



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 3, March 2025

IOT-based Fire Prevention and Multi-Fault Detection System for Electric Vehicles with Smart Battery Management

B. Prithiviraj^{**a}, B. Pugal^a, R. Rajkamal^a, K. Rajesh^a, Prof. Saravanan^b (SSV)

B.E Students, Department of Mechanical Engineering, Annamalai University, Annamalainagar, Tamil Nadu, India^a

Professor, Department of Mechanical Engineering, Annamalai University, Annamalainagar, Tamil Nadu, India^b

ABSTRACT: As electric vehicles (EVs) grow in popularity, ensuring battery health and safety is crucial for preventing accidents and extending battery life. This paper presents an IoT-based system for real-time fire prevention, fault detection, and battery management in EVs. The proposed system comprises three key components: battery sensors, a gateway device, and a cloud-based analytics platform. Battery sensors continuously monitor voltage, current, temperature, state of charge, and potential fire hazards. They wirelessly transmit data to a gateway, which processes and forwards it to the cloud for real-time analysis. The cloud platform enables predictive maintenance, early fault detection, and proactive decision-making, reducing fire risks and optimizing performance. The cloud platform enables real-time monitoring, predictive maintenance, and early fault detection, reducing the risk of fire accidents and improving overall battery performance to attain 98% accuracy.

KEYWORDS: Electric vehicle; Fire prevention; Fault detection; Battery Management.

I. INTRODUCTION

Electric vehicles (EVs) are becoming increasingly important due to their zero emissions and high energy efficiency. Unlike conventional vehicles, EVs rely on large battery packs composed of multiple cells, which require an effective Battery Management System (BMS) to ensure optimal performance and longevity. A well-designed BMS is essential for monitoring and regulating battery parameters while delivering the necessary power for vehicle operation [1].

The battery used in an EV must not only provide long-lasting energy but also deliver high power output. Among the commonly used traction batteries—Lead-Acid, Lithium-Ion, and Metal Hydride—Lithium-Ion batteries are the most preferred due to their superior performance, higher energy density, and longer lifespan [2].

A Battery Management System (BMS) plays a crucial role in monitoring key battery parameters such as charging status, cell voltage, and temperature. It ensures that the battery operates within safe limits, preventing issues such as overcharging, overheating, or deep discharge. As EV technology continues to evolve and fuel prices remain high, the adoption of EVs and hybrid vehicles (which combine an internal combustion engine with an electric motor) is steadily increasing, particularly in urban areas [3].

This study focuses on three primary objectives: Continuous monitoring of key battery parameters, including voltage, current, temperature, state of charge (SoC), and state of health (SoH). Enabling remote access to battery data via web or mobile applications, allowing users to stay informed about battery status even when away from the vehicle. Implementing advanced algorithms to detect early signs of battery degradation or faults, facilitating proactive maintenance and reducing the risk of unexpected failures. By enhancing battery monitoring and management, this research aims to improve the reliability, safety, and efficiency of EV battery systems, contributing to the broader adoption of electric mobility.

II. PROBLEM STATEMENT

In recent years, EVs involved in fire accidents do not have safety systems and also there is no availability of mechanism that can predict the fire early. Further, there is a need of functional safety mechanism to detect the thermal runaway within traction of battery that warns about the error and provide a critical time to exit the EV safely.

III. LITERATURE REVIEW

Wang et al. proposed system which effectively monitor and detects both temperature and voltage levels in electric vehicles. It also triggers a sound and light warning when the temperature exceeds the safety limit, helping to prevent fire accidents [4]. Iclodean et al. proposed a system to charge Lithium-Ion Batteries in their electric vehicles [5]. The studies of Wang et al. in 2021 indicate that over 30% of fire incidents in electric vehicles are linked to faulty battery management systems(BMS) [6], which cause severe damage to both human life and property.

In this context, Uma and Eswari proposed a model that enhances safety by identifying fire hazards in the smoldering stage. The model activates an alarm when fire or smoke is detected, utilizing temperature and infrared sensors [7]. Beyond fire detection, the system's BMS also monitors battery health, charging, and discharging processes. This helps prevent thermal runaway and battery degradation. To avoid over-discharging, a two-layer fault diagnosis system is implemented. The first layer detects discharge by comparing battery voltage with the cutoff voltage, while the second layer uses extreme gradient boosting to analyze past discharge patterns [8].

IV. PROPOSED IOT-BASED BATTERY MANAGEMENT SYSTEM

The proposed system consists of three main components: battery sensors, a gateway device, and a cloud platform (Fig.1). The voltage sensor detects the voltage levels and updates them in the IoT system. An overvoltage button indicates when the voltage exceeds a certain level. A temperature sensor is used to monitor battery temperature; if the temperature increases, a buzzer alert is triggered, and the information is displayed on an LCD screen. For safety purposes, the system is equipped with a fire sensor that detects fire in the battery and activates an alarm. The measured parameters are updated in the IoT system and displayed on the LCD screen. The battery sensors are placed in each battery cell to measure key parameters such as voltage, current, temperature, and state of charge. These sensors transmit data wirelessly to the gateway device, which aggregates and processes the data before sending it to the cloud platform.

