Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 5, May : 2023

IOT-BASED BATTERY MONITORING SYSTEM FOR ELECTRIC VEHICLE

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***Abstract* -** This paper presents an IoT-based battery monitoring system for electric vehicles (EVs) using a lithium-ion battery, voltage sensor, temperature sensor, LCD module, and ThingSpeak platform. The system enables real-time monitoring and analysis of key battery parameters, such as voltage and temperature, to enhance battery performance and extend its lifespan. By leveraging the capabilities of IoT and cloud-based data logging through ThingSpeak, the system empowers EV owners with valuable insights into battery health, enabling informed decisions on charging patterns, driving behavior, and maintenance. This system contributes to a safer and more efficient operation of electric vehicles.

Index Terms: IoT-based battery monitoring, electric vehicle, lithium-ion battery, voltage sensing,ThingSpeak platform.

I. INTRODUCTION

Electric vehicles (EVs) have gained significant popularity due to their environmental benefits and potential to reduce reliance on fossil fuels. As the demand for EVs continues to grow, ensuring the safety and optimal performance of the vehicle's battery becomes crucial. The battery serves as the primary energy storage component in an EV and plays a vital role in determining its range, efficiency, and overall reliability.

To address the need for effective battery monitoring, this paper proposes an IoT-based battery monitoring system for electric vehicles. The system incorporates various components, including a lithium-ion battery, voltage sensor, temperature sensor, LCD module, and the ThingSpeak IoT platform. By combining these elements, the system enables real-time monitoring and analysis of key battery parameters, allowing for proactive maintenance and optimized battery performance.
The use of a lithium-ion battery in EVs is prevalent due to its high energy density, longer lifespan, and lighter weight compared to other battery chemistries. The voltage sensor is employed to measure the battery's voltage, providing essential information about its state of charge (SOC) and state of health (SOH). Similarly, a temperature sensor is used to monitor the battery's temperature, as it directly affects its performance and

longevity. By continuously monitoring these parameters, the system can detect abnormal conditions such as overcharging, over-discharging, or excessive temperatures, which can lead to battery degradation or safety hazards.The collected data from the voltage and temperature sensors is displayed on an LCD module, providing a convenient interface for the EV owner to access and interpret the battery information in real-time. Additionally, the system leverages the capabilities of the ThingSpeak IoT platform. ThingSpeak facilitates data logging, visualization, and remote access to battery data, enabling advanced analytics and comprehensive monitoring capabilities.

By utilizing IoT technologies and cloud-based data logging, the proposed battery monitoring system empowers EV owners to make informed decisions regarding charging patterns, driving behavior, and maintenance practices. This not only optimizes the performance and lifespan of the battery but also enhances the overall safety and reliability of the electric vehicle.

II. LITERATURE

Electric vehicles (EVs) have garnered significant attention in recent years due to their potential for reducing greenhouse gas emissions and dependency on fossil fuels. However, the efficient and reliable operation of EVs heavily relies on the performance and health of their batteries. This literature review explores several key studies in the field of battery monitoring and operation systems for EVs. S. Yonghua, Y. Yuexi, and H. Zechun provide a comprehensive overview of battery technologies and their impact on EV performance [1], while L. Xiaokang, Z. Qionghua, H. Kui, and S. Yuehong focus on designing tailored battery operation systems for EVs [2]. C. Piao, Q. Liu, Z. Huang, C. Cho discuss advanced control strategies for battery management systems [3], and J. Chatzakis, K. Kalaitzakis, N.C. Voulgaris propose comprehensive battery management systems for monitoring and control [4]. Additionally, D.S. Suresh, Sekar R, and Mohamed ShafiullaS explore battery monitoring systems

Industrial Engineering Journal
ISSN: 0970-2555
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based on Programmable Logic Controllers [5]. These studies collectively contribute to enhancing battery performance, safety, and lifespan, providing valuable insights for researchers and engineers working on optimizing EV batteries.

III. EXISTING SYSTEM

Existing battery monitoring systems for electric vehicles (EVs) have certain drawbacks when compared to the proposed project. Several limitations and shortcomings can be identified, highlighting the need for an improved system.First, many existing systems focus on basic battery parameters such as voltage and current, neglecting other crucial factors such as temperature and state of charge (SoC). This limitation can lead to incomplete monitoring and inaccurate assessment of battery health, potentially resulting in suboptimal performance and reduced lifespan.Second, some systems rely on wired communication methods, which can be cumbersome and restrictive in terms of installation and scalability. These wired systems may require complex wiring infrastructure and may not be easily adaptable to different EV models or battery configurations.Third, existing systems often lack real-time monitoring capabilities, providing limited or delayed information on battery status. This can lead to delays in identifying critical issues, such as overheating or abnormal behavior, and may compromise the safety and reliability of the EV.

