated Development Environment) is a simple, yet powerful platform used to program Arduino boards. It supports C and C++ programming languages with an easy-to-understand syntax tailored for microcontroller applications. The IDE provides a clean and intuitive interface where users can write, compile, and upload code directly to Arduino hardware. It includes a rich set of built-in libraries, making it easy to perform common tasks such as reading sensors, controlling LEDs, or operating motors. The integrated Serial Monitor allows real-time communication and debugging between the Arduino and the computer. Compatible with Windows, macOS, and Linux, the IDE is accessible across multiple platforms. Users can extend its functionality using the built-in Library Manager, which offers access to numerous community-developed libraries. As an open-source tool, the Arduino IDE can be customized to fit specific development needs.

CONCLUSION

The project successfully demonstrates an IoT-based EV battery management system integrating ESP8266, sensors, and cloud monitoring. It ensures real-time monitoring, fire protection, and optimized charging cycles. Renewable energy support and remote accessibility enhance efficiency and sustainability. Overall, the system improves safety, reliability, and battery life for electric vehicles.

FUTURE SCOPE

Future enhancements may include integrating AI for predictive battery failure detection. Multi-cell battery balancing algorithms can be implemented. Support for multiple renewable sources can be added for energy optimization. Advanced IoT analytics can improve fleet-level battery management and safety.

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