# IoT-Based Smart Battery Monitoring Framework for Electric Vehicles

Dr Santhoshini P[1], Dhivyadharshini S[2], Sharmili S[3], Viraja T[4]
[1] *Assistant Professor, ECE Department, R.M.D Engineering College, Tiruvallur, India*
[2,3,4] *UG Student, ECE Department, R.M.D Engineering College, Tiruvallur, India*

***Abstract--An Internet of Things (IoT)–based battery monitoring system is proposed for the safe and efficient management of rechargeable batteries used in electric vehicles, renewable energy storage, and industrial applications. The system continuously monitors key battery parameters such as voltage, current, and temperature in real time to detect abnormal operating conditions, including overcharging, undercharging, and overheating. Wireless Power Transfer (WPT) technology is integrated to enable contactless charging, thereby enhancing user safety and minimizing mechanical wear associated with wired connections. An ESP32 microcontroller is employed to process sensor data and to activate protective mechanisms, such as automatic cooling control, under critical temperature conditions. Battery status information and fault alerts are transmitted to a cloud-based IoT platform, allowing remote monitoring, data logging, and predictive maintenance. The proposed system improves battery reliability, operational safety, and overall energy management efficiency.***

***Index Terms*****—IoT, Battery Monitoring System, Electric Vehicle, Wireless Power Transfer, ESP32, Temperature Monitoring, Remote Monitoring.**

## I. INTRODUCTION

The rapid growth of electric vehicles (EVs) and renewable energy systems has increased the demand for efficient and reliable battery management solutions. Batteries are the core energy storage components in EVs, and their performance, safety, and lifespan are highly dependent on proper monitoring and control. Variations in voltage, current, and temperature can lead to critical issues such as overcharging, deep discharge, thermal runaway, and reduced battery efficiency. Therefore, continuous monitoring of battery parameters is essential to ensure safe operation and improved reliability. Traditional battery monitoring methods often require manual inspection or lack real-time fault detection, making them unsuitable for modern EV applications. The integration of the Internet of Things (IoT) enables real-time data collection, wireless communication, and remote access to battery information. IoT-based battery monitoring systems allow users to continuously observe battery health, receive instant alerts during abnormal conditions, and store historical data for analysis and predictive maintenance. This improves system reliability and reduces the risk of unexpected failures. Wireless Power Transfer (WPT) technology has emerged as a promising solution for charging electric vehicle batteries without physical connectors. Contactless charging reduces mechanical wear, eliminates sparking issues, and enhances user safety, especially in harsh or outdoor environments.

When combined with intelligent monitoring, WPT can significantly improve charging efficiency and system safety. In this work, an IoT-based smart battery monitoring system using an ESP32 microcontroller is proposed. The system continuously monitors voltage, current, and temperature using appropriate sensors and processes the data in real time. Protective mechanisms, such as automatic activation of a cooling fan during high-temperature conditions, are implemented to ensure safe battery operation. Battery data and fault alerts are transmitted to a cloud-based IoT platform for remote monitoring, data logging, and analysis. The proposed system aims to enhance battery safety, operational efficiency, and reliability in electric vehicle applications.

In addition to safety, efficient energy utilization is a major concern in electric vehicle battery systems. Improper charging and discharging not only reduce battery life but also increase maintenance costs. By continuously analysing real-time battery parameters, intelligent monitoring systems can support better energy management and extend battery lifespan. Cloud-based data storage further enables long-term performance evaluation and helps in identifying usage patterns that affect battery health. Another important challenge in battery-operated systems is the lack of timely fault detection and user awareness. Without immediate alerts, battery failures can result in sudden vehicle shutdown or permanent battery damage. The proposed IoT-based system addresses this issue by providing instant notifications when abnormal conditions are detected, allowing preventive actions to be taken. Remote accessibility also reduces the need for manual inspection and improves overall system convenience. The use of compact and low-power microcontrollers such as the ESP32 makes the proposed system cost-effective and suitable for real-time applications. With built-in Wi-Fi capability, the ESP32 enables seamless communication between the hardware system and the cloud platform. This allows continuous data transmission, real-time visualization, and improved system scalability for future enhancements. Overall, the integration of IoT technology, wireless charging, and intelligent control mechanisms provides a comprehensive solution for modern electric vehicle battery management. The proposed system contributes to improved safety, reliability, and operational efficiency, making it suitable for next-generation electric vehicle and energy storage applications. This work focuses on the design and implementation of an IoT-based smart battery monitoring system for electric vehicle applications. The proposed system continuously monitors battery voltage, current, and temperature using an ESP32 microcontroller. Wireless Power Transfer is integrated to enable contactless charging while ensuring safe conditions.

