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

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Abstract:

This project introduces an IoT-based Battery Management System (BMS) for Electric Vehicles (EVs), designed to enhance safety through real-time monitoring and fire protection. The system continuously tracks critical battery parameters, such as temperature, voltage, and fire risk, using sensors that transmit data to a cloud platform accessible via mobile and web applications. Key components of the BMS include a fire detection subsystem, which incorporates temperature sensors and smoke detectors to monitor the battery's condition. In the event of any irregularities or anomalies, the system automatically activates cooling measures or fire suppressants to mitigate potential hazards, ensuring the safety of the vehicle and its occupants. This approach not only improves user convenience by sending proactive maintenance alerts but also extends battery life by maintaining optimal operating conditions. Through continuous monitoring, the system provides real-time insights into the battery's status, allowing for early detection of potential issues such as overheating or fire risk. This capability enables users to address problems before they escalate into more significant threats. Experimental results from testing the system show its ability to accurately monitor battery status and quickly respond to potential hazards. The BMS system is shown to be effective in maintaining safety and operational efficiency, marking a significant advancement in EV battery management. By ensuring that the battery operates within optimal conditions, the system contributes to the overall health and longevity of the battery, making it more reliable over time. Furthermore, it reduces the likelihood of battery-related incidents, such as fires, which are a critical concern for EV users. Overall, this IoT-based BMS represents a major step forward in the development of safer, more efficient EV battery management solutions, improving both vehicle safety and user experience while promoting the long-term health of the battery.

Keywords: IOT-Based, Battery Management System (BMS), Electric Vehicles (EVs),Real-time monitoring, Fire protection, ESP32 , DHT Sensor , Buzzer , Relay , DC Fan , Fire Sensor , Smoke Sensor , Voltage Sensor , Battery , Relay , H-Bridge Driver

1.INTRODUCTION

The growing adoption of Electric Vehicles (EVs) represents a significant shift toward sustainable transportation. With the global push to reduce carbon emissions and transition to cleaner alternatives, EVs are becoming a crucial component of the modern automotive landscape. At the core of every electric vehicle lies its battery, which serves as the primary power source and directly impacts the vehicle's performance, range, and efficiency. However, as EVs become more prevalent, the importance of safe and reliable Battery Management Systems (BMS) grows substantially. A robust BMS is essential not only for maximizing the battery's performance but also for ensuring the safety and longevity of the vehicle. With the

increasing adoption of EVs, a reliable BMS can help safeguard the vehicle's batter improving its life span and ensuring it functions safely. EV batteries, particularly lithium-ion batteries commonly used in modern electric vehicles, are prone to various issues such as overcharging, deep discharging, and overheating. These problems can lead to severe consequences, including reduced battery lifespan, performance degradation, and even catastrophic events like thermal runaway, which can result in fires or explosions. Therefore, it is crucial to develop an intelligent system that continuously monitors and manages the health of the battery in real time, ensuring that it operates within safe and optimal conditions. The development of such a system has become even more urgent as EVs become mainstream and more users rely on their performance for daily transportation. The ability to effectively monitor critical parameters like voltage, temperature, and charge cycles can prevent potential issues before they escalate into hazardous situations. Advanced monitoring systems, such as IoT-based Battery Management Systems, enable real-time data collection, predictive maintenance, and prompt issue resolution, ensuring that the battery remains functional and safe throughout its lifespan.

This project presents an IoT-based Battery Management System (BMS) for electric vehicles that aims to enhance battery safety and performance through real-time monitoring and fire protection. By leveraging IoT, the system provides continuous surveillance of key parameters like temperature and voltage. Data from sensors is transmitted to the cloud, giving users remote access and timely alerts, thus ensuring the vehicle's battery health.

