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IoT Based Electrical Vehicle Battery Management System With Charge Monitor , Fire Protection and User Authentication and Access Control

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Abstract— The increasing adoption of electric vehicles (EVs) necessitates advanced battery management systems that ensure safety, reliability, and real-time monitoring. This paper presents an IoT-based Electrical Vehicle Battery Management System (EVBMS) with integrated charge monitoring, fire protection, and user authentication using an ESP32 microcontroller and the Blynk IoT platform. The proposed system continuously monitors battery voltage, battery temperature, and motor temperature using dedicated sensors, while a flame sensor provides early fire detection for enhanced safety. Local system status and alerts are displayed on a 16×2 LCD, and real-time data is transmitted wirelessly to a mobile application for remote monitoring and control. Experimental results obtained from the hardware prototype demonstrate effective system performance. The battery voltage was accurately monitored at 11.05–11.21 V, while the battery temperature remained within safe operating limits at 29.9 °C under normal conditions. Motor overheating and flame detection events were successfully identified and indicated through LCD alerts and Blynk notifications, with automatic motor shutdown enabled via a relay module. The results confirm reliable real-time monitoring, rapid fault detection, and secure user access, making the proposed EVBMS a cost-effective and scalable solution for next-generation smart electric vehicle applications.

Keywords — Electric Vehicle, Battery Management System, IoT, ESP32, Fire Detection, Blynk, Battery Monitoring etc.,

I. Introduction

The rapid growth of electric vehicles (EVs) has increased the demand for efficient, safe, and intelligent battery management systems (BMS). Lithium-ion batteries, which are widely used in EVs, are highly sensitive to operating conditions such as voltage, temperature, and charging behavior. Improper monitoring and control can lead to performance degradation, reduced battery lifespan, and severe safety risks including thermal runaway and fire hazards [1], [4]. A battery management system plays a crucial role in ensuring safe operation by monitoring key parameters such as battery voltage, temperature, and state-of-charge (SOC). Accurate battery characterization and modeling are essential for reliable BMS operation, as errors in estimation can negatively affect battery performance and longevity [2]. Several studies have focused on improving SOC and state-of-health (SOH) estimation using advanced algorithms, including machine learning and adaptive filtering techniques [3], [6], [7], [9]. However, many of these approaches increase system complexity and computational cost. Thermal behavior is another critical factor influencing EV battery safety and efficiency. Variations in ambient and operating temperatures significantly impact battery characteristics, making continuous temperature monitoring essential for EV applications [4]. In addition, charging-related safety issues and fire risks remain major concerns, particularly during fast charging and high-load operating conditions [1], [12]. Despite these challenges, many existing systems lack integrated fire detection and real-time alert mechanisms. Recent advancements in the Internet of Things (IoT) have enabled cloud-based monitoring and remote supervision of battery systems. IoT-based platforms allow real-time visualization, data logging, and user interaction, improving system reliability and scalability [5], [12]. Security-enhanced monitoring approaches, including blockchain-based BMS frameworks, have also been explored to protect battery data transmission [13]. However, most existing solutions focus either on large-scale energy storage systems or grid-level impacts rather than compact, low-cost EV battery safety solutions [10], [11]. To address these limitations, this work proposes an IoT-based Electric Vehicle Battery Management System that integrates real-time voltage monitoring, battery and motor temperature sensing, flame detection, and secure remote monitoring using an ESP32 microcontroller and the Blynk IoT platform. The proposed system aims to provide a cost-effective, reliable, and scalable solution for enhancing EV battery safety and operational awareness.