## II. METHODOLOGY

The proposed IoT-based electric vehicle battery monitoring system is designed to continuously observe battery parameters and ensure safe and efficient operation. The overall methodology involves data acquisition, processing, protection control, wireless charging, and cloud-based monitoring. Initially, the battery voltage, current, and temperature are measured using appropriate sensors interfaced with the ESP32 microcontroller. The collected sensor data is processed in real time to evaluate the operating condition of the battery. Predefined threshold values are used to determine normal and abnormal conditions such as overcharging, deep discharge, and excessive temperature rise. When abnormal temperature conditions are detected, the ESP32 automatically activates a cooling fan to prevent overheating and ensure safe battery operation. Charging and discharging processes are controlled using a relay module to avoid unsafe operating conditions. Wireless Power Transfer (WPT) technology is incorporated to enable contactless charging, reducing dependency on wired connections and minimizing mechanical wear. The ESP32's built-in Wi-Fi capability is used to transmit battery parameters and system status to a cloud-based IoT platform. This enables remote monitoring, real-time visualization, data logging, and alert notification. In the event of faults or abnormal conditions, instant alerts are sent to the user for timely corrective action.

The methodology operates in a continuous loop, ensuring constant monitoring and protection of the battery system. This integrated approach improves battery safety, enhances energy management, and increases the reliability of electric vehicle operation. Overall, the proposed methodology integrates real-time sensing, intelligent control, and cloud-based communication to ensure safe and efficient battery operation. The continuous monitoring of voltage, current, and temperature enables early detection of abnormal conditions. Automated control of charging, discharging, and cooling mechanisms improves system reliability without manual intervention. Wireless Power Transfer supports safe and contactless charging during operation. This structured approach provides a reliable and scalable solution for electric vehicle battery management. The processed sensor data are continuously evaluated against predefined threshold values to determine the battery operating state. Based on this evaluation, appropriate control actions are executed through the relay and cooling system. Simultaneously, all measured parameters are transmitted to the cloud platform for remote monitoring and alert generation. The Block diagram, pictorial representation and sensors involved in Figure 1,2,3.

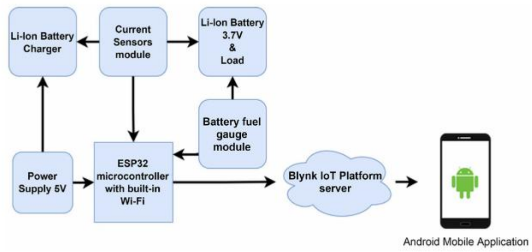


Fig. 1. Block Diagram for an smart vehicle battery monitoring

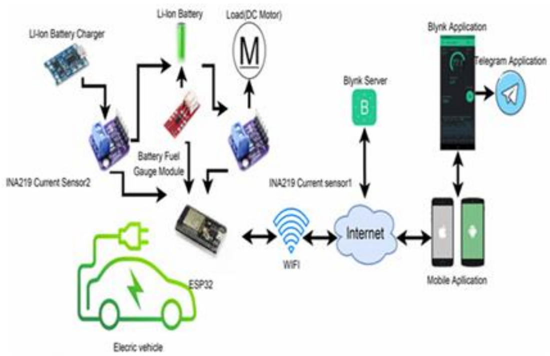


Fig 2: Pictorial Represenatation

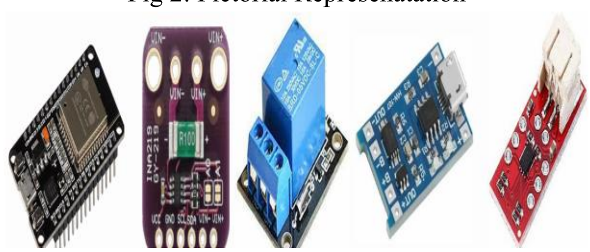

Fig 3: Sensors Involved

## III.WORKING PRINCIPLE

The working principle of the proposed IoT-based electric vehicle battery monitoring system is based on continuous sensing, analysis, and control of battery parameters to ensure safe operation. The system uses sensors to measure battery voltage, current, and temperature in real time. These sensor values are fed to the ESP32 microcontroller, where they are continuously compared with predefined safe threshold levels. If the monitored parameters remain within normal limits, the system operates under standard conditions while transmitting battery data to a cloud-based IoT platform for remote monitoring and data logging. When the battery temperature exceeds the safe limit, the ESP32 automatically activates a cooling fan to reduce heat and prevent overheating. Similarly, a relay-based control mechanism manages the charging and discharging process to avoid overcharging and deep discharge conditions. Wireless Power Transfer (WPT) enables contactless charging of the battery without physical connectors. During wireless charging, the system continues to monitor all battery parameters to maintain safety and efficiency. In the presence of any abnormal condition or fault, alert notifications are generated and sent to the user through the IoT platform. This continuous monitoring and control process ensures improved battery safety, reliability, and efficient energy management in electric vehicle applications