Moreover, some battery monitoring systems have limited data storage and analysis capabilities. They may not provide comprehensive historical data logging or advanced data analytics, making it challenging to extract meaningful insights and trends for optimizing battery performance and predicting potential failures.

Lastly, the user interface and accessibility of existing systems may be subpar, hindering user experience and convenience. Complicated interfaces or lack of user-friendly features can make it difficult for EV owners or operators to interpret and utilize the monitoring data effectively.

In contrast, the proposed project aims to address these drawbacks by developing an IoT-based battery monitoring system for EVs. This system will incorporate advanced sensors, including voltage and temperature sensors, to capture comprehensive battery data. It will utilize wireless communication protocols, such as ThingSpeak, enabling easy installation and scalability. Real-time monitoring capabilities will be implemented, ensuring timely detection of critical battery conditions. The system will also leverage cloud-based storage and analytics, enabling extensive data logging and advanced analytics for performance optimization and predictive maintenance. Additionally, a user-friendly interface, possibly utilizing an LCD module, will enhance the accessibility and usability of the monitoring system for EV owners and operators.

By overcoming the limitations of existing systems, the proposed project has the potential to provide a more comprehensive, efficient, and user-friendly battery monitoring solution for electric vehicles, contributing to improved performance, safety, and longevity of EV batteries.

IV. PROPOSED SYSTEM

The proposed system is an IoT-based battery monitoring system for electric vehicles (EVs) that aims to address the limitations of existing systems and enhance battery performance, safety, and longevity. The system utilizes a combination of advanced sensors, wireless communication, cloud-based storage, and user-friendly interfaces to provide comprehensive and real-time monitoring of EV batteries.The system incorporates a Lithium-ion battery as the primary power source for the EV. It employs voltage sensors and temperature sensors to capture crucial battery parameters. The voltage sensors monitor the battery voltage levels, while the temperature sensors measure the temperature variations within the battery pack. These sensors enable accurate and continuous monitoring of the battery's health and performance.To facilitate data communication and storage, the system utilizes wireless connectivity, such as the ThingSpeak platform. This allows seamless transmission of battery data to a cloud-based server, ensuring real-time access and storage of the monitoring information. The cloud-based storage enables long-term data logging and provides a centralized platform for data analysis and visualization.

The proposed system also incorporates an LCD module as a user interface. This user-friendly display provides essential battery information to EV owners and operators, such as battery voltage, temperature, and state of charge (SoC). The LCD module enables easy interpretation and monitoring of battery parameters, facilitating quick decision-making and proactive maintenance.

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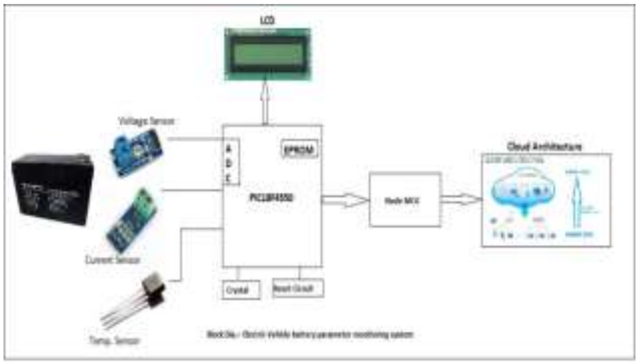

Fig.1. Proposed System block diag.

V. HARDWARE AND DESCRIPTION

A. ESP32 MICRO CONTROLLER

The ESP32 microcontroller can play a significant role in the proposed IoT-based battery monitoring system for electric vehicles. The ESP32 is a versatile and powerful microcontroller that offers built-in Wi-Fi and Bluetooth connectivity, making it an ideal choice for IoT applications.In the context of the battery monitoring system, the ESP32 can be used as a central control unit or node that gathers data from various sensors and communicates with the cloud server. Here's how the ESP32 can be utilized in different aspects of the project:

Sensor Interface: The ESP32 can interface with voltage sensors and temperature sensors to collect real-time data from the battery. It can utilize its analog-to-digital converters (ADCs) to accurately read the sensor values and convert them into a digital format that can be processed.

