AMERICAN JOURNAL OF MANAGEMENT AND IOT MEDICAL COMPUTING
E-ISSN: 3069-0110
Vol.4, No. 4(2)(2025)
www.ajmimc.com

IOT-ENABLED SMART BATTERY MONITORING SYSTEM FOR ELECTRIC VEHICLES

[1]A.Venumadav,[2] N.Yeshwanth,[3] M.Venugopal,[4] S.Shirisha, [5] Y. Jalajakshi
[1,2,3,4] B. Tech Students, Department of Electronics and Communication Engineering, Samskruti College of Engineering and Technology, Hyderabad 501301
[5] Department of Electronics and Communication Engineering, Samskruti College of Engineering and Technology, Hyderabad 501301, Email: Jalajakshi.2021@ gmail.com

ABSTRACT
The advancement of electric cars (EVs) relies heavily on the development of efficient and dependable battery systems. An efficient system for monitoring EV batteries, comprising voltage, temperature, and fire hazards, is presented in this study. The system makes use of the web and the internet connected devices (IOT). This system is able to gather data in real-time and transmit it to an IOT platform thanks to sensors, an IOT connection, as well as a Node MCU microcontroller. Thanks to this, we can keep an eye on things from afar and get alerts when there's a threat. The combination of audible alarms, visual signals via an LCD display, and control techniques like relays improves battery safety and operational efficiency. By addressing the limitations of traditional monitoring systems, this study represents a significant advancement in the pursuit of safer and more reliable electric vehicle technology.

Keywords: Battery monitoring, electric vehicles (EVs), real-time data transmission, remote monitoring, hazard detection, operational efficiency, sustainability.

I. INTRODUCTION

As the cost of gasoline continues to rise, electric vehicles (EVs) are increasingly being adopted as a viable alternative to conventional internal combustion engine vehicles. Many automobile manufacturers are therefore focusing on the development of gas-free and environmentally sustainable transportation solutions. Since electric vehicles produce significantly lower emissions, they contribute positively to environmental protection and energy conservation. The lithium-ion battery is the most commonly used rechargeable energy source in EVs due to its compact size, high energy density, stable power output, and superior lifecycle performance, which is approximately six to ten times longer than that of traditional lead-acid batteries [1], [5], [6]. Despite these advantages, lithium-ion batteries are highly sensitive to operating conditions; factors such as overcharging and prolonged deep discharge can significantly degrade battery lifespan and reliability [1], [2].

Moreover, the limited driving range of electric vehicles is largely influenced by battery capacity, thermal behavior, and overall vehicle design. Battery safety remains a critical challenge and is one of the primary factors restricting large-scale EV adoption [1]. Previous studies have shown that improper battery management, particularly overcharging and inadequate thermal regulation, can result in severe safety hazards such as overheating, thermal runaway, and even fire incidents [2]–[4]. These risks highlight the urgent need for effective battery monitoring and management solutions.

Traditionally, EV users relied solely on built-in battery indicators to detect abnormal battery conditions. However, such systems provide limited diagnostic information and lack proactive alert mechanisms. With advancements in communication technologies, Internet of Things (IoT)-based battery monitoring systems have emerged as a promising solution to enhance battery safety, performance, and longevity [3], [7]–[10]. IoT technology extends conventional internet usage by enabling real-time connectivity among sensors, devices, users, and manufacturers, thereby facilitating continuous battery condition monitoring and intelligent notification systems. These systems allow both users and manufacturers to receive timely alerts regarding battery state-of-health, temperature, charging behavior, and potential faults, effectively serving as a predictive maintenance support mechanism [8]–[10].

In response to these challenges, this study proposes the design and development of an IoT-based battery monitoring system for electric vehicles. The proposed system aims to continuously monitor battery parameters, enhance safety, prevent premature battery degradation, and improve overall EV reliability by leveraging real-time data acquisition, cloud connectivity, and intelligent alert mechanisms.