II. Related Works

Jiang *et al.* analyzed the charging safety of electric vehicles by examining risks such as overvoltage, overcurrent, and thermal instability during charging processes. Their study highlighted that unsafe charging conditions, especially during fast charging, can accelerate battery degradation and increase the likelihood of thermal runaway. The authors also proposed optimization techniques to enhance charging safety and efficiency; however, real-time monitoring and fire detection mechanisms were not considered. [1]

Castano *et al.* studied the influence of battery management systems on lithium-ion battery pack characterization and modeling. The work demonstrated that accurate voltage, current, and temperature measurements significantly affect battery performance, lifespan, and reliability. Although the study provided valuable insights into BMS modeling accuracy, it did not include cloud-based monitoring or real-time user interaction. [2]

Vidal *et al.* presented a comprehensive review of machine learning techniques used for battery state-of-charge (SOC) and state-of-health (SOH) estimation in electrified vehicles. The authors discussed advanced data-driven approaches such as neural networks and deep learning models, showing improved accuracy over traditional estimation methods. However, the computational complexity of these techniques limits their implementation in low-cost embedded EV systems. [3]

Kaushik and Singh investigated the impact of ambient temperature on lithium-ion battery performance in pure electric vehicles. Their experimental analysis revealed that temperature variations significantly influence battery efficiency, discharge characteristics, and overall performance. The study emphasized the importance of continuous thermal monitoring but lacked real-time alerting and remote monitoring capabilities. [4]

Adhikaree *et al.* proposed a cloud-based battery condition monitoring platform using Internet-of-Things technology for large-scale lithium-ion energy storage systems. The system enabled remote monitoring of voltage and temperature parameters across distributed batteries. Although effective for stationary applications, the approach was not specifically designed for mobile electric vehicle systems or fire safety integration. [5]

Javid *et al.* introduced an adaptive online gated recurrent unit (GRU) model for lithium-ion battery SOC estimation. The adaptive learning capability allowed the model to update itself based on changing battery behavior, resulting in improved estimation accuracy. Despite its effectiveness, the study focused primarily on algorithmic performance and did not integrate hardware-based safety protection. [6]

Kim *et al.* proposed an adaptive SOC estimation technique for electric vehicle battery management systems under varying operating conditions. The method improved estimation reliability during dynamic load changes commonly experienced in EVs. However, system-level safety features such as temperature monitoring and fire detection were not addressed. [7]

Luan *et al.* developed a monitoring and simulation platform for lithium-ion battery charging and discharging processes. The platform provided insights into battery behavior under different operating scenarios and load conditions. The study was limited to simulation-based analysis and lacked real-time embedded implementation and IoT connectivity. [8]

A comparative study on extended Kalman filter (EKF) and unscented Kalman filter (UKF) techniques demonstrated improved SOC estimation accuracy for lithium-ion batteries under nonlinear conditions. While the estimation performance was enhanced, the work did not consider practical hardware deployment, safety alerts, or wireless monitoring integration. [9]

Seljeseth *et al.* analyzed the impact of electric vehicle charging on power distribution networks during slow and fast charging operations. The study showed that fast charging introduces significant stress on electrical grids, affecting power quality and stability. However, the work focused on grid-level impacts rather than onboard EV battery safety. [10]

Cao *et al.* proposed a reservation-based electric vehicle charging system using battery switching to reduce charging time and grid congestion. The approach improved charging availability and system efficiency. Nevertheless, internal battery condition monitoring and safety protection mechanisms were not included. [11]

Usmani *et al.* presented an IoT-based solution to prevent lithium-ion battery venting due to overcharging. The system employed real-time monitoring and alert generation to enhance battery safety. While effective in overcharge prevention, the solution did not integrate motor monitoring or access control features. [12]

Faika *et al.* proposed a blockchain-based IoT framework to enhance security in wireless battery management systems. The integration of blockchain improved data integrity and protection against cyber threats. However, the increased system complexity and lack of fire detection limit its suitability for low-cost EV applications. [13]

Gayathri *et al.* analyzed the design and performance of an electric vehicle using a BLDC motor and bidirectional converter. The results demonstrated improved efficiency and regenerative braking capability. The study focused primarily on power electronics performance without incorporating battery safety monitoring. [14]

Sudha and Vadde evaluated the performance of high-power-density BLDC motors for electric vehicle applications. Their analysis highlighted improvements in torque density and efficiency. However, thermal monitoring and intelligent battery protection mechanisms were not addressed in the system design. [15].

