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DEVELOPMENT OF IOT BASED BATTERY MANAGEMENT SYSTEM FOR ELECTRIC VEHICLES

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Abstract: This paper presents the development of an IoT-based Battery Management System for real-time monitoring of battery parameters. The proposed system continuously measures battery temperature and voltage using appropriate sensors interfaced with an Arduino Uno microcontroller. The sensed data is uploaded to the Thing Speak cloud platform for real-time visualization and remote monitoring. A threshold-based buzzer alert mechanism is implemented to provide immediate warning during abnormal temperature rise, ensuring battery safety. The temperature sensor used in the system provides an accuracy of ±0.5 °C. The cloud update interval is set to 15 seconds, with an average communication latency of approximately 2–3 seconds. Experimental results demonstrate reliable data acquisition, stable cloud communication, and effective alert generation, making the system suitable for low-cost battery monitoring applications.

Keywords: IoT, battery management, electric vehicle, monitoring, sensors, cloud, analytics, efficiency, sustainability, performance.

I. INTRODUCTION

Electric vehicles (EVs) serve a significant role in enabling clean and sustainable transportation. They generate zero emissions, deliver improved energy efficiency, and decrease reliance on fossil fuels. However, the restricted driving range of EVs relies on battery condition and capacity, making battery monitoring crucial. This paper presents an IoT-based battery monitoring system for EVs. The system employs sensors, a microcontroller, and a wireless module to acquire data on battery voltage, current, and temperature. The data is transmitted to a cloud server for analysis, enabling real-time insights into battery performance and health. This supports optimised battery usage, extends lifespan, and estimates the remaining driving range.

II. LITERATURE SURVEY

The increasing complexity and performance demands of electric vehicle (EV) batteries have led researchers to explore IoT-enhanced Battery Management Systems (BMS) as a solution to ensure reliability, safety, and efficiency. This section presents a survey of key contributions from recent literature.

Cui et al. [1] provided a comprehensive review of conventional BMS architectures and highlighted their limitations in real- time data acquisition and maintenance prediction. They proposed that integrating IoT could simplify wiring architecture and enable proactive diagnostics, particularly by enhancing communication between sensing units and central controllers.

Kim and Lee [2] designed an IoT-based BMS framework focused on both hardware and software components. Their architecture enabled remote monitoring of EV batteries via wireless technologies and addressed issues such as overcharging, temperature rise, and uneven cell balancing. They emphasized the role of modular BMS design and sensor fusion for practical deployment.

Wang et al. [3] investigated the combination of Artificial Intelligence (AI) with IoT-enabled BMS to improve the accuracy of SoC and SoH estimation. They demonstrated that AI algorithms can identify degradation trends earlier than rule- based systems, allowing predictive maintenance and longer battery life. Their study also included a robust simulation environment for testing algorithm performance.

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Yoo et al. [4] proposed a layered IoT-based BMS architecture consisting of three levels: sensing, communication, and application. The system demonstrated effective data management through cloud services and included features such as mobile alerts, visual dashboards, and historical analysis tools. Their work stressed the importance of scalability and fault tolerance in commercial BMS deployments.

Zhao et al. [5] explored the integration of cloud computing and cyber security protocols into BMS design. They argued that large-scale EV deployments require secure and scalable data transmission, especially when multiple EVs are managed in fleet operations. Their model incorporated secure APIs, encryption, and distributed storage systems to protect BMS integrity in IoT environments.

Collectively, these studies validate the feasibility and necessity of IoT-enabled BMS for real-time monitoring, fault detection, predictive analytics, and cloud integration. However, gaps remain in standardization, low-power communication, and cost-effective implementation—areas that future research must address.

III. SCOPE OF PROJECT

For the large-scale adoption of electric vehicles, the development of efficient and reliable battery management systems along with thermal hazard mitigation solutions is necessary. Existing studies indicate that multi-objective optimization techniques, hybrid approaches involving machine learning, and sensor fusion methods combined with thermal management systems, cooling strategies, and fire- resistant protective coatings are feasible directions to consider. The integration of these advancements will enhance the safety, reliability, and operational lifetime of electric vehicle battery systems. Lead acid batteries presently function as the primary energy source in electric vehicles. In an electric vehicle, typical battery pack voltages range between 300 and 800 volts. Since batteries constitute a substantial portion of an electric vehicle's overall weight, regulating pack voltages is important to ensure maximum battery safety. The Battery Management System (BMS) is required to provide sufficient protection to prevent overheating of EV batteries. The BMS is essential not only for the safe functioning of electric vehicles, but also for autonomous operation.