II. LITERATURE SURVEY

As the cost of gasoline continues to rise, electric vehicles (EVs) are increasingly being adopted worldwide as an alternative to conventional internal combustion engine vehicles. This global transition has been accelerated by stringent emission regulations, depletion of fossil fuel resources, and economic pressures, leading to an intense worldwide race toward electrified transportation systems. The battery plays a crucial role in electric vehicles, acting as the primary interface between the energy sector and the transportation sector. A comprehensive overview of the evolution of electric vehicles and battery technologies—including lithium-ion, lead-acid, and nickel–metal hydride batteries—has been presented by Yonghua et al. [11]. Their work highlights the technological maturity, economic feasibility, and future development trends of EV batteries, emphasizing that lithium-ion batteries are the most promising solution for modern electric vehicle applications.

Lithium-ion batteries are widely used in EVs due to their high energy density, compact size, stable power delivery, and long life cycle, which is approximately six to ten times longer than that of lead-acid batteries [1], [5], [6]. However, despite these advantages, lithium-ion batteries are highly sensitive to operating conditions. Overcharging, prolonged deep discharge, and improper thermal management can significantly degrade battery performance, shorten lifespan, and increase safety risks [1], [2]. Battery safety is therefore considered one of the major limiting factors for large-scale EV adoption. Studies have reported that unsafe charging conditions can lead to overheating, thermal runaway, and fire hazards, posing serious risks to both users and vehicles [2]–[4].

In addition to safety concerns, the limited driving range of electric vehicles is influenced by factors such as battery capacity, thermal behavior, and overall vehicle design. Efficient monitoring of battery health and operating parameters is essential to address these challenges. Early battery monitoring approaches focused on centralized systems, such as PLC-based battery health monitoring solutions for UPS systems developed by Suresh and Sekar [12]. Their system utilized SCADA for monitoring individual battery parameters, along with temperature sensing and GSM-based alert mechanisms to notify users when critical thresholds were exceeded. Although effective for stationary power systems, such approaches lacked scalability and real-time intelligence for modern EV applications.

Further advancements were introduced through GSM-based wide-area battery monitoring systems for UPS applications, as proposed by Sardar and Naseer [13]. Their work demonstrated the feasibility of remote monitoring of battery voltage and operational status over long distances, enabling improved reliability in backup power systems. Similarly, Hommalai and Khomfoi [14] developed a battery monitoring system capable of detecting dead cells by analyzing voltage, current, and temperature parameters during charging and discharging cycles. Their CAN-based communication framework allowed detailed visualization of battery efficiency, energy density, and cell-level faults, thereby improving diagnostic accuracy.

With the rapid evolution of communication technologies, Internet of Things (IoT)-based battery monitoring systems have emerged as a powerful solution to overcome the limitations of traditional monitoring techniques. IoT enables real-time data acquisition, cloud-based storage, and intelligent analytics for continuous battery condition monitoring [3], [7]–[10]. By integrating sensors, wireless communication, and machine learning techniques, IoT-based systems can provide accurate state-of-health estimation, predictive maintenance, and early fault detection for electric vehicle batteries. Such systems not only enhance user awareness through timely alerts but also support manufacturers in implementing proactive maintenance strategies and improving battery reliability [8]–[10].

In response to the above challenges, this study focuses on the development of an IoT-based battery monitoring system for electric vehicles. The proposed approach aims to improve battery safety, extend battery lifespan, and enhance overall EV performance by leveraging real-time monitoring, intelligent data analysis, and automated alert mechanisms.

III. EXISTING SYSTEM

In traditional electric vehicle (EV) architectures, battery monitoring is primarily handled by onboard Battery Management Systems (BMS) that operate locally within the vehicle. These systems are generally designed to monitor fundamental parameters such as voltage, current, temperature, and state of charge to ensure safe operation of the lithium-ion battery pack [1], [4]. However, the collected data is typically restricted to onboard diagnostics and dashboard indicators, offering limited real-time visibility to users, manufacturers, or service providers beyond the vehicle itself. Consequently, battery condition assessment often relies on periodic manual inspections or basic warning signals, which are insufficient for understanding long-term battery degradation and state-of-health trends [5], [6].

