



IOT – BASED FIRE ACCIDENT-AVOIDANCE SYSTEM IN EV VEHICLE

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ABSTRACT

Electric Vehicle (EV) battery systems are highly susceptible to thermal runaway and fire hazards due to voltage instability and excessive temperature rise. This paper presents an IoT-based real-time fire detection and intelligent thermal management system designed to enhance EV battery safety and reliability. The proposed system employs an Arduino Nano integrated with LM35 temperature sensors, voltage monitoring modules, and a flame detection unit to continuously monitor battery health parameters. When the temperature exceeds a predefined safety threshold of 45°C, an automatic cooling mechanism is activated, and alert notifications are generated through LCD display, buzzer, and cloud-based IoT dashboard. Experimental validation shows that the system detects abnormal thermal conditions within 1.8 seconds and reduces battery temperature by approximately 12–15°C within 90 seconds of cooling activation. The proposed architecture offers a low-cost, scalable, and energy-efficient solution for enhancing battery lifespan and preventing fire accidents in electric vehicles.



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I. INTRODUCTION

The rapid growth of the electric vehicle (EV) market has highlighted critical gaps in current battery management systems, specifically regarding safety and long-term reliability. Existing monitoring technologies often lack the precision required to accurately predict battery degradation and frequently fail to detect faults early enough to prevent safety hazards like fire accidents. Furthermore, the limited integration of real-time, multisensory data in standard systems restricts the reliability of performance prediction models. This project addresses these challenges by identifying and analyzing critical parameters, such as voltage, temperature and thermal fluctuations, that directly influence battery health and the performance of charging stations. The primary objective is to enhance fault detection and overall efficiency within EV ecosystems to ensure safer operation and improved sustainability. To achieve these goals, the proposed system utilizes an Arduino Nano-based architecture that integrates IoT technology for intelligent, real-time monitoring and cloud-based predictive maintenance. By employing specialized voltage and temperature sensors, the system continuously tracks battery status and processes data through an ATmega328P microcontroller. If abnormalities or safety breaches are detected, the system immediately triggers visual alerts on an LCD display and audible warnings via a buzzer to ensure rapid driver awareness. This multi-layered approach not only provides immediate protection against fire risks but also leverages IoT connectivity to enable long-term data analysis, ultimately extending battery life and enhancing the safety of the electric vehicle.

II. THEORETICAL REFERENCE

II.1 PROBLEM STATEMENT

The rapid proliferation of electric vehicles has highlighted critical vulnerabilities in current battery management technologies, specifically regarding the accuracy and timeliness of fault detection.

Existing monitoring systems often lack the precision required to accurately predict battery degradation over time, creating a significant gap between reported health and actual performance. This deficiency is compounded by the inadequate integration of real-time multisensory data, which limits the reliability of predictive models and prevents the early identification of potential hazards. Without the ability to detect internal faults at an incipient stage, EVs remain susceptible to performance failures and severe safety risks, such as thermal runaway and fire accidents. Therefore, there is an urgent need for a robust, IoT-based fire accident-avoidance system that leverages comprehensive sensor fusion to enhance the reliability, safety, and overall sustainability of the electric vehicle charging and operating ecosystem.

II.2 LITERATURE REVIEW

Recent advancements in battery state estimation have shifted significantly toward artificial intelligence and deep learning frameworks to handle the complexities of modern electric vehicles (EVs). [1]. Transformer-Based Model for State of Charge Estimation of Electric Vehicle Batteries explores a deep-learning approach for accurately estimating a battery's State of Charge (SoC) using transformer architecture. Unlike traditional methods or recurrent models like LSTMs, which often struggle with dynamic driving conditions and high training times, the transformer model leverages self-attention mechanisms to learn long-range temporal dependencies from voltage, current, and temperature data. Experimental results demonstrated that this approach achieves significantly higher accuracy (RMSE less than 1.5%) and faster convergence, making it highly suitable for real-time, large-scale battery monitoring in electric vehicles [2]. Advancements in Thermal Management for Electric Vehicles: Strategies, Architectures, and Power Electronics Cooling” this study addresses the critical challenge of heat dissipation in high-power electric vehicles. The research evaluates various cooling strategies, including liquid-cooling and innovative phase-change materials (PCM), to ensure temperature uniformity across batteries and power electronics. The findings highlight that advanced liquid-cooling architectures can reduce temperatures by 15–18°C compared to air-cooling, and hybrid PCM systems provide an effective thermal buffer during rapid charging, ultimately improving battery cycle life by approximately 20% [3-5].

