IOT Based Battery Management System In Electric Vehicle

Mrs. S.Francis Shamili[1], Mohamed Thoufik K[2], Nandhakishore O[3], Naveenkumar S[4], Nishanth S[5]
[1]Assistant professor, Dept of CSE
[2, 3, 4, 5]Dept of CSE
[1, 2, 3, 4, 5] Dhanalakshmi Srinivasan Engineering College (Autonomous), Perambalur, Tamil Nadu, India.

Abstract- *The increasing adoption of electric vehicles (EVs) underscores the need for efficient and safe battery management systems. This paper proposes an Internet of Things (IoT)-based battery monitoring system designed to enhance the safety, efficiency, and reliability of EV batteries. The proposed system integrates multiple sensors, including voltage, temperature, and flame sensors, with an IoT-enabled microcontroller (NodeMCU) to provide real-time monitoring of battery parameters. The system detects abnormal conditions such as overvoltage, overheating, and fire hazards, and triggers automated corrective actions, including triggering a buzzer alarm and disconnecting the battery through a relay module. In addition, the system offers remote monitoring capabilities, allowing users to track battery health, voltage levels, and temperature trends through a web or mobile interface. Historical data is stored in the cloud, enabling predictive maintenance and early fault detection. The integration of IoT technology not only ensures immediate response to critical situations but also improves the long-term performance and lifespan of the battery. This scalable and adaptable system provides a comprehensive solution for battery safety in EVs, making it applicable to a variety of electric vehicle applications, from personal cars to commercial fleets.*

Keywords- IoT-based Battery Monitoring, Electric Vehicle (EV), Battery Safety, Real-time Data Monitoring, Temperature Sensor, Voltage Sensor, Flame Sensor, Predictive Maintenance, Relay Module, Cloud-based Monitoring, Automated Safety Protocols, Battery Health Management, Battery Performance Optimization, EV Battery Management System.

I. INTRODUCTION

The rapid advancement of electric vehicle (EV) technology has significantly transformed the automotive industry, driven by the growing demand for sustainable and environmentally friendly transportation solutions. Central to the performance, efficiency, and safety of EVs is their battery management system (BMS), which plays a crucial role inmonitoring and controlling the charging, discharging, and overall health of the battery. As the global shift towards electric mobility continues, the need for more advanced, reliable, and real-time monitoring systems for EV batteries has become more prominent.

Conventional battery management systems, while effective in basic monitoring tasks, often lack the capability to provide real-time data transmission, remote access, and predictive maintenance features, leading to increased operational risks and reduced battery lifespan. These traditional systems typically rely on analog circuitry and basic protection mechanisms, which cannot adequately address the growing complexity and safety concerns associated with modern EV battery systems. Moreover, such systems are limited in their ability to predict potential failures or hazards, such as thermal runaway, overcharging, or short circuits, which can result in catastrophic battery failures.

As electric vehicles continue to evolve and become more sophisticated, the need for intelligent and adaptable battery management systems becomes ever more critical. The proposed IoT-based system not only addresses the current gaps in traditional BMS but also provides a scalable, customizable solution that can be adapted to meet the specific needs of various EV applications. In this paper, we explore the design, development, and implementation of this advanced system, highlighting its key features, advantages, and potential applications in the growing electric vehicle market.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

The development of an IoT-based Battery Management System (BMS) for Electric Vehicles (EVs) begins with the identification of critical issues associated with traditional battery monitoring mechanisms. Existing systems often lack intelligent fault detection, real-time monitoring, and user-friendly interfaces, leading to inefficiencies in battery usage, reduced lifespan, and safety risks. Therefore, the first step in conceptualizing the proposed system was to identify the core limitations in current BMS implementations.

Through extensive research into recent advancements in EV technology, it was observed that the integration of IoT with sensor-based systems could provide significant improvements in battery monitoring and management. This realization led to the exploration of key technologies and components that could be used to design a smart, responsive, and efficient BMS.

The research focused on selecting suitable hardware such as:

Voltage Sensors – to detect overvoltage or undervoltage conditions.
Temperature Sensors – to monitor battery heat and prevent thermal runaway.
Flame Sensors – to detect early fire or combustion threats.
Arduino Microcontroller – for data processing and system control.
NodeMCU (ESP8266) – to enable wireless IoT-based communication.
LCD Display, Relay Module, and Buzzer – to provide local alerts and automated battery isolation during faults.

2.1 Identification of the Problem

Electric vehicles (EVs) rely heavily on the performance and safety of their battery systems. However, issues such as overcharging, overheating, deep discharge, and fire hazards continue to pose significant threats to battery health and user safety. Conventional battery monitoring systems lack real-time insights, automated responses, and remote access, making them inefficient in preventing critical failures. These shortcomings highlighted the need for an intelligent and IoT-integrated battery monitoring system.