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III. Proposed Method

An IoT-based Electrical Vehicle Battery Management System (EVBMS) designed to enhance battery safety, monitoring, and user accessibility. The system employs an ESP32 microcontroller as the central processing unit to collect and analyze real-time data from multiple sensors. Key battery parameters such as voltage, battery temperature, and motor temperature are continuously monitored using appropriate sensing modules, while a flame sensor is used to detect potential fire hazards. The ESP32 processes the sensed data and displays system status and alerts on a 16×2 LCD for local monitoring. Simultaneously, the data is transmitted wirelessly to the Blynk IoT platform using built-in Wi-Fi, enabling remote monitoring through a smartphone application. User authentication within the Blynk platform ensures secure access and control of the system. In the event of abnormal conditions such as overheating or flame detection, the controller activates protective mechanisms including buzzer alerts and motor isolation through a relay module. This integrated approach ensures real-time monitoring, enhanced safety, and secure remote access, making the proposed system suitable for smart electric vehicle battery management applications. The figure

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1 shows that the proposed architecture. And figure 2 shows that the implementation flow chart.

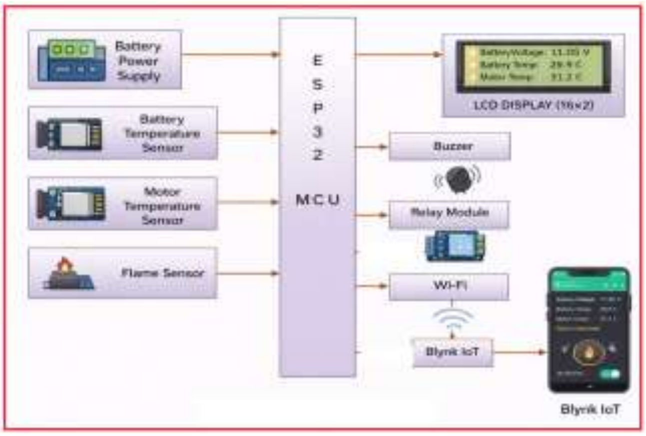

Fig. 1. Architecture of the proposed method

A. Hardware Setup

1) Battery Power Supply

The battery power supply provides the required electrical energy to operate the ESP32 microcontroller, sensors, and peripheral modules. It also represents the electric vehicle battery whose voltage and safety conditions are continuously monitored by the system.

2) ESP32 Microcontroller Unit

The ESP32 acts as the central control and processing unit of the system. It collects data from all connected sensors, processes the information in real time, and executes decision-making logic based on predefined safety thresholds. The ESP32 also manages communication with the LCD, relay, buzzer, and Blynk IoT platform through its built-in Wi-Fi module.

3) Battery Voltage Sensing

The battery voltage is measured using a voltage sensing module that scales down the battery voltage to a safe range for the ESP32's analog input. The measured voltage is continuously monitored to assess the charging condition and overall battery health.

4) Battery Temperature Sensor

The battery temperature sensor monitors the thermal condition of the battery pack. The sensed temperature is compared with predefined safe limits to detect overheating conditions, enabling early warning and protective action to prevent battery damage or thermal runaway.

5) Motor Temperature Sensor

The motor temperature sensor continuously monitors the temperature of the EV motor. If excessive heating is detected, the ESP32 identifies the abnormal condition and initiates protective measures to avoid motor failure.

6) Flame Sensor

The flame sensor detects the presence of fire or flame near the battery or motor region. Upon flame detection, the sensor sends a digital signal to the ESP32, triggering immediate safety responses such as alerts and motor shutdown.