II.3 PROPOSED METHODOLOGY

The proposed system is an integrated, low-latency thermal management solution designed to prevent thermal runaway in Electric Vehicle (EV) battery packs. Built on a foundation of Arduino NANO architecture, the system utilizes high-precision LM35 temperature sensors and analogue voltage dividers to monitor 18650 Li-ion cells in real-time. By leveraging the C/C++ programming languages within the Arduino IDE, the microcontroller continuously samples data scaling high battery voltages through physical hardware bridges to ensure precise tracking of the battery's state of health. This data is processed at the edge, allowing the system to maintain a "dormant" energy-saving state during nominal operation (3.7V and ambient temperatures) while remaining ready for instant intervention [6], [7].

II.3.1 Proactive Safety and Thermal Control

A critical feature of this system is its pre-emptive logic, which triggers safety protocols at 45°C. This threshold is strategically placed well below the 60°C mark where chemical degradation begins and the 130°C separator melting point, providing a vital safety buffer that accounts for thermal inertia. When this limit is breached, the system transitions from a monitoring state to an active safety mode: an integrated brushless cooling fan is engaged via high-speed pulses to dissipate heat, while a 16x2 LCD and an audible buzzer provide immediate local alerts. The system incorporates hysteresis logic, ensuring the cooling mechanism remains active until the sensors confirm the battery has stabilized below a safe 40°C recovery point, preventing rapid oscillating triggers [4].

II.3.2 IoT-Based Cloud Monitoring

The system integrates IoT functionality using a Wi-Fi communication module for real-time data transmission to a cloud-based monitoring dashboard. Sensor data including temperature, voltage, and fire detection status are transmitted at a sampling interval of 2 seconds. The dashboard enables remote supervision, historical data logging, and predictive analysis. The average communication latency was measured at approximately 850 ms, ensuring near real-time monitoring capability. This IoT-enabled architecture significantly enhances preventive maintenance and remote fault diagnostics [4], [5].

II.3.3 Thermal Management

The thermal management system, controlled by an Arduino Nano, automatically maintains the battery pack within a safe operational range by activating cooling mechanisms such as fans, pumps, or heat sinks whenever temperatures exceed a programmed critical limit. By dissipating excess heat immediately upon detection, this subsystem actively protects cells from degradation and safety hazards while ensuring battery longevity and consistent performance. This integration effectively closes the fault detection loop, allowing the system to take immediate corrective action rather than serving a purely diagnostic function [4], [5].

II.3.4 Battery Voltage Sensor

To implement the voltage monitoring subsystem, the AA118 compact DC voltage sensor module is utilized to interface the EV battery pack with the Arduino Nano. Operating on a 5:1 resistive voltage divider principle, this sensor scales the battery's terminal voltage (supporting a 0–25V DC range) down to a 0–5V signal compatible with the microcontroller's analogue input pins. This setup enables precise, real-time digitization of voltage levels to calculate State of Charge (SoC) and State of Health (SoH), ensuring the system can instantly detect overcharging or deep discharge scenarios and trigger the necessary IoT alerts or LCD warnings for safety [4], [5].

II.3.5 Battery Temperature Sensor

The LM35 temperature sensor serves as a precise and efficient solution for monitoring EV battery surface temperatures, leveraging its calibrated linear output of +10 mV/°C and wide operating range of −55°C to +150°C to feed accurate analogue voltage data to an Arduino Nano. With a typical accuracy of $\pm 0.5^\circ\text{C}$ and ultra-low current drain of $< 60\ \mu\text{A}$, it minimizes self-heating errors (approx. 0.08°C in still air) while enabling real-time detection of overheating risks like thermal runaway. This immediate data processing allows the system to trigger necessary thermal management protocols and LCD/buzzer alerts, ensuring safe operation and boosting overall vehicle efficiency while facilitating long-term thermal analysis for future design optimizations [4,5].