2.2 Background Study

A review of existing Battery Management Systems (BMS) revealed that many do not support predictive maintenance or cloud-based data analysis. Research papers, case studies, and technical blogs on EV batteries, IoT applications in electric vehicles, and sensor-based monitoring systems were studied. This helped in understanding the current technological gaps and the scope for implementing smart monitoring using embedded systems and IoT technologies.

2.3 Component Selection and Technology Research

To implement a smart and responsive monitoring system, research was conducted to identify suitable components and technologies. The selection was based on reliability, cost-effectiveness, and ease of integration.

Voltage Sensor: Monitors voltage to detect overcharge or deep discharge.
Temperature Sensor: Detects abnormal heat levels that could lead to thermal runaway.
Flame Sensor: Identifies combustion or fire near the battery unit.
Arduino UNO: Acts as the main controller for sensor data processing and decision-making.
NodeMCU (ESP8266): Provides Wi-Fi capability for IoT-based data transmission.
Relay Module: Enables automatic disconnection of the battery in case of faults.
LCD Display and Buzzer: Offer local alerts and real-time feedback.

2.4 IoT and Cloud Integration Study

Research was extended to understand how cloud platforms and IoT protocols (like MQTT, HTTP) can be used to transmit sensor data for remote monitoring. Platforms like Blynk, ThingSpeak, and Firebase were evaluated for real-time data visualization and notification capabilities. IoT integration also allows historical data analysis, improving fault prediction and decision-making.

2.5 Defining the Project Scope and Objectives

Based on the research, the objective was defined as designing an IoT-based system that could:

Monitor critical battery parameters in real-time.
Alert users and trigger automated safety responses.
Provide remote access to data through cloud-based dashboards.
Enable predictive maintenance through historical data analysis.

2.6 Idea Finalization

After thorough evaluation and literature review, a complete system design was conceptualized that uses a combination of sensors, microcontrollers, IoT modules, and cloud interfaces. The finalized idea addresses real-world challenges in EV battery safety and efficiency while being scalable and adaptable for different electric vehicle platforms.

III. PROPOSED SYSTEM

The proposed system is an **IoT-based Battery Management System (BMS)** designed specifically for electric vehicles (EVs) to enhance the safety, performance, and lifespan of the battery pack. By combining embedded sensors with microcontrollers and IoT connectivity, the system continuously monitors battery health and executes automated safety responses in real-time.

3.1 System Overview

The system architecture integrates hardware components such as voltage sensors, temperature sensors, flame sensors, an Arduino microcontroller, NodeMCU (ESP8266), a relay module, a buzzer, and an LCD display. These components work together to monitor voltage levels, detect abnormal heat, identify fire hazards, and trigger emergency actions when necessary.

3.2 Key Features and Functionalities

Voltage Monitoring: Continuously checks the battery voltage. If the voltage exceeds or drops below safe limits, it triggers alerts and disconnects the battery to prevent overcharging or deep discharge.
Temperature Monitoring: Detects battery overheating. If temperature crosses the threshold, it activates a buzzer alert and disconnects the battery to prevent thermal runaway.
Fire Detection: Uses a flame sensor to identify the presence of fire near the battery. On detection, the system initiates shutdown procedures via the relay and buzzer.
Real-Time Data Transmission: NodeMCU collects sensor data and uploads it to a cloud platform for real-time monitoring.
Remote Access: Users can view voltage, temperature, and flame status from any location through a web or mobile dashboard.
Local Monitoring: An LCD display provides visual updates on battery status, ensuring local awareness without needing an external device.
Automated Safety Measures: The relay module disconnects the battery automatically upon detecting unsafe conditions, preventing damage and improving response time.

3.3 IoT Integration

NodeMCU, functioning as the IoT communication module, sends real-time sensor data to cloud platforms such as Blynk or ThingSpeak. Users are notified through push alerts or dashboard updates, enabling remote diagnostics and predictive maintenance. Historical data is logged for performance analysis and early fault detection.

3.4 Control Unit: Arduino

The Arduino UNO serves as the main processing unit, reading data from sensors, comparing values against predefined thresholds, and executing corresponding actions. It ensures reliable decision-making by:

Activating the buzzer in emergencies.
Displaying data on the LCD.
Sending commands to the relay for battery disconnection.
Transmitting data to the NodeMCU.

3.5 Safety and Reliability

The system emphasizes a proactive approach to battery management:

Fail-safe Design: Immediate shutdown upon critical sensor readings.
Redundancy: Multiple sensors ensure detection of various fault types.
Audible and Visual Alerts: Ensures that even local users are immediately informed of any abnormality.

