

The Wireless Enabled Intelligent Battery Health And Performance Monitoring System

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Abstract- This paper presents the use of Wireless technology to monitor various parameters of an electric vehicle's battery. Since electric vehicles rely entirely on battery power, ensuring the battery's health and performance is crucial. The proposed system aims to simplify the process of monitoring battery performance through Wireless-based solutions, allowing for real-time and remote tracking. The primary goal is to support green energy initiatives and enhance the intelligence of electric vehicles by keeping track of battery metrics such as voltage, temperature, current, and available charge. These parameters are uploaded to the cloud, incorporating the principles of the Internet of Things (Wireless). The Wireless-based battery monitoring system is composed of two main components: (i) a monitoring device and (ii) a user interface. Experimental results demonstrate that the system effectively tracks and reports battery performance. The increasing adoption of electric vehicles (EVs) necessitates efficient and reliable battery management systems to ensure optimal performance, safety, and longevity. This project focuses on the design and development of an Wireless-based Efficient Battery Monitoring System (BMS) for EVs. The BMS is comprised of a network of battery sensors, microcontrollers, wireless communication modules, and cloud-based analytics. These components work together to provide accurate and real-time insights into the battery's health and performance, ultimately enhancing EV reliability and user experience. This innovative approach not only improves battery management but also contributes to the overall sustainability of electric transportation by extending battery life and reducing downtime. In recent years, the demand for reliable, efficient, and intelligent energy storage systems has grown rapidly with the widespread use of electric vehicles, renewable energy systems, and portable electronics. This project Wireless Enabled Intelligent Battery Health and Performance Monitoring presents a smart system designed to monitor critical battery parameters such as voltage, current, temperature, and state of charge in real time. The system employs embedded sensors and a microcontroller-based data acquisition unit that continuously gathers battery performance data. Using wireless communication technologies such as Wi-Fi or Bluetooth, the collected information is transmitted to a central monitoring platform or a mobile application, allowing users to remotely access and analyze battery status.

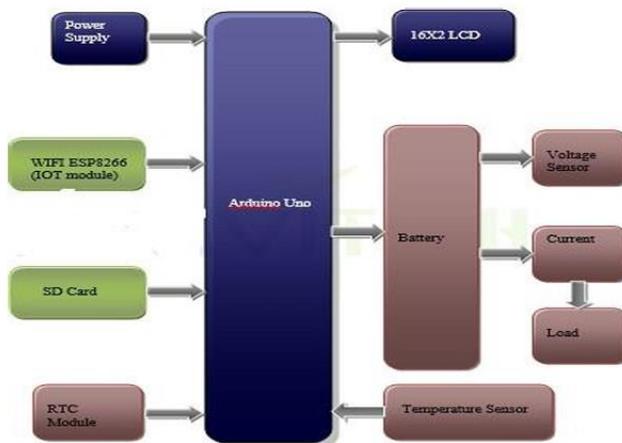
Keywords- Battery health monitoring, wireless communication, Wireless, state of charge (SOC), state of health (SOH), microcontroller, predictive maintenance, smart energy system

I. INTRODUCTION

The global transition toward electrification and renewable energy integration has intensified the need for efficient, intelligent, and reliable battery monitoring systems. Batteries serve as the cornerstone of modern energy ecosystems—powering electric vehicles (EVs), renewable energy storage systems, smart grids, and portable electronic devices. However, the performance, reliability, and safety of these energy storage systems heavily depend on the continuous assessment of battery health and operational conditions. Conventional Battery Management Systems (BMS), while effective in basic monitoring and protection, face major challenges such as wiring complexity, data latency, limited scalability, and the inability to perform predictive diagnostics. Traditional wired BMS architectures often require complex harnesses to connect multiple sensing nodes to a central controller, increasing system weight, cost, and vulnerability to signal degradation or mechanical failure. In contrast, a wireless-enabled BMS eliminates physical interconnections by employing Wireless Sensor Networks (WSN) that transmit real-time data such as voltage, current, temperature, and internal resistance to a central gateway. The removal of wired constraints also reduces maintenance overhead and enhances system reliability in harsh or dynamic environment. Electric vehicles (EVs) are steadily becoming a significant force in the transportation industry. Their appeal lies in being environmentally friendly, as they produce zero emissions—making them an ideal solution for reducing pollution. With the rising cost of traditional fuels, battery-powered vehicles are gaining popularity. As a result, automakers are actively seeking alternative energy sources to replace gasoline. Utilizing electric energy not only supports environmental protection efforts but also aligns with sustainable development goals. Most electric vehicles rely on rechargeable lithium-ion batteries, which are more compact and efficient compared to conventional lead-acid batteries. However, the lifespan of lithium-ion batteries can be

negatively affected by conditions such as overcharging and deep discharging. Another major limitation of EVs is their restricted travel range, influenced by battery capacity and vehicle design. Safety concerns related to current battery technologies also hinder wider adoption. From a consumer perspective, one of the most pressing issues is the limited battery capacity and the lack of widespread charging infrastructure. These challenges contribute to range anxiety, where drivers hesitate to use EVs for long-distance travel. These concerns often outweigh even the cost of the vehicle or its battery. Despite advancements in battery technologies, such barriers continue to limit EV adoption. Overall, the Wireless Enabled Intelligent Battery Health and Performance Monitoring System represents a significant advancement in energy storage technology. It not only provides real-time, accurate, and non-intrusive monitoring but also enables predictive maintenance, fault detection, and performance optimization. This intelligent approach aligns with the goals of Industry 4.0 and smart energy systems, paving the way for sustainable, efficient, and autonomous power solutions in the era of digital energy transformation.

