IOT-ENABLED BATTERY SAFETY SYSTEM FOR ELECTRIC VEHICLE

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ABSTRACT

As electric vehicles (EVs) become more prevalent, ensuring the safety and efficiency of their battery systems is critical. This project presents an IoT-based Battery Management System (BMS) designed specifically for electric vehicles, focusing on real-time charge monitoring and fire protection. The system continuously tracks key battery parameters such as voltage, current, temperature, and state of charge (SoC), using sensors integrated with a microcontroller. Data is transmitted to a cloud-based platform via IoT modules, enabling remote monitoring and alerts through a user-friendly mobile or web interface. In addition to charge monitoring, the system incorporates a fire detection mechanism by analyzing abnormal temperature rises or smoke levels using appropriate sensors. In the event of potential fire hazards, the system can trigger immediate alerts and activate preventive measures, such as disconnecting the power supply or activating a cooling mechanism. This smart BMS enhances the safety, reliability, and lifespan of EV batteries while providing users and manufacturers with valuable diagnostic information. The integration of IoT ensures accessibility, scalability, and proactive fault detection, making it a robust solution for modern EV battery management challenges.

Keywords: Electric Vehicle, Battery Management System, IoT, Fire Protection, State of Charge, Real-time Monitoring, Safety System, Smart BMS, Temperature Sensor, Cloud Connectivity

I. INTRODUCTION

With the global shift toward sustainable transportation, electric vehicles (EVs) have gained significant attention due to their low environmental impact and energy efficiency. As the heart of EV performance lies in the battery system, the need for an intelligent and reliable Battery Management System (BMS) has become more crucial than ever. The BMS is responsible for monitoring, controlling, and protecting the battery to ensure safe and optimal operation under various conditions. This smart BMS enhances the safety, reliability, and lifespan of EV batteries while providing users and manufacturers with valuable diagnostic information.

Traditional BMS solutions, though functional, often lack advanced features like remote monitoring, predictive diagnostics, and real-time alerts. By integrating Internet of Things (IoT) technologies, these limitations can be overcome. IoT enables seamless data transmission between the battery system and a centralized platform, allowing users or manufacturers to track battery health, performance metrics, and potential faults in real time from any location.

One of the most critical risks associated with EV batteries is the potential for overheating or fire due to overcharging, short circuits, or thermal runaway. To address this issue, the proposed system incorporates fire detection and prevention mechanisms. Temperature and smoke sensors are used to detect early signs of fire hazards, and immediate actions can be triggered, such as system shutdown or activating a cooling fan, to prevent accidents.

This project aims to develop a smart, IoT-enabled BMS that not only monitors charge levels and usage patterns but also enhances safety through proactive fire protection. The system uses a microcontroller to interface with sensors and IoT modules, offering real-time data visualization through cloud services. This approach ensures better battery health management, reduces the risk of failure, and improves the overall safety and reliability of electric vehicles.

II. EXISTING METHOD

Electric vehicles currently utilize conventional Battery Management Systems (BMS) to maintain the safety and efficiency of battery operations. These systems typically involve monitoring basic parameters such as voltage, current, and temperature to protect against overcharging, deep discharging, and short circuits. While they serve essential functions, these methods often lack real-time communication capabilities and advanced fault prediction.

Most existing BMS are embedded directly within the vehicle and do not support wireless data transfer or remote access. Additionally, fire protection mechanisms are either absent or limited to basic thermal cutoffs without any intelligent detection or automated alert system. This creates a gap in early hazard detection and fails to provide users with remote visibility or timely notifications in the event of battery anomalies.