3.6 Scalability and Adaptability

The modular structure of the proposed system allows:

Integration of additional sensors or modules.
Application across personal, commercial, or industrial EVs.
Future upgrades like GPS tracking, GSM alerts, or solar charging integration.

3.7 Summary

In essence, the proposed system provides a **comprehensive and intelligent solution** to EV battery monitoring. By combining real-time sensing, automated safety protocols, and IoT-based data transmission, the system not only ensures safety and performance but also empowers users with remote access and insights, making it a modern and practical solution for electric vehicle management.

IV. SYSTEM DESIGN

The **system design** of the IoT-based Battery Management System (BMS) for Electric Vehicles (EVs) is centered around a layered architecture comprising sensing, control, communication, and output modules. The design ensures real-time monitoring, swift response to anomalies, and seamless user interaction.

ARCHITECTURE DIAGRAM

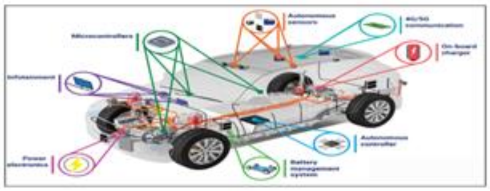

FIG.4.1 SYSTEM ARCHITECTURE

4.1 Block Diagram

The system is structured with the following components:
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[Voltage Sensor] ┐
[Temperature Sensor] ─▶ [Arduino UNO] ─▶ [Relay Module] ─▶ [Battery]
[Flame Sensor] ┘            │
                 ├──▶ [LCD Display]
                 ├──▶ [Buzzer]
                 └──▶ [NodeMCU (ESP8266)] ─▶ [Cloud Server / IoT Dashboard]
```

4.2 Hardware Components

- **Voltage Sensor**: Measures real-time voltage of the battery and sends data to Arduino.
- **Temperature Sensor**: Detects heat levels to identify overheating.
- **Flame Sensor**: Senses fire hazards in the battery compartment.
- **Arduino UNO**: Acts as the central processing unit for data evaluation and decision-making.
- **Relay Module**: Controls the physical disconnection of the battery in case of abnormal conditions.
- **NodeMCU (ESP8266)**: Facilitates Wi-Fi-based transmission of sensor data to the cloud.
- **LCD Display**: Shows local output like voltage, temperature, and fire status.
- **Buzzer**: Emits sound alerts during critical conditions to alert the user immediately.

4.3 Software Design

The software logic is embedded in the Arduino and NodeMCU firmware. It includes:

- **Sensor Data Acquisition**: Reading analog/digital signals from sensors.
- **Threshold Evaluation**: Comparing sensor values with predefined safety limits
- **Action Triggering**: Activating buzzer, relay, and display based on sensor data.
- **IoT Communication**: Sending data to cloud using HTTP/MQTT protocols via NodeMCU.
- **Remote Monitoring Interface**: Cloud dashboard or mobile app to show real-time readings.

4.4 System Workflow

1. **Initialization**: All sensors and modules are initialized after the system powers on.
2. **Data Collection**: Sensors begin to collect voltage, temperature, and flame data.
3. **Processing**: Arduino evaluates sensor values against safety thresholds.
4. **Alerting & Action**:
   - If abnormal voltage is detected → alert shown on LCD + IoT message.
   - If high temperature or flame is detected → buzzer sounds + battery disconnected using relay.
5. **Cloud Upload**: NodeMCU sends the sensor readings to a real-time cloud server.
6. **Remote Access**: User can view readings on a mobile app or website dashboard.

4.5 Design Considerations

- **Modularity**: System components are independent and replaceable.
- **Low Power Consumption**: Ideal for electric vehicle environments.
- **Ease of Integration**: Easily scalable for more sensors or control units.
- **Reliability**: Designed to respond immediately to any anomaly.

V. CONCLUSION

In this paper, we have proposed an IoT-based battery monitoring system for electric vehicles that leverages wireless communication and cloud computing to collect and analyze battery data in real-time. Our system offers granular and accurate insights into battery health and performance, real-time monitoring and analysis capabilities, cloud-based analysis, and enhanced safety. Through our experiments and evaluations, we have demonstrated the effectiveness and reliability of our system in detecting potential issues and providing actionable insights to users. We have also shown that our system can be easily integrated into existing electric vehicle infrastructure and can scale to accommodate large fleets of vehicles.

The paper described the design and development of an IoT-based battery monitoring system for electric vehicle to ensure the battery performance degradation. We are developing the system for battery management in electric vehicle by controlling the crucial parameters such as voltage and temperature. It is very important that the BMS should be well maintained with battery reliability and safety. This present paper focusses on the study of Battery Management System and optimizes the power performances of electric vehicles. Moreover, the target of reducing the greenhouse gases can greatly be achieved by using battery management system.

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