2. LITERATURE SURVEY

Author: Landge Pradip et.al**Title:** Battery Management System for Electric Vehicles with Charge Monitoring and Fire Protection**Year:** 2024.In this paper, Landge Pradip et.al. (2024) present the development of a Battery Management System (BMS) specifically designed for Electric Vehicles (EVs). The main focus of the BMS is to monitor the battery's status and ensure the safe operation of the EV by tracking crucial parameters such as charge levels and temperature. The system utilizes Bluetooth HC-05 as the communication module, allowing for efficient wireless data transmission between the BMS and the monitoring device. This enables real-time monitoring of battery health, which is essential for ensuring the longevity and safety of the EV battery.The BMS helps prevent issues like overcharging or deep discharging by providing constant updates on the battery's charge status. This constant feedback helps maintain the battery's optimal performance and ensures it operates within safe parameters. Additionally, the system is designed to include fire protection features, ensuring that the battery remains safe under various operational conditions. The Bluetooth communication further enhances the usability of the system, as users can easily access battery data through a mobile device or a connected platform. The overall contribution of this work lies in offering an efficient, low-cost solution for monitoring and protecting EV batteries, ensuring their reliability and longevity in everyday use.

Dr. N.Sambasiva Rao et.al. (2024) developed an advanced Battery Management System (BMS) for Electric Vehicles (EVs) that focuses on continuous monitoring of critical battery parameters to ensure safe and efficient operation. The system tracks parameters such as temperature, voltage, and charge levels, providing real-time data that

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is crucial for maintaining battery health and preventing issues such as overcharging, deep discharging, and overheating. Additionally, the BMS includes fire protection features to safeguard the battery from potential fire hazards caused by malfunctions. One of the key innovations of this system is the use of a Wi-Fi communication module, enabling remote monitoring and control through a mobile or web application. This allows users to access battery data from anywhere, ensuring that any issues are detected promptly. The overall contribution of this work lies in offering a comprehensive and cost-effective solution to improve the reliability, safety, and longevity of EV batteries.

R. Anjaneyulu Naik et.al. (2024) present the development of a Battery Management System (BMS) for Electric Vehicles (EVs) that incorporates real-time charge monitoring and fire protection using the Internet of Things (IoT). The system is designed to track crucial battery parameters, including charge levels, temperature, and voltage, ensuring optimal battery performance and safety. The primary contribution of this work lies in the use of the Node MCU, which is integrated into the system for real-time monitoring of the battery's charge. The Node MCU communicates the battery's status to the cloud, allowing users to remotely access and manage the system through a mobile or web interface. The system also features fire protection mechanisms that activate when abnormal conditions, such as overheating or high voltage, are detected. This helps prevent potential fire hazards, making the EV safer for users. The integration of IoT technology in the BMS enhances the efficiency of monitoring and allows for timely intervention in case of potential issues, thus extending the battery's lifespan. The combination of charge monitoring and fire protection in real-time is a significant step toward ensuring both the longevity and safety of EV batteries, providing a comprehensive solution to battery management in electric vehicles.

Suyash S. Hujare et.al. (2024) present the development of a Battery Management System (BMS) for Electric Vehicles (EVs) focused on continuously monitoring various crucial parameters to ensure safe and efficient battery operation. The primary parameters tracked by the system include voltage, temperature, and current, which are essential for maintaining optimal battery health. By constantly monitoring these parameters, the system can detect any irregularities or potential risks that could affect the battery's performance or safety. One of the key features of this BMS is its ability to provide real-time data, allowing for timely interventions if any abnormalities, such as overheating or overcharging, are detected. This helps prevent potential hazards like battery failure or fires, ensuring that the EV operates safely. Additionally, the system is designed with fire protection mechanisms to further enhance safety. Overall, this work contributes to the field of electric vehicle battery management by offering a reliable, real-time solution for monitoring and protecting EV batteries.