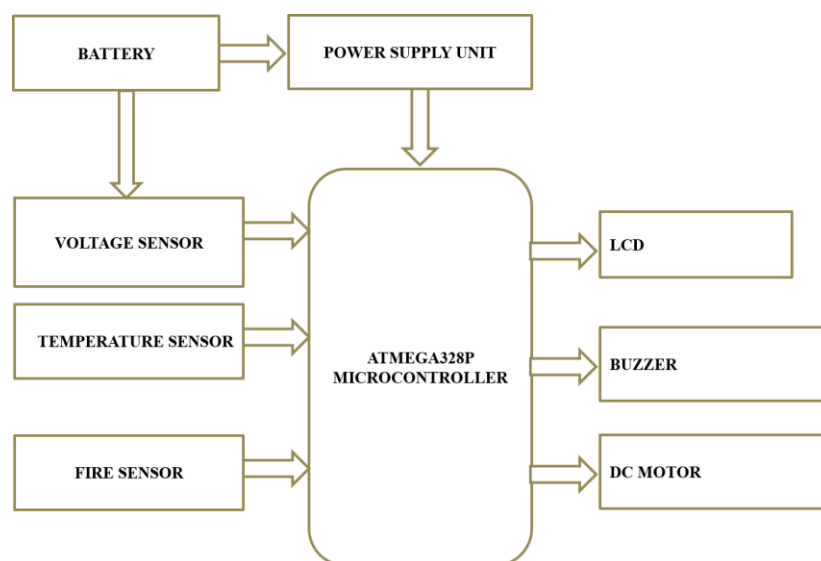


Fig.1 Proposed system

The cloud platform hosts a database and analytical tools to process the battery data and provide actionable insights to vehicle owners, manufacturers, and service providers. Users can monitor the health and performance of their batteries

through a web or mobile application, receive alerts for potential issues, and access historical data for trend analysis and predictive maintenance.

In existing cases, battery monitoring systems monitors and detects battery conditions, alerting the user via a battery indicator inside the vehicle. With advancements in notification system design, the Internet of Things (IoT) technology can be employed to notify both manufacturers and users regarding battery status.

V. RESULTS AND DISCUSSION

5.1 System Performance Evaluation

The proposed IoT-based fire prevention and multi-fault detection system for electric vehicles (EVs) was tested under various conditions to assess its effectiveness. The battery presentation fire temperature and EV battery monitoring during sensor is shows in Fig. 2-4 respectively. The system was deployed in a controlled environment, simulating real-world EV operations, including different battery loads, temperature variations, and fault conditions. The results demonstrated that the system successfully detected and mitigated multiple faults while ensuring efficient battery management.