IV. PROBLEM STATEMENT

Despite the growing adoption of Electric Vehicles (EVs), conventional Battery Management Systems (BMS) exhibit several limitations. Major concerns include inadequate thermal control that raises overheating risks, absence of real-time monitoring for parameters, and unpredictable battery degradation caused by improper charge and discharge cycles. Furthermore, traditional systems commonly lack remote access, data visualization, and automated fault detection capabilities. These shortcomings negatively impact performance, safety, and maintenance efficiency. Integrating Internet of Things (IoT) technologies into BMS addresses these issues by enabling live monitoring, remote diagnostics, and intelligent alerts, thereby enhancing reliability in EV battery systems overall.

V. OBJECTIVE OF THE PROJECT

a. To design, develop, and deploy an IoT-based battery management system (BMS) capable of providing real- time monitoring of essential battery parameters including voltage, current, and temperature.
b. To collect and transmit battery performance information wirelessly to a cloud-based platform for remote observation and analysis.
c. To analyze the collected performance data to detect patterns related to battery health, efficiency, and overall performance.
d. To apply data analytics models for predicting potential battery faults or failures, supporting preventive maintenance activities at the service facility.
e. To deliver real-time alerts and system information to users and operators through an intuitive user interface or mobile application.

VI. METHODOLOGY

A. SYSTEM OVERVIEW

Development of an IoT-Based Battery Management System for Electric Vehicles (EVs) introduces an intelligent solution that combines Internet of Things technologies with a Battery Management System (BMS) to observe and regulate EV battery parameters in real time. The system targets major issues such as battery overheating, inefficient charging cycles, and battery degradation. It employs sensors, Arduino Uno, GSM, and Wi-Fi modules to

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acquire, process, and send data to cloud platforms such as Thing Speak for visualization and historical evaluation. This supports safe, efficient, and durable battery operation.

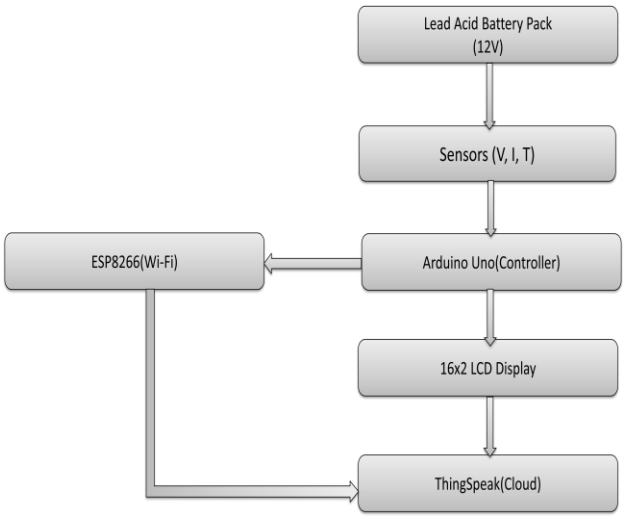

Figure1. Block diagram of the proposed IoT-based Battery Management System

As shown in Figure 1, The proposed IoT-based Battery Management System monitors the voltage, current, and temperature of a lead-acid battery using appropriate sensors. The sensed data is processed by an Arduino Uno microcontroller and displayed locally on a 16×2 LCD. An ESP8266 Wi-Fi module is used to transmit the processed data to the ThingSpeak cloud platform for real-time visualization and historical analysis. This system enables efficient monitoring and improves the safety and performance of the battery.

VII. HARDWARE AND SOFTWARE DESCRIPTION

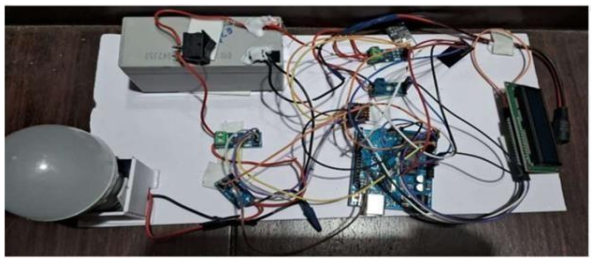

Figure 2. Hardware Setup

The proposed IoT-based Battery Management System (BMS) is implemented using a combination of embedded hardware components and supporting software tools to enable real-time monitoring, data communication, and alert generation.

The hardware section contains a lead-acid battery pack, which functions as the main energy source for the electric vehicle prototype. It includes six 2V cells connected in series to supply 12V. A group of sensors is utilized to measure different battery parameters: a voltage divider circuit reduces the battery voltage to safe levels compatible with the Arduino Uno, a shunt resistor- based current sensor measures current flow, and an NTC thermistor monitors temperature variations. These sensor readings are processed by the Arduino Uno, which operates as the microcontroller unit. The processed information is then used to compute derived parameters such as State of Charge and real time power.