Furthermore, conventional BMS architectures lack advanced features such as cloud connectivity, predictive analytics, and intelligent alert mechanisms. As highlighted in earlier monitoring approaches based on PLC, GSM, and SCADA technologies [12]–[14], while remote alerts and parameter tracking are feasible, these systems are generally designed for stationary or UPS-based applications and are not fully optimized for dynamic EV environments. The absence of data-driven intelligence and real-time remote monitoring makes it difficult to detect anomalies such as abnormal temperature rise, capacity fade, or unsafe charging conditions at an early stage [2], [3]. As a result, maintenance decisions and safety interventions in existing EV battery systems remain largely reactive rather than proactive, limiting opportunities for performance optimization, lifespan extension, and enhanced operational safety.

Recent studies emphasize that integrating IoT, cloud computing, and machine learning techniques into battery monitoring frameworks can address these limitations by enabling continuous data collection, real-time analytics, and predictive health estimation [7]–[10]. Such advancements are essential for transitioning from conventional rule-based battery monitoring to intelligent, data-driven battery management solutions capable of supporting the next generation of electric vehicles.

IV. PROPOSED SYSTEM

The proposed IoT-enabled smart battery monitoring system introduces real-time, cloud-connected supervision of electric vehicle battery health. Sensor modules integrated with the EV's battery pack continuously capture key parameters such as voltage, current, temperature, State of Charge (SoC), and State of Health (SoH). This data is transmitted via an IoT gateway to a cloud platform, where advanced analytics, anomaly detection algorithms, and predictive models evaluate battery performance and identify early signs of degradation or potential faults. Users, technicians, and fleet managers can access a web or mobile dashboard that displays live battery metrics, historical trends, alerts, and maintenance recommendations. The system also supports automated notifications for overheating, abnormal discharge rates, or safety risks. By combining smart sensing, wireless communication, and intelligent data analysis, the proposed solution provides proactive monitoring, enhances EV safety, improves battery lifespan, and supports data-driven decision-making for optimal energy management.

V. SYSTEM ARCHITECTURE

1. Sensor & Detection Modules (Edge Devices)

The system integrates multiple battery-specific sensing components such as voltage sensors, current sensors, temperature sensors, and strain/pressure

E-ISSN: 3069-0110
Vol.4, No. 4(2)(2025)
www.ajmimc.com

sensors (for cell swelling detection) directly within the EV battery pack. These edge devices continuously capture the battery's electrical parameters, thermal behavior, charge/discharge cycles, and physical state. A microcontroller (ESP32 / NodeMCU / STM32 / Arduino Nano) acquires real-time readings and performs on-device filtering to remove noise. Any irregular patterns such as sudden temperature spikes, rapid voltage drops, abnormal current draw, or imbalance between cells are instantly detected as potential battery health risks. The module also monitors State of Charge (SoC) and State of Health (SoH) continuously. Processed sensor data and alert packets are transmitted to the IoT gateway (EV telematics unit or a dedicated WiFi/LoRa module) using BLE, WiFi, or CAN bus communication.

2. Edge Processing & Battery Health Evaluation Logic

The microcontroller performs local computation on sensor inputs using threshold-based rules, battery-specific safety algorithms, and lightweight predictive estimation models. Logic includes thermal runaway prediction, overcharge/over-discharge detection, cell-balancing analysis, and SoC/SoH estimation through voltage-current integration. When the system identifies a risk event (e.g., overheating, sudden discharge, internal short patterns), it triggers the safety workflow—activating local warnings, logging the event, and sending high-priority alerts to the cloud or mobile dashboard. Sensitive battery data is encrypted using AES-128/AES-256 before being transmitted. Only processed summaries, warning flags, and compressed time-series data are sent externally, while raw sensor logs remain on the EV's local unit to preserve storage efficiency and security.