To better understand the limitations of current systems, the following table compares conventional BMS with modern IoT-integrated solutions:

TABLE 1: *Comparison Between Traditional BMS and IoT- Based BMS.*

Feature	Traditional BMS	IoT-Based BMS (Proposed)
Parameter Monitoring	Voltage, Current, Temperature	Voltage, Current, Temperature, SoC, SoH
Remote Monitoring	Not Available	Available via Web/Mobile Interface
Data Logging	Limited or None	Cloud-based Real-Time Logging
Fire Detection	Basic Thermal Protection Only	Smoke & Temperature Sensors with Alerts
Predictive Fault Detection	Not Supported	Supported with Sensor Analytics
User Alerts	Not Available	Available through SMS/Email/App Notification
Scalability	Limited	High – Can be integrated into IoT networks

From the comparison, it is evident that traditional BMS are not well-equipped to handle the modern-day requirements of EV safety and efficiency. The absence of real-time monitoring and intelligent protection features increases the risk of system failure and user unawareness during emergencies. Hence, a shift toward IoT-based systems is necessary to overcome these challenges and enhance vehicle safety and performance.

III. PROPOSED METHOD

To overcome the limitations of conventional Battery Management Systems, this project proposes an IoT-based Smart Battery Management System (BMS) for Electric Vehicles. The system is designed to monitor battery charge levels, predict faults, and detect early signs of fire hazards using sensors and real-time cloud connectivity. The integration of IoT technology allows for data to be monitored remotely through a mobile application or web interface, offering enhanced safety, convenience and reliability.

The proposed system employs a microcontroller (such as Arduino or ESP32) to collect data from various sensors. These include voltage and current sensors to track the battery's performance, and temperature/smoke sensors for fire detection. This data is transmitted wirelessly to a cloud server using Wi-Fi or GSM modules. Users can access battery status, receive alerts, and take preventive measures remotely.

Additionally, if abnormal readings such as high temperature or voltage are detected, the system can automatically cut off the power supply or activate a safety mechanism (e.g., a cooling fan or buzzer). This approach ensures real-time monitoring, fast response to potential hazards, and detailed diagnostics for predictive maintenance. The system is designed to monitor battery charge levels, predicted the system.

TABLE 2: Components & Function

Component/Feature	Function
Voltage Sensor	Monitors battery voltage to prevent overcharging
Current Sensor	Measures current flow to avoid overloads
Temperature Sensor	Detects abnormal heat, triggers fire warning
Smoke Sensor	Senses smoke indicating fire or short circuit
Microcontroller	Processes sensor data and manages system logic
IoT Module (Wi-Fi/GSM)	Sends data to the cloud for remote monitoring
Cloud Server	Stores data logs, generates alerts, provides remote access
Mobile/Web Interface	Displays real-time battery stats and notifications
Relay/Safety Mechanism	Cuts power or triggers fan/buzzer in case of emergency

A. Working Principle:

The proposed IoT-based Battery Management System operates by continuously monitoring key parameters of the electric vehicle's battery using sensors. These parameters include voltage, current, temperature, and smoke levels. Each sensor feeds real-time data to a microcontroller, which processes and analyzes the information. If the system detects abnormal readings—such as overheating, overvoltage, or smoke—the microcontroller immediately triggers protective actions. These actions may include disconnecting the battery using a relay module, activating a cooling fan, or sounding a buzzer to alert nearby users.

Simultaneously, the microcontroller sends the sensor data to a cloud platform via an IoT communication module (like Wi-Fi or GSM). This allows remote users to monitor the battery status through a web dashboard or mobile app. Alerts and notifications are also sent in real time to prevent potential hazards. The system ensures that the battery operates within safe limits, protects against fire risks, and keeps the user informed regardless of their location.

B. Challenges:

Implementing an IoT-based Battery Management System for electric vehicles comes with several technical and practical challenges. One of the main issues is ensuring accurate sensor calibration, as incorrect readings from voltage, current, temperature, or smoke sensors can lead to false alerts or overlooked faults. Additionally, the power consumption of the microcontroller and IoT modules must be optimized, since constant data transmission can quickly drain the battery, especially in smaller or low-capacity systems. Maintaining consistent network connectivity is also critical for real-time monitoring—poor signal strength or internet disruptions can delay important alerts and impact system reliability.