SAI DURGA PRASAD K et.al. (2023) developed a Battery Management System (BMS) for Electric Vehicles (EVs) focused on continuously monitoring key battery parameters to ensure safe and optimal performance. The system monitors parameters like voltage, temperature, and current, which are critical for maintaining battery health and preventing issues such as overheating or overcharging. A crucial aspect of the system is the integration of the State of Charge (SoC) implementation, which helps assess the battery's charge status and ensures that the battery operates within safe limits. For communication, the system utilizes the Bluetooth HC-05 module, which allows for wireless monitoring and control through mobile devices or other connected platforms. This ensures that users can access real-time battery data, such as charge levels and temperature, remotely. Additionally, the system includes fire protection mechanisms to enhance safety by detecting and addressing potential fire hazards. The overall contribution of this work lies in providing a reliable.

B.V. Manikandan et.al. (2023) present the development of a Battery Management System (BMS) specifically designed for electrical drives, focusing on continuous monitoring of essential battery parameters to ensure safety and efficient operation. The system tracks critical parameters such as voltage, temperature, and current, which are vital for maintaining battery health and preventing potential risks like overheating, overcharging, or deep discharge. A key aspect of this BMS is its use of real-time monitoring, enabling it to detect irregularities and respond promptly to protect the battery from damage. For safety and alerting purposes, the system incorporates an alarm mechanism that notifies users if any of the monitored parameters exceed safe thresholds. This early warning system helps to prevent battery failures and ensures that the electrical drive operates under safe conditions. The system also includes fire protection features, adding an extra layer of safety by detecting and responding to fire risks.
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Prof. Dr. Malkar (2024) discusses the development of a Battery Management System (BMS) designed to enhance the safety of electric vehicles (EVs) by continuously monitoring the condition and charging status of the battery. The system employs advanced sensors and smart technology to detect potential hazards, such as fire risks, ensuring that the battery operates under optimal and safe conditions. By monitoring key parameters like voltage, temperature, and current, the system can identify any abnormalities that may lead to safety concerns, such as overheating or overcharging. One of the core features of this BMS is its fire protection mechanism. If the system detects any unusual conditions, such as a sudden temperature rise or voltage irregularities, it automatically disconnects the battery from the vehicle's power system. This proactive measure helps prevent potential fire hazards or accidents, safeguarding both the vehicle and its occupants. The paper highlights the importance of integrating smart technology into EV battery management to ensure safety, increase battery life, and minimize the risk of fire-related incidents. Through real-time monitoring and immediate intervention, the system provides a reliable solution for enhancing the safety of electric vehicle batteries.

3. PROPOSED METHODOLOGY

The proposed methodology for the IoT-based Electrical Vehicle (EV) Battery Management System (BMS) focuses on continuous monitoring of the battery's key parameters such as charge, voltage, temperature, and current. The system employs sensors to capture real-time data, ensuring that the battery operates within safe limits. These parameters are sent to a cloud platform via a communication module, enabling remote monitoring and control through mobile or web applications. The system also incorporates fire protection by detecting abnormal conditions like overheating or excessive voltage, triggering immediate actions like disconnecting the battery or activating cooling mechanisms to prevent potential hazards. A key feature of the system is its integration with an IoT-enabled infrastructure that provides real-time alerts to users, informing them of any potential issues with the battery. This helps ensure the safety, longevity, and performance of the EV battery. The overall approach emphasizes reliability, safety, and user-friendly monitoring of battery health.

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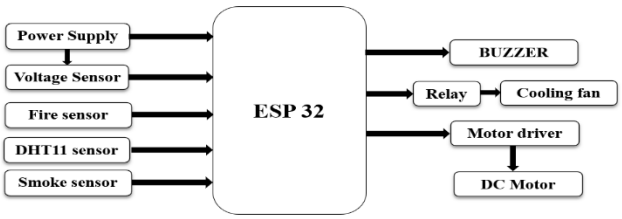


Figure 1: Proposed BMS system.

The proposed methodology typically includes the following keycomponents:

- **Battery Parameter Monitoring**: The system continuously monitors crucial battery parameters such as voltage, temperature, current, and charge levels. These parameters are tracked in real time to ensure the battery operates optimally and safely.