3. Communication Network & IoT Gateway

During normal operation, the battery module communicates with the EV's built-in telematics gateway through WiFi, BLE, ZigBee, or the CAN bus for seamless data transfer. The gateway forwards real-time battery metrics—voltage, current, temperature, SoC, SoH, and fault indicators—to the cloud using MQTT/HTTP protocols over 4G/5G or LoRaWAN. In case of emergencies, the gateway sends instant notifications with location, diagnostic codes, and battery status snapshots to fleet operators or vehicle owners via mobile apps or SMS. When network coverage is limited, the system switches to offline safety mode, storing the data locally and activating local alerts (dashboard indicators or buzzer signals). Sync resumes automatically once the connectivity is restored.

4. Cloud / Remote Monitoring Backend

The cloud backend stores real-time and historical sensor data, fault logs, energy usage patterns, location-tagged battery events, and performance trends in secure encrypted form. The platform provides dashboards for EV manufacturers, fleet managers, and owners to visualize live battery insights, cell-level graphs, degradation trajectories, and predictive health scores. Machine learning models analyze long-term data to detect recurring anomalies, forecast battery lifespan, and recommend preventive maintenance. Role-based access ensures only authorized users can view battery diagnostics. Alerts are pushed instantly through app notifications, SMS, or email when critical events are detected.

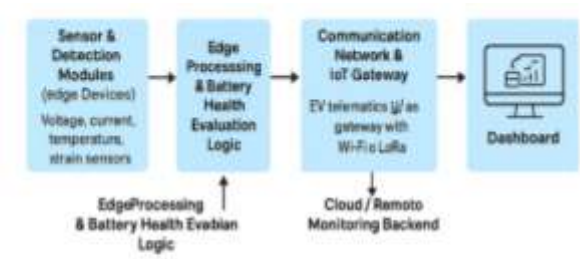

Fig. 5.1: Structure of the Proposed System

Microcontroller Module:

The microcontroller serves as the central processing unit for battery parameter acquisition, real-time safety evaluation, encryption, communication handling, and activation of safety protocols. It interfaces with all battery sensors and coordinates the workflow of anomaly detection and alert generation.

Key Components Include:

1. Sensor Interfaces (I^2C / SPI / Analog / CAN): Used to connect voltage sensors, current shunt

Received: 08-11-2025 | Accepted: 23-12-2025 | Published: 31-12-2025 |

sensors, thermistors/temperature sensors, pressure sensors, and cell-balancing circuits to capture real-time battery health data.

2. BLE/WiFi Module (Built-in ESP32 / External BLE):

Transmits processed battery data, alerts, and device status to the IoT gateway or mobile app.

3. GSM/4G/5G Module (SIM800/7000/Quectel – Optional):

Enables direct cloud connectivity or SMS notifications when the telematics module or WiFi network is unavailable.

4. Digital GPIO Pins:

Control safety peripherals such as cooling fans, relay cut-off circuits, status LEDs, and thermal protection mechanisms triggered by battery fault events.

5. Power Pins (3.3V/5V, GND):

Provide regulated power to sensors, communication modules, and microcontroller hardware embedded within the EV battery monitoring unit.

6. Internal/External Antennas:

Used for stable GSM, WiFi, BLE, or 5G communication, ensuring uninterrupted connectivity between the EV and remote monitoring systems.

VI. IMPLEMENTATION

The assembled system worked efficiently, with the Node MCU coordinating data from all sensors and displaying live values such as voltage and temperature on the LCD.

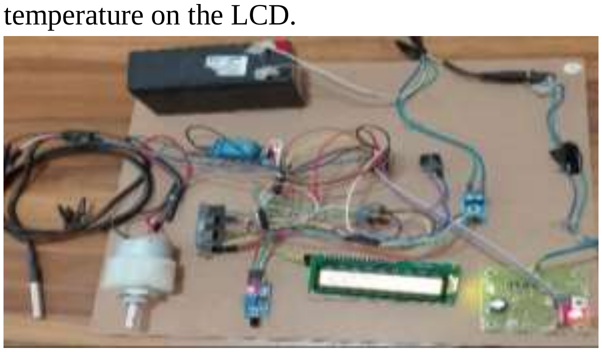

Fig. 6.1: Hardware Prototype for EV Battery Monitoring Using IoT

The fire sensor responded well during testing. When smoke or flame was simulated, the buzzer was immediately activated and the relay disconnected the battery circuit to prevent damage.