7) LCD Display (16×2)

The 16×2 LCD provides local visualization of system parameters including battery voltage, battery temperature, motor temperature, and warning messages. This ensures real-time monitoring even without mobile or internet access.

8) Buzzer Alert System

The buzzer provides an audible alert during abnormal conditions such as overheating or flame detection. This ensures immediate attention and enhances system safety.

9) Relay Module

The relay module electrically isolates and controls the motor supply. When unsafe conditions are detected, the ESP32 activates the relay to disconnect the motor, preventing further operation and ensuring protection.

10) DC Motor

The DC motor represents the electric vehicle drive unit in the prototype. It operates under normal conditions and is automatically disconnected during fault or emergency situations.

11) Wi-Fi Communication

The ESP32 uses its built-in Wi-Fi capability to transmit real-time sensor data to the cloud. This enables continuous remote monitoring and control of the EV battery management system.

12) Blynk IoT Platform

The Blynk IoT platform provides a secure cloud-based interface for remote monitoring. Sensor data such as battery voltage, temperatures, flame status, and vehicle status are displayed in real time on a mobile application. User authentication ensures controlled and authorized access to the system.

B. Algorithm

IoT-Based EV Battery Management System

Step 1: Start the system.
Step 2: Initialize the ESP32 microcontroller, voltage sensor, battery temperature sensor, motor temperature sensor, flame sensor, LCD display, relay module, buzzer, and Wi-Fi connection.
Step 3: Establish a secure connection with the Blynk IoT cloud platform.
Step 4: Continuously read battery voltage using the voltage sensing module.
Step 5: Read battery temperature and motor temperature from their respective sensors.
Step 6: Monitor flame sensor output for fire detection.
Step 7: Display the measured voltage and temperature values on the 16×2 LCD.
Step 8: Transmit real-time sensor data to the Blynk IoT application via Wi-Fi.
Step 9: Compare battery temperature, motor temperature, and flame sensor values with predefined safety thresholds.
Step 10:

- If all parameters are within safe limits, allow normal motor operation and continue monitoring.
- If any abnormal condition is detected (over-temperature or flame detection), proceed to Step 11.

Step 11: Activate the buzzer to generate an audible alert.
Step 12: Display warning messages on the LCD indicating the detected fault.

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Step 13: Send alert notifications to the user through the Blynk IoT application.
Step 14: Deactivate the relay to disconnect the motor and prevent further operation.
Step 15: Continue monitoring the system parameters and wait until safe conditions are restored.
Step 16: Repeat Steps 4–15 continuously.
Step 17: End the algorithm.