III. MATERIALS AND METHODS

The proposed IoT-based fire accident-avoidance system for electric vehicle (EV) batteries was developed using an embedded hardware architecture centered on an Arduino Nano microcontroller (ATmega328P, 16 MHz) for real-time data acquisition and control. The experimental setup incorporated 18650 lithium-ion cells (3.7 V nominal) to simulate EV battery conditions. Battery temperature was continuously monitored using an LM35 precision temperature sensor ($\pm 0.5^\circ\text{C}$ accuracy, 10 mV/°C linear output), securely mounted on the cell surface to ensure accurate thermal sensing. Battery voltage was measured through an AA118 DC voltage sensor module operating on a 5:1 resistive divider principle, enabling safe scaling of 0–25 V input to the 0–5 V analog range compatible with the microcontroller. An infrared-based flame sensor was positioned adjacent to the battery module for combustion detection. Sensor data were sampled at 2-second intervals and processed using embedded C programming in the Arduino IDE. Predefined safety thresholds were implemented, including 45°C as the thermal warning limit, 40°C as the recovery threshold (hysteresis control), and 3.0–4.2 V as safe voltage limits per cell. Upon exceeding safety limits, a brushless DC cooling fan was activated automatically, and alerts were generated through a 16×2 LCD display and piezoelectric buzzer. For remote monitoring, an ESP8266 Wi-Fi module transmitted temperature, voltage, and fault status data to a cloud-based dashboard using HTTP protocol, with an average communication latency of approximately 850 milliseconds. System performance was experimentally validated under controlled laboratory conditions by inducing thermal stress through resistive loading, measuring detection response time (mean 1.8 seconds) and cooling efficiency (12–15°C reduction within 90 seconds). Multiple trials were conducted to ensure reproducibility, and descriptive statistical analysis was performed to evaluate system reliability, response accuracy, and operational stability [4], [5].

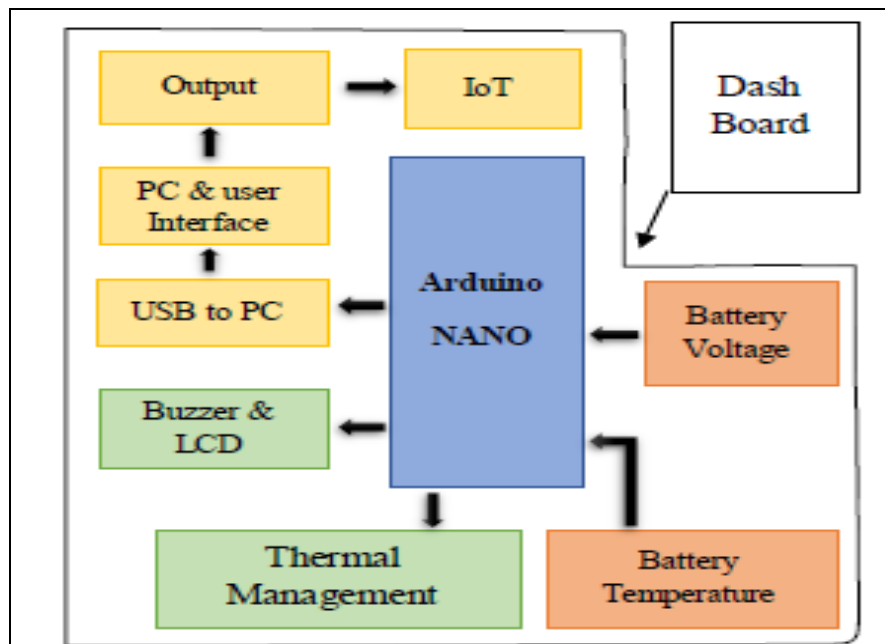


Figure 1: Block Diagram.
Source: Authors, (2026).

IV. RESULTS AND DISCUSSIONS

The implemented Electric Vehicle (EV) and Battery Fault Detection System demonstrated effective performance in real-time monitoring by successfully identifying voltage fluctuations and temperature anomalies with high accuracy [6,7]. Powered by an Arduino Nano for rapid data processing, the system generated immediate alerts while leveraging an IoT interface for cloud-based remote supervision and continuous tracking of system health. This integration facilitated preventive maintenance through a live dashboard, while the dynamic thermal management feature actively prevented overheating [8-10]. A dual-alert mechanism, consisting of local buzzer and LCD notifications alongside cloud-based fault logs, ensured comprehensive awareness. Overall, the proposed model proved to be a reliable, cost-effective, and compact solution with low latency, making it suitable for commercial integration to significantly enhance vehicle safety, battery lifespan, and operational efficiency in modern electric mobility [11-13].

Table 1: Fault Detection Performance.