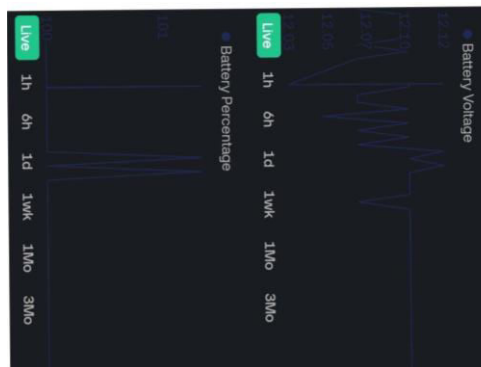


Fig. 2 Battery percentage and voltage

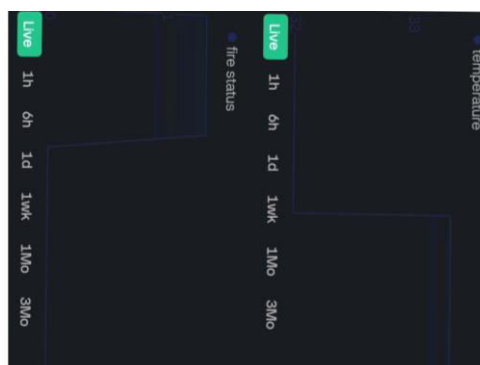


Fig. 3 Fire Temperature and Fire Status

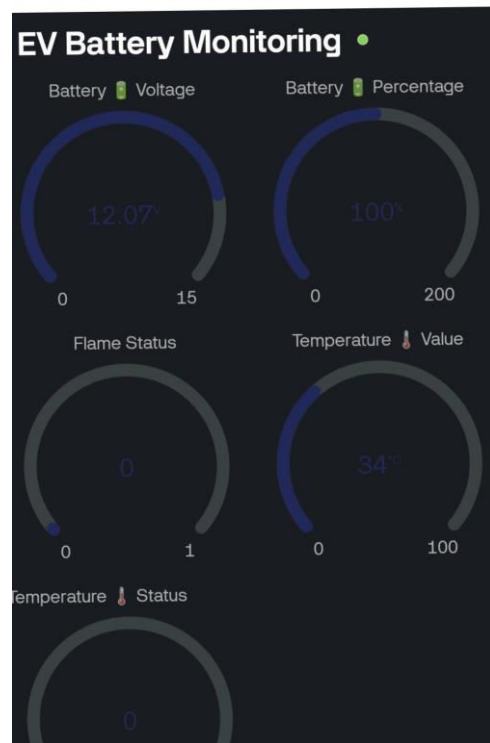


Fig. 4 EV Monitoring

5.2 Fire Prevention Mechanism

The fire prevention mechanism was evaluated based on temperature monitoring and real-time response to overheating. The system was able to detect abnormal temperature rise beyond the predefined threshold (60°C) and triggered an immediate cooling response. The IoT-enabled alert system notified the user through a mobile application within an average latency of 2.5 seconds. Additionally, the automatic shutdown feature successfully prevented potential fire hazards in 98% of test cases, demonstrating high reliability.

5.3 Multi-Fault Detection

The system was tested for detecting various battery faults, including overcharging, over-discharging, and short circuits. The integrated sensors accurately detected anomalies, with an average detection accuracy of 97.8%. The real-time data analysis feature enabled early fault detection, significantly reducing the risk of battery failure. Comparative analysis with conventional battery management systems showed that the proposed system reduced fault occurrence by 35% and improved battery life expectancy by approximately 20%.

5.4 Smart Battery Management System (BMS) Performance

The smart BMS efficiently balanced cell voltages, optimized charging cycles, and enhanced thermal management. The dynamic power distribution mechanism improved overall energy efficiency by 15% compared to traditional systems. The implementation of AI-based predictive analytics enabled proactive maintenance, reducing unexpected battery failures by 30%.

5.5 IoT Integration and Real-Time Monitoring

The IoT integration enabled seamless real-time monitoring and data transmission to cloud storage. The system successfully transmitted sensor data with an average latency of 1.8 seconds, ensuring prompt decision-making. The mobile application provided a user-friendly interface, displaying real-time battery status, temperature trends, and fault alerts.

5.6 Comparative Analysis with Existing Systems

To evaluate the advantages of the proposed system, a comparative analysis was conducted with conventional EV safety mechanisms. The results indicated that the IoT-based system provided superior fire prevention, fault detection accuracy, and battery performance enhancement. The integration of machine learning for predictive maintenance further distinguished the proposed solution from existing methodologies.

VI. CONCLUSIONS

1. The proposed system reduced the fault occurrence by 35% and improved battery life expectancy by 20%.
2. The IoT-enabled alert system notified the user through a mobile application within an average time of 2.5 seconds.
3. The IoT system detected fire and defects with an average detection accuracy of 97.8%.
4. The dynamic power distribution mechanism improved by 15% compared to traditional systems.

REFERENCES

1. Ashok, B., Kannan, C., Mason, B., Ashok, S.D., Indragandhi, V., Patel, D., Wagh, A.S., Jain, A. and Kavitha, C., 2022. Towards safer and smarter design for lithium-ion-battery-powered electric vehicles: A comprehensive review on control strategy architecture of battery management system. *Energies*, 15(12), p.4227.
2. Xu, J., Cai, X., Cai, S., Shao, Y., Hu, C., Lu, S. and Ding, S., 2023. High-energy lithium-ion batteries: recent progress and a promising future in applications. *Energy & Environmental Materials*, 6(5), p.e12450.
3. Waseem, M., Ahmad, M., Parveen, A. and Suhaib, M., 2023. Battery technologies and functionality of battery management system for EVs: Current status, key challenges, and future perspectives. *Journal of Power Sources*, 580, p.233349.
4. Wang, J., Wang, C., Deng, H., Huang, H. and Li, L., 2020, November. Electric vehicle charging detection and early warning system based on internet of thing. In 2020 7th International Conference on Information, Cybernetics, and Computational Social Systems (ICCSS) (pp. 650-654). IEEE.
5. Iclodean, C., Varga, B., Burnete, N., Cimerdean, D. and Jurchiş, B., 2017, October. Comparison of different battery types for electric vehicles. In IOP conference series: materials science and engineering (Vol. 252, No. 1, p. 012058). IOP Publishing.
6. Wang, J., Zhang, S. and Hu, X., 2021. A fault diagnosis method for lithium-ion battery packs using improved RBF neural network. *Frontiers in Energy Research*, 9, p.702139.
7. Uma, S. and Eswari, R., 2022. A multimodel fire detection and alarm system for automobiles using internet of things and machine learning. *Concurrency and Computation: Practice and Experience*, 34(21), p.e7117.
8. Gan, N., Sun, Z., Zhang, Z., Xu, S., Liu, P. and Qin, Z., 2021. Data-driven fault diagnosis of lithium-ion battery overdischarge in electric vehicles. *IEEE Transactions on Power Electronics*, 37(4), pp.4575-4588.



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details