remote and wireless monitoring of battery systems. Using communication technologies such as Wi-Fi or Bluetooth, the system will transmit data to a mobile or web-based platform where users can conveniently access real-time battery information. This eliminates the need for manual inspection and complex wiring systems, making the solution efficient and easy to deploy. The wireless interface will also facilitate early fault detection and instant alerts in case of abnormal operating conditions, such as overheating, overcharging, or deep discharging. Furthermore, the project aims to integrate intelligent diagnostic algorithms to evaluate the battery's state of health (SOH) and predict future performance trends. This predictive capability will help in optimizing charging cycles, reducing maintenance costs, and extending battery life. The ultimate goal is to develop a reliable, scalable, and cost-effective solution that can be applied in electric vehicles, renewable energy systems, and portable electronic devices. Through this intelligent monitoring approach, the project contributes to advancing smart energy management systems and promoting sustainable, safe, and efficient battery utilization in modern technological applications.



4.1 Block Diagram of Proposed System

II. AIM AND OBJECTIVES

The main aim of this project, “Wireless Enabled Intelligent Battery Health and Performance Monitoring,” is to design and develop a smart, real-time system capable of continuously monitoring the condition and performance of rechargeable batteries using wireless communication technology. The system seeks to enhance battery reliability, safety, and lifespan by providing accurate information about essential parameters such as voltage, current, temperature, and state of charge (SOC). By collecting and analyzing this data intelligently, the project aims to prevent unexpected battery failures and ensure optimal performance across various applications. Another key objective of the project is to enable

Objective of the Paper

The primary objective of this project is to develop a wireless and intelligent system capable of monitoring the health and performance of batteries in real time. The system aims to collect vital parameters such as voltage, current, temperature, and state of charge (SOC) using suitable sensors. This data will be processed by a microcontroller and transmitted wirelessly to a user interface. By continuously observing these parameters, the system will help users understand the operating condition of the battery and take necessary actions to prevent damage or failure. Another major objective is to implement wireless communication technology to allow remote battery monitoring. Using Wi-Fi or Bluetooth modules, the system will send data to a mobile application or computer dashboard. This eliminates the need for manual inspection and allows real time tracking of battery performance from anywhere. The wireless feature also makes the system flexible and suitable for applications in electric vehicles, solar energy storage, and other portable devices. The project also focuses on integrating intelligent algorithms to estimate the state of health (SOH) and predict battery degradation patterns. By analyzing the collected data, the system will be able to provide early warnings of faults such as overcharging, overheating, or deep discharging. This predictive maintenance capability helps extend battery lifespan, improve safety, and reduce maintenance costs. Finally, the project aims to create a cost-effective, reliable, and user-friendly solution that contributes to efficient energy management. The system should be easy to install, scalable,

and adaptable to different battery technologies. Through these objectives, the project supports the development of smarter and more sustainable energy systems for modern industrial and consumer applications.

Existing System

In the existing battery monitoring systems, battery performance and health assessment are primarily carried out using wired monitoring setups or manual testing methods. These systems typically rely on basic measuring instruments such as voltmeters, ammeters, and temperature sensors connected through physical wiring to a local display or control unit. The data collected is either manually recorded or displayed locally, offering limited functionality in terms of real-time monitoring, remote access, and predictive analysis. Most conventional systems lack wireless communication capabilities, resulting in difficulties when monitoring large or distributed battery banks, such as those used in electric vehicles, renewable energy storage systems, or telecommunications backup units. Technically, the existing systems are often built around simple microcontroller-based platforms like Arduino Uno or PIC controllers that collect data from analog sensors. Voltage sensors (0–25 V range) and current sensors (ACS712 type, ± 30 A range) are commonly used to measure battery characteristics. The temperature is typically monitored using LM35 or thermistor sensors. The acquired data is displayed on a small LCD module (16×2 or 20×4) or transmitted via serial communication to a computer for analysis. However, these systems are not designed for wireless communication or remote monitoring. They also lack advanced data processing capabilities, such as filtering, data logging, or fault prediction. Moreover, existing systems generally do not include intelligent algorithms for estimating State of Charge (SOC) or State of Health (SOH). SOC is often estimated manually or through fixed lookup tables, which do not adapt to changing load or environmental conditions. As a result, these systems fail to provide accurate and dynamic assessments of battery health. Additionally, they are not capable of generating automatic alerts during abnormal conditions like overcharging, deep discharge, or thermal runaway, which increases the risk of damage or failure. From a system design perspective, the wired configuration of the existing setup introduces limitations in scalability and maintenance. It increases installation complexity and is unsuitable for mobile or large-scale applications. The absence of wireless connectivity, cloud integration, and predictive analytics restricts their use in modern intelligent energy systems. Therefore, while the existing systems can measure basic parameters effectively, they fall short in providing real-time, wireless, and intelligent monitoring required for high-performance and safety critical applications. These drawbacks