C. Implementation

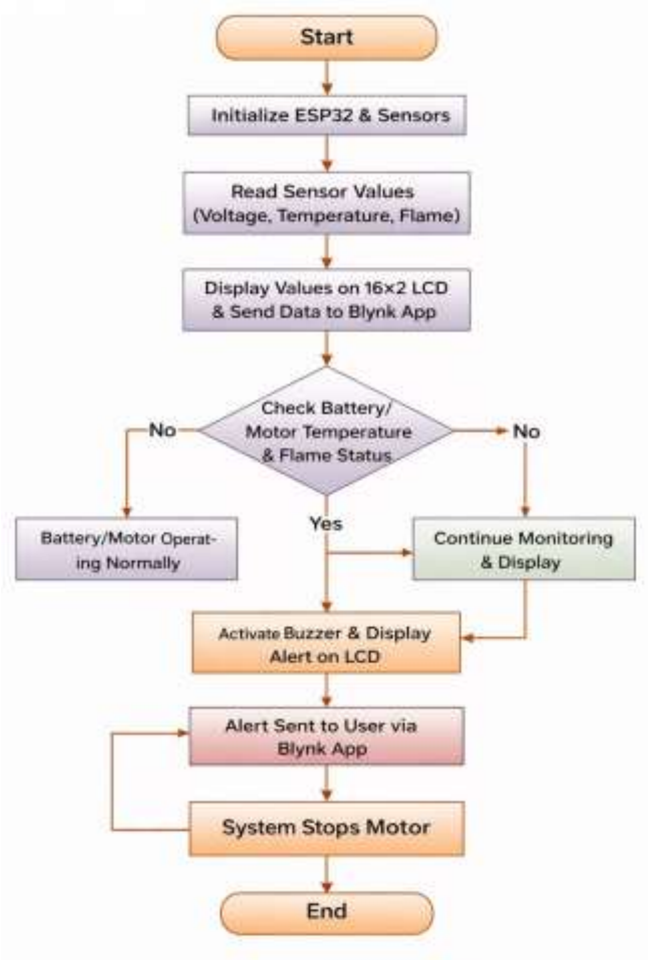

Fig. 2. Implimentation of the flow chart

IV. Experimental Results

The proposed IoT-based Electric Vehicle Battery Management System (EVBMS) was experimentally validated using a hardware prototype integrated with an ESP32 microcontroller, multiple sensors, and the Blynk IoT platform. The system was tested under normal and abnormal operating conditions to evaluate its monitoring accuracy, responsiveness, and safety performance. This fig.3 shows the fully assembled IoT-based EV Battery Management System prototype. It includes the ESP32 controller, lithium-ion battery pack, DC motor, voltage sensor, temperature sensors, flame sensor, relay circuitry, and LCD display. All modules are interconnected and powered by the battery pack. The setup demonstrates real-time monitoring and protection of EV battery and motor parameters under normal and abnormal operating conditions.

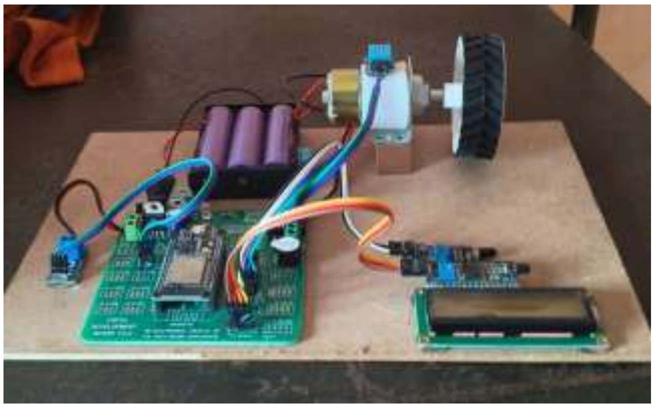

Fig. 3. Complete Hardware Prototype

This fig.4 displays the LCD message "Flame Detected", which confirms successful detection of fire by the flame sensor. When flame or fire is detected near the battery or motor region, the sensor sends a signal to the ESP32. The controller immediately updates the LCD, activates the buzzer, and prepares protective actions such as motor shutdown. This output validates the fire protection feature of the system.

Fig. 4. Flame Detection Indication on LCD

In this fig.5 shows that the LCD displays "Motor overheat detected", indicating that the motor temperature has crossed the predefined safety threshold. The ESP32 continuously monitors motor temperature using a temperature sensor. When overheating occurs, the system generates warnings and disables the motor via the relay module to prevent damage. This ensures safe and reliable EV motor operation

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Fig. 5. Motor Overheating Detection

This fig.6 shows the real-time battery voltage value (11.05 V) displayed on the 16×2 LCD. The voltage sensor continuously measures the battery voltage and sends data to the ESP32. Displaying voltage locally allows quick verification of battery charge condition and ensures the battery operates within safe limits.