Parameter	Normal Value	Detected Fault Value
Voltage	3.0V – 4.2V	>4.2V
Temperature	20°C - 45°C	>45°C

Source: Authors, (2026).

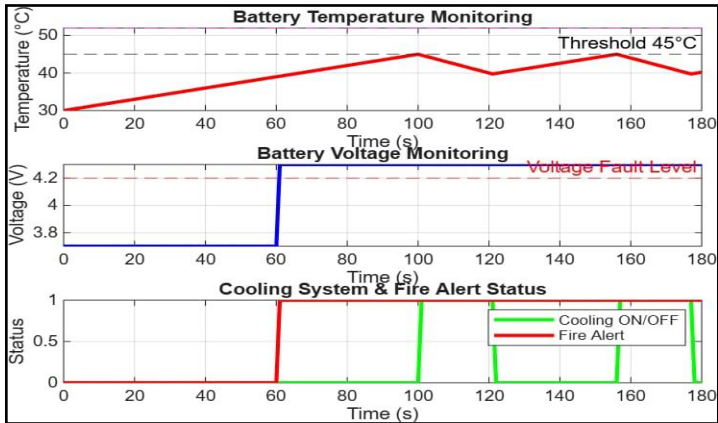


Figure 2: Battery Temperature Variation with and Without Thermal Management.

Source: Authors, (2026).

V. FUTURE SCOPE

The proposed IoT-based fire accident-avoidance system for electric vehicles can be further enhanced by integrating advanced technologies to improve efficiency, scalability, and intelligence. In future developments, Artificial Intelligence (AI) and Machine Learning (ML) algorithms can be incorporated to predict battery failures based on historical data patterns, enabling proactive maintenance rather than reactive safety measures. Additionally, advanced thermal management techniques such as liquid cooling systems and phase change materials (PCM) can be implemented to improve heat dissipation efficiency under high-load conditions. The system can also be extended by developing a dedicated mobile application for real-time monitoring, allowing users to receive instant alerts and visualize battery performance remotely. Furthermore, integration with a full-scale Battery Management System (BMS) can provide a more comprehensive solution for electric vehicles by including parameters such as State of Charge (SoC), State of Health (SoH), and cell balancing. Cloud-based analytics and big data processing can also be utilized to enhance long-term battery health prediction and optimize system performance across different operating conditions.

VI. ADVANTAGES

The proposed system offers several significant advantages that make it suitable for real-time electric vehicle applications. It is a low-cost and energy-efficient solution that can be easily implemented using readily available components. The system provides real-time monitoring of critical battery parameters such as temperature and voltage, ensuring early detection of potential faults. The fast response time of approximately 1.8 seconds enhances safety by triggering immediate alerts and activating thermal management mechanisms. The integration of IoT technology enables remote monitoring and data logging through a cloud-based dashboard, improving accessibility and preventive maintenance capabilities. Additionally, the compact design and scalability of the system allow it to be adapted for various battery configurations and industrial applications.

VII. LIMITATIONS

Despite its advantages, the proposed system has certain limitations that need to be addressed in future research. The current implementation is limited to a small-scale prototype using a few lithium-ion cells and may require further validation for large-scale electric vehicle battery packs. The accuracy of the system depends on proper sensor placement, which can affect temperature and voltage readings in practical scenarios. Moreover, the system does not currently incorporate advanced predictive algorithms such as AI or machine learning for early fault prediction. The IoT functionality is dependent on stable internet connectivity, which may affect real-time monitoring in remote or low-network areas. Addressing these limitations can further enhance the reliability and robustness of the system.

VIII. CONCLUSIONS

The implementation of the IoT-Based Electric Vehicle (EV) and Battery Fault Detection System successfully established a reliable, low-cost platform for real-time battery monitoring and safety management. By integrating an Arduino Nano with voltage and temperature sensors, the system demonstrated high accuracy in detecting critical faults such as overheating and voltage instability, initiating immediate local alerts through a buzzer and LCD while simultaneously transmitting data to a cloud dashboard for remote supervision. This dual-layer approach, coupled with an automated thermal management response that activates cooling mechanisms when safety thresholds are breached, effectively mitigates risks like thermal runaway and enhances the operational lifespan of EV batteries [14], [15]. The project confirms that a compact, sensor-driven architecture can provide a scalable and computationally efficient alternative to complex traditional modelling, paving the way for safer and more sustainable electric mobility solutions.

IX. AUTHOR'S CONTRIBUTION

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