- **Real-Time Data Transmission**: Data collected from the battery is sent to a cloud platform via an IoT module, providing remote access to users through mobile or web applications. This allows users to monitor the battery's status from anywhere.

- **Improved Vehicle Safety:** By integrating fire protection and real-time monitoring, this IoT-based BMS ensures both the safety of the vehicle occupants and the reliability of the EV's battery system, fostering long-term usage and reduced risks of battery-related incidents

- **Fire Protection Mechanism**: The system is equipped with fire protection features. In case of abnormal conditions like overheatingthe system automatically turn on the fan. In over voltage condition system automatically disconnects the battery to prevent accidents like fires or thermal runaway.

- **User Alerts and Notifications**: The system sends real-time alerts to users about critical battery conditions such as temperature fluctuations, low voltage, or fire risk. This helps in preventing potential damage and enhances safety.

- **Performance Evaluation**: The system is evaluated based on its effectiveness in ensuring battery safety and longevity, while also providing continuous charge monitoring and fire protection in real-time.

Applications:

The IoT-based Battery Management System (BMS) for electric vehicles has numerous applications, including:
• **Electric Vehicles (EVs)** (ensuring battery safety, longevity, and performance)
• **Fleet Management** (real-time monitoring of multiple EVs for optimized battery health)
• **Electric Vehicle Charging Stations** (providing safety and efficiency in charging operations)

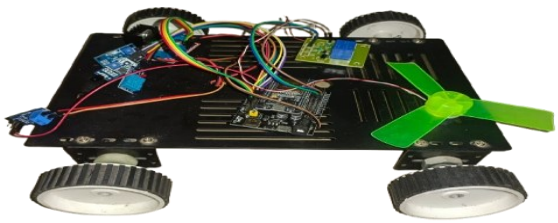
Advantages:

The IoT-based Battery Management System (BMS) offers numerous benefits, improving the safety, efficiency, and longevity of electric vehicle (EV) batteries. Some of its key advantages include:

- **Real-Time Monitoring:** Continuous monitoring of battery parameters such as temperature, voltage, and charge levels ensures the battery operates within safe limits, reducing the risk of malfunction.
- **Improved Safety:** The BMS can detect early signs of issues like overheating or voltage irregularities and trigger fire protection mechanisms to prevent accidents, enhancing user safety
- **Remote Accessibility:** With IoT integration, users can monitor their EV's battery performance remotely via mobile or web applications, enabling them to take timely action if needed.
- **Preventive Maintenance:** The system can send proactive alerts about potential issues, helping users avoid costly repairs and extend the battery's lifespan by enabling timely intervention.
- **Enhanced Efficiency:** By managing battery charge cycles and optimizing performance, the IoT-based BMS ensures the battery operates efficiently, maximizing its range and performance.
- **Fire Protection:** The integrated fire detection and cooling systems prevent potential battery fires by automatically activating cooling mechanisms and disconnecting power supply when unsafe conditions are detected.
- **Cost Savings:** By preventing battery damage through proactive monitoring and early issue detection, the IoT-based BMS helps reduce repair and replacement costs, providing long-term savings for the vehicle owner.
- **Increased Battery Life:** The real-time monitoring and optimization of charging cycles help maintain the battery in optimal condition, significantly extending its overall lifespan and reducing the frequency of replacements.

4. PROJECT MODEL

The IoT-based Electric Vehicle Battery Management System (BMS) with Charge Monitoring and Fire Protection ensures the safe and efficient operation of EV batteries. It continuously monitors critical parameters such as voltage, temperature, and current to prevent overcharging and overheating. The system integrates fire protection mechanisms, activating cooling systems or disconnecting the battery when anomalies are detected. With IoT technology, users can remotely monitor the battery's status, ensuring safety and optimal performance for the vehicle.