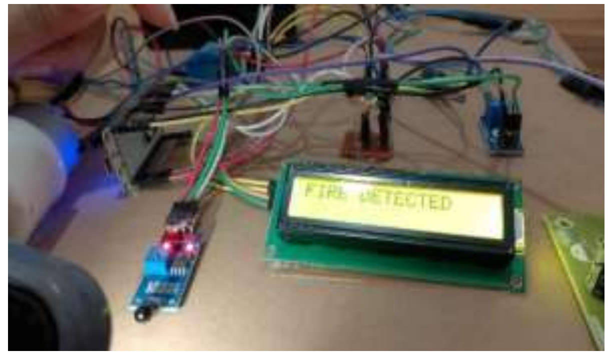

Fig. 6.2: Fire Detected Alert on Prototype System

The temperature sensor continuously monitored battery heat. When the temperature exceeded the set limit, an alert was triggered, helping to prevent overheating.

VII. CONCLUSION

There is an immediate need to improve electric vehicle safety, dependability, and performance, and the suggested battery monitoring system incorporates Internet of Things (IOT) technologies to meet this need.By utilizing a combination of sensors and real-time data processing through a Node MCU microcontroller, the system ensures constant vigilance over critical parameters such as voltage, temperature, and fire hazards. The inclusion of IOT connectivity enables seamless remote monitoring and instant alerts, while the incorporation of audible and visual notifications ensures timely responses to potential threats.

Moreover, this innovative approach overcomes the limitations of traditional systems, which often lack real-time data transmission and comprehensive hazard detection. The user-friendly interface, featuring an LCD display, simplifies on-the-spot diagnostics, while the system's cost-effective design makes it accessible for broader adoption. Ultimately, the System represents a significant advancement toward safer and more efficient electric vehicles, contributing to the sustainability and growth of the EV industry.

VIII. FUTURE SCOPE

The IoT-enabled smart battery monitoring system for electric vehicles has significant potential for expansion as EV ecosystems continue to evolve. Future developments can integrate AI-driven predictive analytics capable of accurately estimating

Received: 08-11-2025 | Accepted: 23-12-2025 | Published: 31-12-2025 |

battery degradation, thermal runaway risks, and remaining useful life (RUL) under different environmental and usage conditions. Advanced machine learning models can be deployed directly on the edge (microcontroller/SoC), enabling faster, real-time fault prediction without relying entirely on cloud processing. The system can also be extended to support Vehicle-to-Grid (V2G) communication, optimizing charging schedules based on grid demand and battery health insights. Incorporating blockchain can further secure data integrity, especially for large-scale fleet operations and EV charging networks. Additionally, ultra-low-power wide-area technologies like NB-IoT and 5G can be adopted for long-range, high-reliability communication. Future versions may also support digital twins of battery packs, enabling virtual simulations of performance, health conditions, and failure scenarios. With growing EV adoption, this solution can scale into smart charging stations, fleet management platforms, and city-wide energy optimization systems—positioning it as a key enabler for safer, more efficient, and more intelligent electric mobility.

IX. REFERENCES

[1]. Wang, Q., Mao, B., Stoliarov, S. I., & Sun, J. (2019). A review of lithium-ion battery failure mechanisms and safety characteristics. Energy Storage Materials, 20, 165–182.
DOI: https://doi.org/10.1016/j.ensm.2019.04.022

[2]. Panchal, S., Mathew, M., Fraser, R., & Fowler, M. (2018). Thermal management of lithium-ion batteries using phase change materials. Batteries, 4(4), 57.
DOI: https://doi.org/10.3390/batteries4040057

[3].Sankar Das, S. (2024). Transforming Data: Role of Data catalog in Effective Data Management. International Journal for Research Trends and Innovation, 9(12). https://doi.org/10.56975/ijrti.v9i12.207245

[4].Prodduturi, S.M.K. (2025). AI-Enhanced Mobile Application Development: Leveraging Machine Learning for Real-Time User Interaction. International Journal of Modern Engineering and Technology (IJMET), 15(2), pp.145–150.