Another key challenge is minimizing false positives, where minor fluctuations or environmental factors may mistakenly trigger safety actions. Designing the system to handle such situations without unnecessary intervention requires careful filter and logic implementation. Cost is also a consideration, as the addition of sensors, cloud services, and communication modules can increase the total project expense. Finally, ensuring the system reacts quickly and effectively in emergency scenarios, such as fire detection or overheating, is crucial to prevent damage. This demands efficient coding, reliable hardware, and thorough testing under various operating conditions.

C. Block Diagram:

Below is the block diagram representing the working of the system

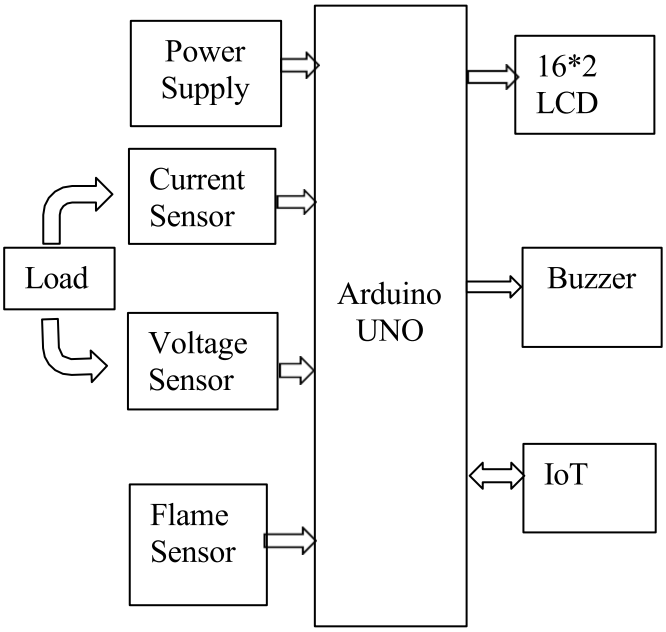

Figure: block diagram of IoT enabled battery safety system for ev's

This block diagram represents an IoT-based Battery Management System (BMS) with Fire Protection using an Arduino UNO as the central controller. It monitors key battery parameters through voltage, current, and flame sensors to ensure safe operation. The power supply provides energy to the system, while the Arduino UNO processes sensor data and controls outputs such as an LCD display for real-time monitoring, a buzzer for fault alerts, and an IoT module for remote data transmission**.** If abnormalities like overvoltage, overcurrent, or fire hazards are detected, the system triggers alarms and sends notifications via IoT, enhancing the safety and reliability of electric vehicle batteries.

D. RESULTS AND DISCUSSION

The IoT-enabled battery safety system for electric vehicles was successfully tested for its main functions, including battery parameter monitoring, fire detection, and real-time alerts. The system monitored key parameters such as battery voltage, temperature, and charge level using sensors connected to a microcontroller. The data was sent to an IoT platform for remote access. During testing, the battery voltage was observed to stay within 47.8V to 54.2V, and the temperature stayed below 43°C, which are within the safe limits for a typical EV battery.

The system was also able to detect overcharging and deep discharge conditions. When the voltage crossed the safe limit or when the battery was too low, the system triggered alerts and disconnected the charging circuit to prevent damage. For fire safety, the flame sensor responded quickly to the presence of heat or fire-like conditions and activated a buzzer and sent alerts through the IoT app. Overall, the results show that the system is reliable for monitoring battery safety, reducing risks related to overcharging, overheating, or fire. It improves the safety and lifespan of the battery and provides real-time alerts for quick response.

E. CONCLUSION

The proposed IoT-based Battery Management System (BMS) with Fire Protection enhances the safety, reliability, and efficiency of electric vehicle battery systems. By integrating voltage, current, and flame sensors with an Arduino UNO**,** the system continuously monitors battery health and detects potential hazards in real time. The inclusion of an LCD display, buzzer, and IoT module allows for instant fault detection, local alerts, and remote monitoring, ensuring proactive safety measures. This smart BMS not only prevents issues like overcharging, overheating, and fire risks but also improves battery lifespan and overall system performance. With IoT-enabled connectivity, users can track battery status remotely, making it a cost-effective and scalable solution for modern electric vehicle applications.

F. REFERENCES

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