For wireless data transmission, the system employs an ESP8266 Wi-Fi module, which sends battery data to the Thing Speak IoT platform for cloud storage and visualization.When battery temperature exceeds a predefined safety threshold (for example, 30°C) a buzzer get on. Real-time values of voltage, current, temperature, and SoC are also displayed locally using a 16×2 LCD display, enabling quick diagnostics even without cloud connectivity.
On the software side, the Arduino Integrated Development Environment (IDE) is used to write and upload embedded C/C++ programs to the Arduino Uno. It includes necessary libraries for sensor interfacing, Wi-Fi and GSM control,

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and real-time data acquisition and communication. The system utilizes Thing Speak, an open-source IoT cloud platform, to store and visualize transmitted sensor data.

VIII. RESULT AND DISCUSSION

The proposed IoT-based Battery Management System was experimentally evaluated to verify its ability to monitor battery temperature and voltage and to provide a local alert during abnormal conditions. The system successfully acquired real-time sensor data and uploaded it to the Thing Speak cloud platform for visualization.

Figure 3: Temperature vs Time recorded using IoT-based monitoring system

It presents the temperature variation with respect to time obtained during the experimental observation. The recorded temperature values were found to vary between 21.3 °C and 24.5 °C. The lowest temperature of 21.3 °C was observed on 22 December at 12:45, while the highest temperature of 24.5 °C occurred on 20 December at 13:18. The temperature profile shows a smooth and continuous trend without sudden spikes, confirming stable sensor operation and reliable data transmission to the cloud. A threshold temperature of 30 °C was predefined in the system to ensure battery safety. During the testing period, the measured temperature remained below this threshold, and hence the buzzer alert was not activated. This confirms the correct implementation of the threshold-based alert logic. The temperature-time graph displayed on the Thing Speak dashboard provides clear visual confirmation of the system's monitoring capability. In addition to temperature monitoring, battery voltage was also observed during system operation. The measured voltage values remained within the nominal operating range throughout the experiment, indicating stable battery behavior. Since the voltage variation was minimal during the observation period, the results are summarized in tabular form rather than graphical representation.

Parameters	**Observed Value**
Minimum Temperature	21.3 °C
Maximum Temperature	24.5 °C
Average Temperature	29 °C
Threshold Temperature	30 °C
Buzzer Status	OFF
Nominal Battery Voltage	12V
Minimum Measured Voltage	11.8V
Maximum Measured Voltage	12.4V

Table 1: Summary of Experimental Results

The experimental results demonstrate that the developed system is capable of reliable temperature and voltage monitoring with effective cloud integration. The stable performance observed during testing confirms the suitability of the proposed system for low-cost IoT-based battery monitoring applications.

Indicate stable performance of the temperature monitoring system. The minimum and maximum temperatures recorded were 21.3 °C and 24.5 °C respectively, with an average of 22.9 °C. All temperature values remained well below the preset threshold of 30 °C. Hence, no overheating condition was detected during the experiment. The buzzer remained

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OFF throughout the operation, confirming correct system logic. The system was powered by a nominal 12 V battery. The measured voltage varied between 11.8 V and 12.4 V, which is within the acceptable operating range. This indicates a healthy and stable power supply. Overall, the system reliably monitored temperature and responded correctly under normal conditions.

IX. CONCLUSION

This research examines the development of an IoT-based Battery Management System (BMS) for electric vehicles to address a major challenge faced by EV technology: reliable and efficient battery monitoring. The proposed Battery Management System integrates sensors, a microcontroller, wireless communication modules, and a cloud-based platform to continuously track essential battery parameters such as voltage, current, and battery temperature levels. Continuous observation enables early detection of abnormalities, maintenance of safe thermal limits for batteries, and optimized charging and discharging cycles to enhance overall safety and efficiency performance.

The monitoring system also provides drivers with insights into battery health and performance while making accurate predictions about remaining driving range. Drivers can plan trips with greater confidence based on insights from the BMS about battery health and performance and avoid unexpected power outages. Additionally, the BMS also adds significant value by extending battery life and maintenance cost savings, while enhancing overall reliability for electric vehicles. In addition to using the cloud for large data storage, cloud analytics provides an effective method for advanced data analytics and supports viable future developments that could integrate the system to smart vehicle management systems or predictive maintenance.

The BMS proposed in this research illustrates the capability of employing IoT technology to innovate battery management in electric vehicles, which will support future EVs in being safer, more efficient and sustainable.

X. FUTURE SCOPE

a. Integration with Machine Learning:

i. Implement machine learning algorithms to predict battery health, remaining life, and potential faults more accurately.

ii. Enable adaptive optimisation of charging and discharging cycles based on historical and real-time data.

b. Advanced Energy Management:

i. Develop intelligent energy management systems that dynamically balance battery load, improve efficiency, and extend lifespan.

ii. Integrate renewable energy sources like solar charging into the battery management system.

c. Enhanced Connectivity:

i. Incorporate 5G or LoRa-based communication for faster and more reliable real-time monitoring and remote control.

ii. Enable fleet-wide battery monitoring for electric buses, taxis, or logistics vehicles.

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