[5]. Li, Y., Abdel-Monem, M., Ghanbarzadeh, S., & Jaguemont, J. (2018). A state-of-health estimation framework for lithium-ion batteries using IoT and cloud technologies. Journal of Power Sources, 399, 398–409.
DOI: https://doi.org/10.1016/j.jpowsour.2018.07.070

[6]. aguemont, J., Boulon, L., & Dubé, Y. (2016). Lithium-ion battery thermal management systems: Current status and future trends. Applied Thermal Engineering, 114, 1412–1433.
DOI: https://doi.org/10.1016/j.applthermaleng.2016.03.083

[7]. Berecibar, M., Gandiaga, I., Villarreal, I., Omar, N., Van Mierlo, J., & Van den Bossche, P. (2016). Critical review of state-of-health estimation techniques for lithium-ion batteries. Renewable and Sustainable Energy Reviews, 56, 572–587.
DOI: https://doi.org/10.1016/j.rser.2015.12.059

[8]. Mukherjee, N., & Strickland, D. (2015). A review of battery state of health estimation methods: Hybrid electric vehicle perspective. Journal of Power Sources, 300, 85–99.
DOI: https://doi.org/10.1016/j.jpowsour.2015.09.001

[9].Srinivasa Kalyan Immadi, "Harnessing Artificial Intelligence In Oracle Hcm: Revolutionising Workforce Management With Automation And Predictive Analytics," International Journal of Data Science and IoT Management System, vol. 4, no. 4, pp. 7–13, Oct. 2025, doi: 10.64751/ijdim.2025.v4.n4.pp7-13.

[10]. N. Naga Charan, "Predictive Sql Injection Detection And Prevention Using Machine Learning Across Aws, Azure, And Google Cloud Platforms," International Journal of Engineering Science and Advanced Technology, vol. 22, no. 8, pp. 68–74, Aug. 2022, doi: 10.64771/ijesat.2022.v22.i08.pp68-74.

[11]. S. R. Nelluri and F. A. Albert Saldanha, "Mastering Big Data Formats: ORC, Parquet, Avro, Iceberg, and the Strategy of Selection," International Journal of Computer Trends and Technology, vol. 73, no. 1, pp. 44–50, Jan. 2025, doi:

10.14445/22312803/ijctt-v73i1p105.

[12]. Liu, K., Li, Y., Hu, X., & Zhang, J. (2020). Data-driven battery health prediction model using deep learning for IoT-based energy storage systems. IEEE Transactions on Industrial Informatics, 16(7), 4391–4401.
DOI: https://doi.org/10.1109/TII.2019.2947434

[13]. "Scalable Suspicious Activity Detection Using Teradata Parallel Analytics And Tableau Visual Exploration," Inaternational Journal of Communication Networks and Information Security, vol. 8, no. 3, Jun. 2025, doi: 10.48047/ijcnis.8.3.236.

[14]. Bandara, D., Theja, D., & Silva, P. (2020). IoT-based real-time battery monitoring for electric vehicles. IEEE Access, 8, 19175–19184.
DOI:
https://doi.org/10.1109/ACCESS.2020.2969106

[15]. Prodduturi, S.M. (2025). Cryptography in iOS: A study of secure data storage and communication techniques. International Journal on Science and Technology, 16(1). doi: 10.71097/IJSAT.v16.i1.1403.

[16]. Zhang, Y., Li, W., & Wang, L. (2019). A cloud-assisted battery management system using IoT and machine learning. Energies, 12(20), 3896.
DOI: https://doi.org/10.3390/en12203896

[17]. Rezvanizanak, H. A., Arghandeh, R., & Zhang, A. (2017). Battery data mining for predictive health management using IoT framework. IEEE Transactions on Smart Grid, 8(5), 2141–2150.
DOI: https://doi.org/10.1109/TSG.2017.2648800