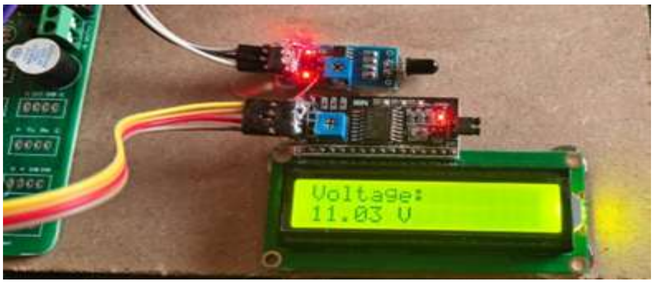

Fig. 6. Battery Voltage Display on LCD

The fig.7 shows that the Blynk IoT dashboard used for remote monitoring. The application displays:

- Battery voltage in graphical form
- Battery temperature (29.9 °C)
- Motor status
- Flame detection status
- Vehicle ON/OFF status

The data is updated in real time using ESP32 Wi-Fi connectivity. Only authenticated users can access the dashboard, ensuring secure monitoring and control of the EV system

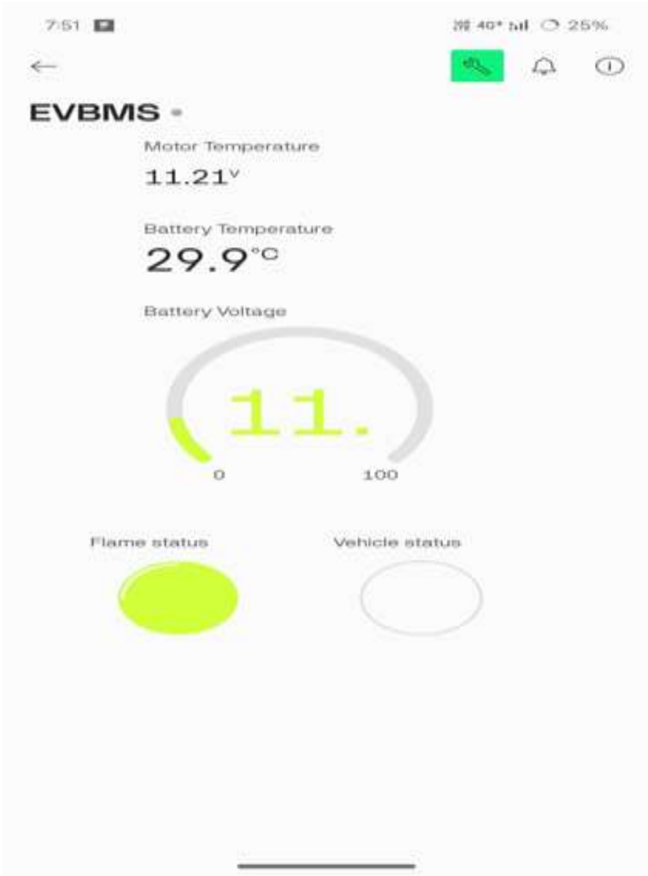

Fig. 7. Blynk IoT Mobile Application Dashboard

TABLE I. OBSERVED SYSTEM PARAMETERS

Parameter	Observed Value	Safe Range	Status
Battery Voltage (V)	11.05 V	10.5 – 12.6 V	Normal
Battery Temperature (°C)	29.9 °C	0 – 45 °C	Normal
Motor Temperature (°C)	31.2 °C	0 – 60 °C	Normal
Flame Status	No Flame Detected	No Flame	Safe

Table 1 summarizes the real-time operating parameters of the EVBMS. All measured values remained within predefined safety limits, confirming stable system operation and effective sensing performance. The battery voltage variation over time is shown in Fig.8. The voltage remains stable between 11.05 V and 11.21 V, indicating reliable charge monitoring. Minor fluctuations are due to load variation, but the values remain within the safe operating range shows in.