This working principle follows a continuous closed-loop operation, integrating sensing, processing, control, and communication. This approach ensures uninterrupted monitoring, improved battery lifespan, and enhanced safety, making the proposed system suitable for electric vehicle applications. This constant monitoring and automated control not only improves battery lifespan but also enhances vehicle reliability and driver safety. Additionally, it allows real-time performance analysis, helping optimize energy usage and reduce maintenance issues. Overall, the system integrates sensing, control, and communication to provide a smarter and safer battery management solution for electric vehicles. Wireless charging allows the battery to receive power without physical connections while monitoring remains active. Users are instantly notified via the IoT platform if any unsafe condition occurs. This ensures reliable operation, extends battery life, and improves overall energy efficiency in electric vehicles. The proposed battery monitoring system employs embedded and cloud-based software to enable real-time data acquisition, processing, and remote monitoring. The ESP32 microcontroller is programmed using an Arduino-based ESP32 development environment that supports Embedded C/C++ programming and provides the necessary libraries for sensor interfacing and wireless communication. The embedded firmware performs continuous monitoring of battery voltage, current, and temperature, compares the measured values with predefined threshold limits, and controls protective components such as the relay and cooling fan during abnormal operating conditions.

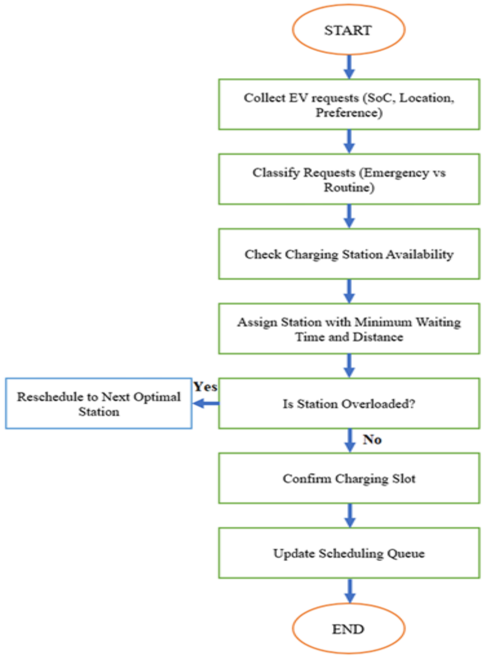


Fig 4: Flow Chart

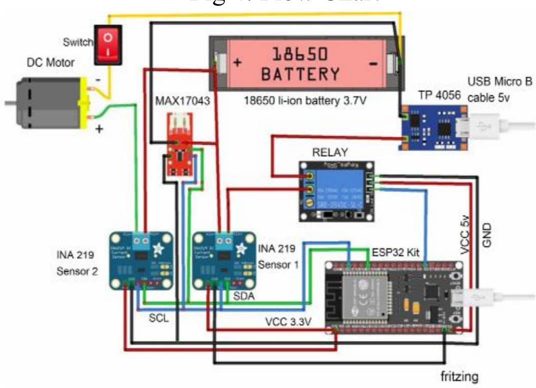


Fig 5: Circuit Diagram

Wireless communication is established using the built-in Wi-Fi module of the ESP32 to transmit battery parameters and system status to a cloud-based IoT platform. The IoT platform enables real-time visualization, data logging, and alert notification, thereby supporting remote monitoring and analysis. Standard communication and sensor libraries are utilized to ensure reliable operation and scalability of the proposed system.

## IV.EXPERIMENTAL RESULTS

The proposed IoT-based battery monitoring system was implemented and tested using an ESP32 microcontroller, voltage and current sensors, a temperature sensor, relay module, cooling fan, and a wireless power transfer charging unit. Experimental tests were conducted under different operating conditions to evaluate the performance of the monitoring, protection, and communication functionalities. During normal operating conditions, the system accurately measured battery voltage, current, and temperature in real time, and the data were successfully transmitted to the cloud-based IoT platform with minimal delay. The monitored parameters were displayed continuously, confirming reliable wireless communication and data logging. When the battery temperature exceeded the predefined threshold, the cooling fan was automatically activated, and the temperature was observed to reduce to safe levels, demonstrating effective thermal protection. Charging and discharging control was tested by varying the battery voltage levels. The relay module successfully disconnected the charging path when the voltage exceeded the safe limit and reconnected it when normal conditions were restored. Wireless power transfer charging was verified to operate without physical contact while maintaining continuous battery monitoring and protection.

Fault conditions triggered alert notifications, confirming proper system response. The experimental results demonstrate that the proposed system provides reliable battery monitoring, effective protection, and improved operational safety for electric vehicle applications.