highlight the necessity for an advanced, wireless-enabled intelligent monitoring system that ensures accuracy, safety, and improved energy efficiency. This method is used either when charging the transmission line, or, when there is very low load at the receiving end. Due to very low or no load a very low current flows through the transmission line. Shunt capacitance in the transmission line cause Ferranti Effect. The receiving end voltage may become double the sending end voltage (generally in case of very long transmission lines). To compensate, shunt inductors are connected across the transmission line.

Arduino UNO (Microcontroller)

The analog signals from the voltage, current, and temperature sensors are fed into the Arduino's Analog-to-Digital Converter (ADC) pins. The microcontroller digitizes these inputs, processes them using programmed logic, and calculates parameters such as State of Charge (SOC) and State of Health (SOH). It then sends the processed data to the NodeMCU for wireless transmission and drives the LCD, LED, Buzzer, and Relay as per defined safety and monitoring protocols.



Fig.4.3 Arduino UNO (Microcontroller)

III. METHODOLOGY

The methodology for the Wireless Enabled Intelligent Battery Health and Performance Monitoring System involves a systematic approach to the design, development, and implementation of both hardware and software components to achieve real-time, accurate, and intelligent monitoring of battery performance. The system architecture consists of four major stages: data acquisition, data processing, wireless communication, and intelligent analysis with user interfacing. The data acquisition stage utilizes high-precision sensors to measure key electrical and thermal parameters of the battery such as voltage, current, and temperature. A voltage sensor (0–25V range) and current sensor (ACS712 type, ± 30 A range) are interfaced with a

microcontroller unit (MCU) such as ESP32, which is selected for its integrated Wi-Fi and Bluetooth capabilities, dual-core processor, and high ADC resolution for accurate analog signal conversion. The temperature is monitored using an LM35 or DS18B20 digital temperature sensor, providing precise thermal readings essential for evaluating battery health and safety. The raw sensor data are conditioned through appropriate filtering and scaling circuits to minimize noise and measurement errors before being processed by the MCU. The wireless communication stage enables seamless transmission of the processed data to a remote monitoring device through Wi-Fi or Bluetooth. The ESP32's onboard Wi-Fi module connects the system to a cloud server or a local network, while Bluetooth Low Energy (BLE) is used for short-range communication with a smartphone application. The transmitted data are visualized on a mobile or web-based dashboard, developed using platforms such as Blynk, ThingSpeak, or a custom-built IoT interface, where users can view real-time voltage, current, temperature, SOC, and historical performance trends.

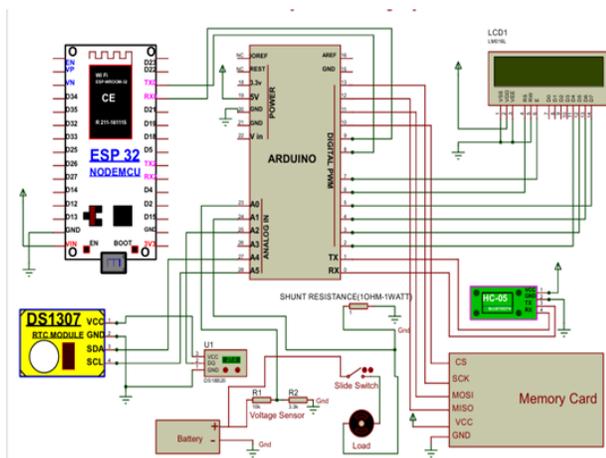


Fig. 5.1 System Design and Layout

The system design is based on a modular, layered architecture that divides the entire setup into functional units for sensing, processing, communication, and display. This modularity enhances scalability, simplifies debugging, and ensures compatibility with diverse battery chemistries (e.g., Li-ion, Lead-acid, or NiMH).

IV. CONCLUSION

The Wireless Enabled Intelligent Battery Health and Performance Monitoring System (WEIBHPMS) represents a significant technological advancement in the field of battery management and energy monitoring. By integrating embedded control, Wireless communication, and intelligent data analytics, the system provides a comprehensive solution for

real-time, accurate, and wireless supervision of critical battery parameters such as voltage, current, temperature, State of Charge (SOC), and State of Health (SOH). This innovation addresses the limitations of traditional battery monitoring systems, which often rely on manual inspection, wired data collection, and delayed fault detection.

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