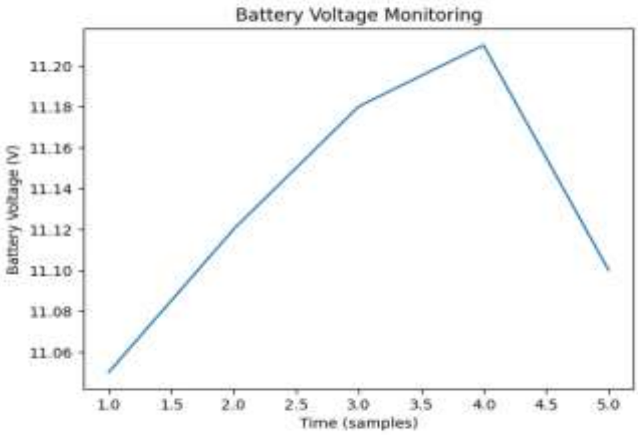

Fig. 8. Baatery Voltage Monitoring

Fig.9 illustrates the temperature variation of both the battery and motor. The battery temperature remains around 29.9 °C, while the motor temperature stays near 31.2 °C, confirming efficient thermal performance. Continuous monitoring enables early detection of overheating conditions.

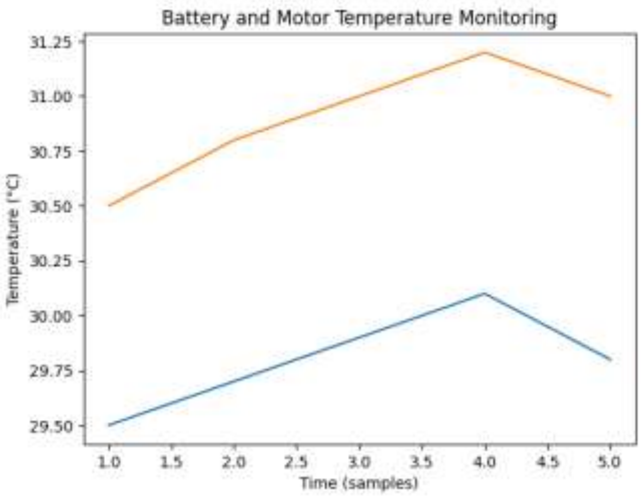

Fig. 9. Battery and Motor Temperature Monitoring

Table 2 highlights the intelligent response of the proposed system under various operating conditions. The ESP32 successfully initiates alerts and protective actions, ensuring safety and reliability.

TABLE II. SAFETY EVENT DETECTION AND SYSTEM RESPONSE

Event Detected	Sensor Triggered	System Action
Battery Overtemperature	Temperature Sensor	Alert + Motor Shutdown
Motor Overheating	Temperature Sensor	Alert + Relay OFF
Fire/Flame Detection	Flame Sensor	Buzzer + LCD Alert + Motor OFF
Normal Condition	All Sensors	Normal Operation

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V. CONCLUSION AND FUTURE SCOPE

This work presented the design and implementation of an IoT-based Electric Vehicle Battery Management System (EVBMS) that enables real-time monitoring, enhanced safety, and secure remote access. The proposed system integrates battery voltage sensing, battery and motor temperature monitoring, and flame detection using an ESP32 microcontroller. Local visualization through a 16×2 LCD and remote monitoring via the Blynk IoT platform ensure continuous supervision of critical EV parameters. Automatic safety mechanisms such as buzzer alerts and relay-based motor isolation provide effective protection against overheating and fire hazards. The experimental validation confirms the reliability, responsiveness, and practical feasibility of the proposed system, demonstrating its suitability for smart and safe electric vehicle applications. EVBMS can be further enhanced by incorporating advanced SOC and SOH estimation algorithms using machine learning techniques for improved battery health prediction. Integration of GPS and GSM modules can enable real-time vehicle tracking and emergency notifications. The system can be extended to support high-voltage battery packs and fast-charging stations with advanced protection circuits. Cloud analytics and data logging can be added for long-term performance analysis and predictive maintenance. Additionally, the inclusion of blockchain-based security and vehicle-to-grid (V2G) communication can improve data security and enable intelligent energy management in future electric vehicle ecosystems.

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