## VI. RESULTS AND DISCUSSIONS

The proposed IoT-based battery monitoring system was experimentally implemented using an ESP32 microcontroller voltage and current sensors, a temperature sensor, a relay module, a cooling fan, and a wireless power transfer charging unit. The system was tested under various operating conditions to evaluate monitoring accuracy, protection response, and communication reliability. The experimental results show that the system successfully monitored battery voltage, current, and temperature in real time and transmitted the data to the cloud-based IoT platform with minimal latency. The measured parameters remained stable under normal operating conditions, demonstrating reliable sensor performance and effective data acquisition. When the battery temperature exceeded the predefined threshold, the cooling fan was automatically activated, resulting in a noticeable reduction in temperature and confirming effective thermal management. The charge–discharge control mechanism operated correctly by disconnecting the charging path when the battery voltage exceeded safe limits and restoring normal operation once the voltage returned to acceptable levels. Wireless power transfer charging was successfully achieved without physical connectors while maintaining continuous monitoring and protection. Fault conditions generated timely alert notifications, enabling prompt user awareness and corrective action. Overall, the results confirm that the proposed system enhances battery safety, operational reliability, and energy management efficiency, making it suitable for electric vehicle applications.

## VII.CONCLUSIONS & FUTURE WORK

An IoT-based smart battery monitoring system with integrated wireless power transfer has been presented for electric vehicle applications. The system continuously monitors battery voltage, current, and temperature using an ESP32 microcontroller and ensures safe operation through automatic control of charging, discharging, and cooling mechanisms. Real-time data transmission to a cloud-based IoT platform enables remote monitoring, alert generation, and data logging, thereby improving battery safety and energy management efficiency. In future, the proposed system can be extended by incorporating advanced battery health estimation techniques such as State of Charge and State of Health analysis, machine-learning-based fault prediction, improved wireless charging efficiency, and support for multi-battery configurations, making it more suitable for next-generation electric vehicle systems

## ACKNOWLEDGMENT

The authors express their sincere gratitude to the Principal, R.M.D Engineering College and thank all the teaching and non-teaching Faculty of Electronics and Communication Department, for their blessing and support throughout the dissertation. The authors gratefully acknowledge the moral support given by RMD IDEA Lab.

## REFERENCES

[1] A.Trivino, J. M. González-González, and J. A. Aguado, ‘‘Wireless power transfer technologies applied to electric vehicles: A review,’’ Energies, vol. 14, no. 6, p. 1547, Mar. 2021, doi: 10.3390/en 14061547.

[2] R. Tavakoli, T. Shabanian, E. M. Dede, C. Chou, and Z. Pantic, ‘‘EV misalignment estimation in DWPT systems utilizing the roadside charging pads,’’ IEEE Trans. Transport. Electrific., vol. 8, no. 1, pp. 752–766, Mar. 2022, doi: 10.1109/TTE.2021.3091969.

[3] A. Zakerian, S. Vaez-Zadeh, and A. Babaki, ‘‘A dynamic WPT system with high efficiency and high power factor for electric vehicles,’’ IEEE Trans. Power Electron., vol. 35, no. 7, pp. 6732–6740, Jul. 2020, doi: 10.1109/TPEL.2019.2957294.

[4] M. R. R. Razu, S. Mahmud, M. J. Ud2021din, S. S. Islam, B. Bais, N. Misran, and M. T. Islam, ‘‘Wireless charging of electric vehicle while driving,’’ IEEE Access, vol. 9, pp. 157973–157983,.

[5] S. Ghazizadeh, K. Ahmed, M. Seyedmahmoudian, S. Mekhilef, J. Chandran, and A. Stojcevski, ‘‘Critical analysis of simulation of misalignment in wireless charging of electric vehicles batteries,’’ Batteries, vol. 9, no. 2, p. 106, Feb. 2023, doi: 10.3390/batteries9020106.

[6] H.J. Bergveld, Battery Management Systems Design by Modeling, 2001, ISBN 9074445-51-9

[7] D. Bell, “A battery management system,” Master’s thesis, School Eng., Univ. Queensland, St. Lucia, Australia, 2000.

[8] Sandeep Dhameja, Electric Vehicle Battery Systems, 2002, ISBN 0-7506-9916-7.

[9] K. Shimitzu, N. Shirai, and M. Nihei, “On-board battery management system with SOC indicator,” in Proc. Int. Electric Vehicle Symp., vol. 2, 1996, pp. 99–104.

[10] Ng, K.S.; Moo, C.S.; Chen, Y.P.; Hsieh, Y.C. Enhanced coulomb counting method for estimating state-of-charge and state-of-health of lithium-ion batteries. Appl. Energy 2009, 86,1506–1511.

[11] Pattipati, B.; Pattipati, K.; Christopherson, J.P.; Namburu, S.M.; Prokhorov, D.V.; Qiao, L. Automotive Battery Management System. In Proceedings of IEEE AUTOTESTCON, Salt Lake City, UT, USA, 8–11 September 2008; pp. 581–586.