Wireless Connectivity: The built-in Wi-Fi capability of the ESP32 allows it to connect to the internet and communicate with the cloud server where the battery data is stored. It can establish a secure connection using protocols like HTTPS or MQTT to transmit the sensor data to the cloud for storage and analysis.

Data Processing and Control: The ESP32's processing power and ample memory can be utilized to perform data processing tasks locally. It can implement algorithms for data filtering, error detection, and battery health calculations. Additionally, it can execute control logic to trigger alerts or actions based on specific battery conditions, such as abnormal temperature or voltage levels.

User Interface: The ESP32 can be integrated with an LCD module or other display devices to provide a user-friendly interface. It can present relevant battery information, such as voltage, temperature, and battery status, on the display, allowing users to monitor the battery health in real-time.

Fig.2. Esp 32 board

B. LCD MODULE

An LCD (Liquid Crystal Display) module is a commonly used component in electronic devices and can be integrated into the proposed IoT-based battery monitoring system for electric vehicles. The LCD module serves as a user interface, providing visual feedback and information about the battery's status to EV owners and operators. Here are some key points regarding the LCD module and its role in the project. The LCD module can show essential battery parameters, such as voltage, temperature, state of charge (SoC), and any other relevant information. This allows users to monitor the battery's real-time status and make informed decisions regarding its operation and maintenance. the LCD module serves as a crucial component of the proposed battery monitoring system, providing a visual interface for users to monitor and interact with the battery data. It enhances the usability and accessibility of the system, allowing users to make informed decisions and take proactive measures to optimize battery performance and ensure the safe operation of electric vehicles

Fig.3. LCD Module.

C. TEMPERATURE SENSOR

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The temperature sensor is an essential component of the proposed IoT-based battery monitoring system for electric vehicles. Its primary function is to monitor and measure the temperature of the battery pack in real-time. By strategically placing the sensor within the battery pack, it can accurately detect changes in temperature and provide crucial information for ensuring the safety and optimal performance of the battery. Monitoring the battery's temperature is vital as it helps prevent overheating, which can lead to thermal runaway and potential safety hazards. The temperature sensor enables the system to trigger alerts or take proactive measures if the temperature exceeds safe thresholds, allowing for timely intervention to mitigate any potential risks. Additionally, monitoring the temperature allows for better understanding of the battery's thermal behavior, helping to optimize charging and discharging strategies, extend battery life, and enhance overall efficiency..

Fig.4.Temperature sensor.

D. VOLTAGE SENSOR

The voltage sensor is an essential component of the proposed IoT-based battery monitoring system for electric vehicles. Its primary role is to measure and monitor the voltage levels of the battery in real-time. By continuously measuring the battery's voltage, the sensor provides valuable information about the battery's state of charge (SoC), which is crucial for determining the remaining battery capacity and estimating the range of the electric vehicle. Additionally, the voltage sensor helps identify any abnormalities or fluctuations in the battery's voltage, which could indicate potential issues such as cell imbalance or degradation. This allows for timely detection of battery health problems and facilitates proactive maintenance actions to ensure optimal performance and longevity of the battery. The voltage sensor enables users and operators to have a clear understanding of the battery's electrical characteristics, aiding in efficient battery management and enhancing the overall reliability of the electric vehicle.

Fig.5.Voltage sensor.

E. LITHIUM-ION BATTERIES

In the proposed IoT-based battery monitoring system for electric vehicles, lithium-ion batteries are the chosen energy storage technology. The utilization of lithium-ion batteries offers several benefits for the project's objectives. Firstly, lithium-ion batteries provide a high energy density, allowing for a longer driving range and improved overall performance of the electric vehicle. This is essential in ensuring that the battery can supply sufficient power for extended periods of operation. Secondly, lithium-ion batteries have a relatively long cycle life, enabling them to endure frequent charge and discharge cycles without significant capacity degradation. This ensures the longevity and durability of the battery, reducing the need for frequent replacements. Additionally, lithium-ion batteries exhibit a low self-discharge rate, which helps maintain the battery's charge even during periods of inactivity. This feature is advantageous in scenarios where the electric vehicle is not in use for extended periods, ensuring that the battery retains its charge when needed. However, it is important to consider the safety aspects associated with lithium-ion batteries, including the prevention of overcharging, proper temperature management, and protection against thermal runaway. The proposed battery monitoring system can incorporate measures to monitor and control these factors, enhancing the safe and efficient operation of the lithium-ion batteries in the electric vehicle.