5. EXPERIMENTAL RESULTS

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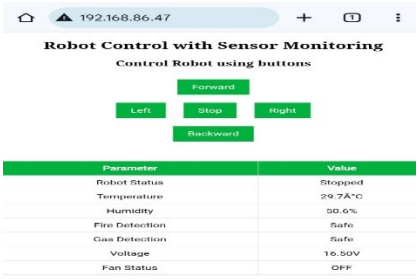

Figure 2. Stable Condition

Figure 3. Temperature Increase Condition

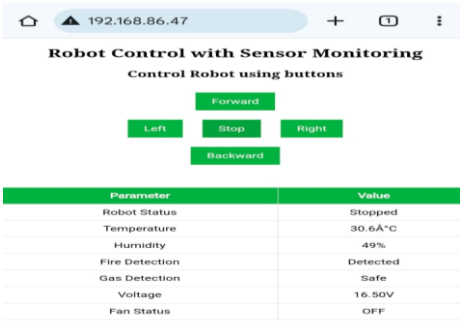

Figure 4. Fire Detection Condition

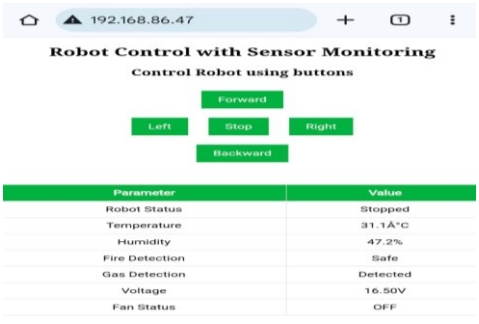

Figure 5. Smoke Detection Condition

The results section demonstrates a web-based interface for controlling a robot equipped with sensor monitoring. The interface, hosted on a local network, allows users to operate the robot using buttons for movement commands such as forward, left, stop, right, and backward. Additionally, the system provides real-time monitoring of various parameters, including robot status, temperature, humidity, fire detection, gas detection, voltage levels, and fan status. Different test conditions are illustrated, such as a stable condition where all parameters remain normal, a temperature increase condition indicating a rise in heat levels, a fire detection condition where the system identifies fire hazards, and a smoke detection condition where gas presence is detected. The conclusion highlights the significance of integrating sensors and actuators with the ESP32 microcontroller, enhancing safety, automation, and efficiency, particularly for applications like Electric Vehicles (EVs). This system ensures real-time monitoring of critical parameters, improving overall security and operational effectiveness.

5. CONCLUSION

The integration of various sensors and actuators, controlled by the ESP32 microcontroller, has significantly enhanced the safety, automation, and overall efficiency of Electric Vehicles (EVs). This sophisticated system allows for continuous real-time monitoring of key parameters, such as battery voltage, temperature, humidity, and fire or smoke detection. With the ability to identify potential hazards promptly, the system ensures that any issues are immediately addressed, thereby preventing catastrophic failures or dangerous situations from occurring.

By implementing timely interventions, such as activating alarms, controlling cooling systems, and triggering ventilation mechanisms, the system plays a crucial role in preventing battery failures, fires, or overheating. These proactive measures help safeguard the vehicle, ensuring that any irregularities are detected and mitigated before they can escalate into major issues. This approach not only promotes the safety of vehicle occupants but also ensures that the EV remains in optimal working condition.

The incorporation of intelligent safety and automation systems ultimately results in a safer and more reliable driving experience for EV users. As these technologies continue to evolve, they contribute to improving the overall user experience by ensuring that critical vehicle components remain secure and function as expected. This adds significant value to the electric vehicle's performance and safety.

In the long run, these advancements also contribute to the long-term health of the vehicle's components. By providing a proactive approach to vehicle management, the system helps enhance energy efficiency and sustainability, reducing the risk of unexpected maintenance issues. As a result, this technology plays a vital role in ensuring that Electric Vehicles remain dependable, efficient, and safe for everyday use.

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