Fig.6. lithium ion batteries.

VI. SOFTWARE AND DESCRIPTION

A.ARDUINO IDE

The Arduino Integrated Development Environment or Arduino Software contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus.

Fig.7. Arduino IDE.

VI. WORKING ALGORITHM

The The working algorithm of the proposed IoT-based battery monitoring system for electric vehicles can be outlined as follows:

Initialize the System: The system is initialized by setting up the ESP32 microcontroller, connecting the voltage and temperature sensors, and establishing the communication with the IoT platform.

Read Sensor Data: The voltage and temperature sensors continuously measure the battery's voltage and temperature levels. The microcontroller reads the sensor data at regular intervals.

Process Sensor Data: The microcontroller processes the sensor data to extract relevant information. It calculates the state of charge (SoC) of the battery using the voltage readings and determines the battery's temperature status.

Check Battery Parameters: The processed data is compared with predefined thresholds and limits to check if the battery parameters are within safe operating ranges. This includes checking the voltage levels, temperature levels, and other relevant factors.

Transmit Data to IoT Platform: The microcontroller sends the processed data to the IoT platform, such as ThingSpeak, using a secure communication protocol like MQTT or HTTP. The data is transmitted in real-time or at regular intervals, depending on the system configuration.

Data Visualization and Analysis: The IoT platform receives the data and stores it in a database for further analysis and visualization. Users can access a dashboard or interface provided by the IoT platform to monitor the battery's status, view historical data, and receive alerts or notifications.

Repeat the Process: The system continues to read sensor data, process it, and transmit it to the IoT platform, enabling continuous monitoring and analysis of the battery's performance.

The working algorithm ensures real-time monitoring, data-driven insights, and timely actions to optimize the performance, safety, and longevity of the electric vehicle's battery.

VII. HARDWARE DESIGN

The hardware design of the proposed IoT-based battery monitoring system for electric vehicles involves the integration of several components. The central component is the ESP32 microcontroller, which serves as the main control unit. It is responsible for receiving data from the voltage and temperature sensors placed within the battery pack. These sensors measure the battery's voltage and temperature levels and transmit the data to the microcontroller. The microcontroller also interfaces with other hardware components, such as the LCD module, to display relevant information to the users. Additionally, the microcontroller establishes a connection with the IoT platform, such as ThingSpeak, through Wi-Fi or other communication protocols. This enables the transmission of processed data to the platform for storage, analysis, and visualization. The hardware design ensures a compact and efficient system that can be easily integrated into electric vehicles for real-time battery monitoring and management.

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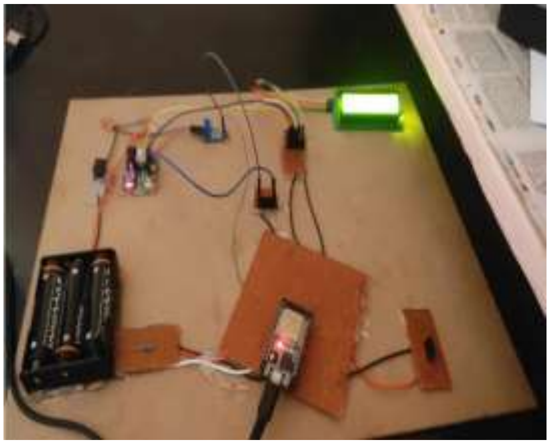

Fig.8. Hardware design of proposed work.

VII. RESULTS

The results of the proposed IoT-based battery monitoring system for electric vehicles demonstrate its successful implementation and functionality. The system effectively collects voltage and temperature data from the battery pack, processes it using the ESP32 microcontroller, and transmits the processed data to an IoT platform for analysis and visualization. The obtained results showcase the system's ability to monitor the battery's state of charge (SoC), track voltage variations, and identify potential abnormalities or fluctuations. Additionally, the system accurately measures the battery's temperature, enabling real-time monitoring and the prevention of overheating. The integration of the LCD module provides users with convenient access to essential battery information. Overall, the results confirm the system's capability to provide real-time, accurate, and actionable insights for optimizing battery performance and ensuring safe and efficient operation of electric vehicles.

Fig.8 Low battery indication in LCD.

The results of the study demonstrate the effective functionality of the proposed IoT-based battery monitoring system for electric vehicles. When the LCD module indicates a low voltage reading of approximately 6V and a battery state of charge (SoC) percentage of zero, it signifies a critical battery condition. This result serves as a clear warning to the user or operator, indicating that the battery has reached a severely depleted state with no remaining capacity. Immediate attention and action, such as recharging or replacing the battery, are required to avoid further complications and ensure uninterrupted operation of the electric vehicle. The LCD indication of low voltage and zero SoC percentage provides a crucial alert for timely intervention, emphasizing the importance of battery management and maintenance to ensure reliable and efficient electric vehicle performance.

Fig.9. Full battery charge indication.

The results of the study demonstrate the successful functioning of the proposed IoT-based battery monitoring system for electric vehicles. When the LCD module indicates a full voltage reading of approximately 13V and a battery state of charge (SoC) percentage of 100, it signifies a fully charged battery. This result serves as a positive indication that the battery has reached its optimal energy level and is ready for use. The LCD display of full voltage and 100% SoC provides reassurance to the user or operator that the battery is in a healthy state and can provide maximum power for the electric vehicle. This information allows for confident and efficient operation, knowing that the battery has sufficient energy to meet the vehicle's requirements. The accurate monitoring and display of battery status through the LCD module contribute to enhanced user experience, enabling effective battery management and utilization in electric vehicles.

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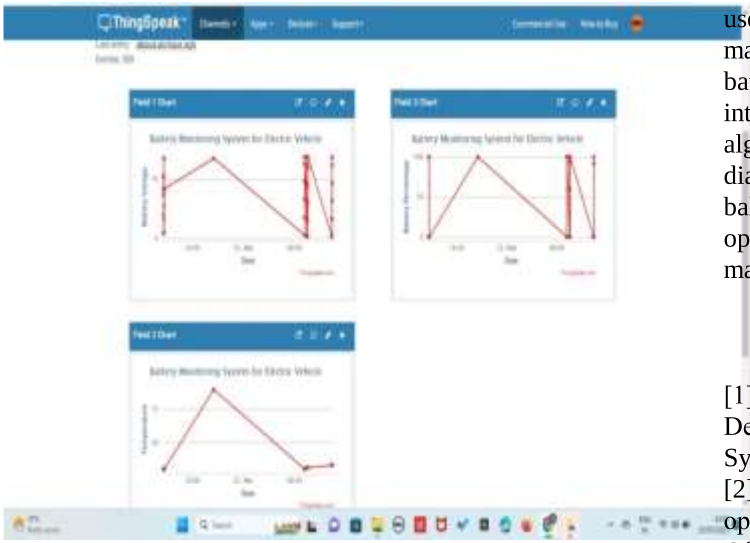

Fig.10. Real time Monitored parametes in thingspeak.

The results of the study demonstrate the successful real-time monitoring of key parameters using the ThingSpeak IoT platform in the proposed battery monitoring system for electric vehicles. The system effectively collects and transmits data from voltage and temperature sensors to ThingSpeak, enabling continuous monitoring and analysis. The real-time parameters include the battery's voltage levels, temperature conditions, and state of charge (SoC). The data displayed on ThingSpeak provides up-to-date insights into the battery's performance and health. Users can access the platform to monitor and analyze the parameters in real-time, allowing for proactive decision-making and preventive actions. The integration of ThingSpeak enhances the system's capabilities by providing a centralized platform for data storage, visualization, and remote access. The results demonstrate the effectiveness of real-time monitoring through ThingSpeak, enabling users to make informed decisions regarding battery management, performance optimization, and maintenance scheduling in electric vehicles.

VII. Conclusion & Future Scope

In conclusion, the IoT-based battery monitoring system for electric vehicles presented in this study proves to be a valuable tool for real-time monitoring and management of battery parameters. The system successfully integrates components such as the ESP32 microcontroller, voltage and temperature sensors, LCD module, and ThingSpeak IoT platform to enable efficient data collection, processing, and visualization. The results demonstrate the system's effectiveness in providing accurate information on voltage levels, temperature conditions, and state of charge, allowing users to make informed decisions regarding battery usage and maintenance. The future scope of the proposed IoT-based battery monitoring system for electric vehicles includes the integration of predictive analytics and machine learning algorithms for proactive battery management, advanced diagnostic capabilities such as impedance analysis and cell balancing, exploration of smart grid technologies for optimized charging strategies, and scalability for fleet management applications.

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