IOT Based Battery Management System for Electric Vehicle

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Abstract - The Battery Management System (BMS) is one of the most important components in Electric Vehicles (EVs) and battery-powered energy storage systems. It plays a vital role in ensuring the safety, reliability, and efficient operation of battery packs. As the demand for electric vehicles continues to increase worldwide, the need for advanced battery monitoring and protection systems has become more significant. A BMS continuously monitors important battery parameters such as voltage, current, temperature, state of charge (SOC), and state of health (SOH). By tracking these parameters, the system helps maintain the battery within safe operating limits and improves its overall performance and lifespan One of the major challenges associated with battery systems is the risk of overheating, overcharging, deep discharging, and short circuits, which can lead to battery degradation or even fire accidents. To address these issues, the proposed system incorporates a burning prevention mechanism that detects abnormal battery conditions at an early stage. Temperature sensors are used to monitor the thermal condition of the battery in real time. When the battery temperature exceeds a predefined threshold value, the system immediately disconnects the battery output using a protection relay and activates a buzzer to alert the user. This rapid response helps prevent thermal runaway and reduces the risk of battery fires. The proposed IoT-based Battery Monitoring and Burning Prevention System provides continuous monitoring of a lead-acid battery and stores key operating parameters, including battery voltage, charging and discharging current, temperature, state of charge, and remaining battery capacity. A Wireless Local Area Network (WLAN) serves as the communication backbone, enabling real-time transmission of battery data to a central monitoring platform. The collected information from multiple battery nodes is analyzed to identify abnormal operating conditions and potential faults. Users can remotely access battery status through an IoT interface, making it easier to monitor battery health and performance from any location. The system offers enhanced safety, improved battery life, reduced maintenance costs, and better energy management. It is particularly useful in electric vehicles, renewable energy storage systems, UPS units, and industrial battery banks. By integrating real-time monitoring, fault detection, IoT connectivity, and automatic protection features, the proposed system provides a reliable and intelligent solution for battery management and fire prevention, contributing to the safe and efficient utilization of modern battery technologies.

Keywords: Battery Management System (BMS), Electric Vehicle (EV), Internet of Things (IoT), Lead-Acid Battery, State of Charge (SOC), Thermal Protection, Battery Monitoring, Fire Prevention.

1. INTRODUCTION

The rapid growth of industrial automation and electric vehicle (EV) technology has increased the complexity of electronic systems, making fault detection and fault isolation essential for ensuring system reliability and safety. Among the various components of an EV, the battery is the most critical and vulnerable element, as its performance directly affects vehicle efficiency, lifespan, and operational safety. Battery performance is influenced by several factors, including depth of discharge (DoD), charging duration, temperature, and operating conditions. Continuous monitoring of these parameters is therefore necessary to identify faults at an early stage and prevent system failures. A battery is an electrochemical device that converts chemical energy into electrical energy. Lead-acid batteries are widely used in applications such as uninterruptible power supplies (UPS), telecommunications, and backup power systems due to their low cost and reliability. To ensure uninterrupted operation, important battery parameters such as terminal voltage, charging and discharging current, state of charge (SOC), and temperature must be monitored regularly. The integration of Internet of Things (IoT) technology enables real-time acquisition, transmission, and analysis of these parameters, providing accurate information about battery health and operating conditions. Battery Management Systems (BMS) have become an indispensable part of EVs, hybrid electric vehicles (HEVs), UPS systems, and other energy storage applications. A BMS continuously monitors battery voltage, current, temperature, and SOC while controlling charging and discharging processes to ensure safe and efficient operation. It also performs cell balancing, thermal management, and fault diagnosis to improve battery performance and extend battery life. By communicating with the vehicle's electronic

control unit (ECU), the BMS provides information regarding available battery capacity and driving range. Battery safety is a major concern in EV applications, particularly due to the risks associated with overheating, overcharging, and thermal runaway. Effective thermal management is required to maintain battery temperature within a safe operating range and prevent fire hazards. In addition, accurate SOC estimation and charging control help avoid over-voltage conditions that may damage the battery or lead to hazardous situations. Therefore, the implementation of an IoT-enabled BMS with fault detection and thermal protection mechanisms plays a significant role in enhancing battery safety, reliability, and operational efficiency. This work focuses on real-time battery monitoring and fault analysis using IoT technology, providing an effective solution for improving battery management and preventing battery-related failures in EV systems. Overall, the motivation for selecting a battery management system and burning prevention system for electric vehicle batteries as a project can be driven by the need for safety, reliability, battery performance optimization, compliance with standards and regulations, innovation, technological advancement, and environmental sustainability, with the ultimate goal of advancing electric vehicle technology and ensuring the safe and efficient operation of EV batteries.

2. LITERATURE SURVEY

[1] Atzori et al. (2017) presented a comprehensive review of the Internet of Things (IoT), discussing its architecture, enabling technologies, applications, challenges, and future directions. The study highlighted the importance of wireless communication and sensor networks for intelligent monitoring systems.

[2] Yong Tian et al. (2017) proposed nonlinear observer-based techniques for accurate State of Charge (SOC) estimation of lithium-ion batteries. Their work improved battery monitoring accuracy and enhanced battery management system performance.

[3] López-Benítez et al. (2017) developed a statistical model for IoT data traffic based on real-world measurements. The study emphasized efficient data analysis and communication strategies for IoT-based monitoring applications.

[4] Hannan et al. (2017) reviewed energy storage systems used in electric vehicles. The study discussed battery technologies, performance characteristics, and management requirements for EV applications.

[5] Mohamad et al. (2016) designed a real-time vehicle monitoring and tracking system using Arduino, GPS, GSM, and IoT technologies. The system demonstrated reliable remote monitoring and data visualization capabilities.

[6] Xia et al. (2016) explored Industrial IoT applications for condition monitoring, traceability, and tracking. The study showed how IoT technologies improve maintenance efficiency and system reliability.

[7] Wu et al. (2015) investigated the effects of overcharging and over-discharging on lithium-ion batteries. Their research highlighted the importance of battery protection mechanisms to ensure safety and extend battery life.

[8] Lu et al. (2013) reviewed key challenges in lithium-ion battery management for electric vehicles. The paper discussed battery monitoring, thermal management, fault diagnosis, and safety requirements.

[9] Barré et al. (2013) reviewed lithium-ion battery ageing mechanisms and estimation techniques. The study emphasized the importance of monitoring battery health to improve performance and reliability.

[10] Xiong et al. (2013) proposed an Adaptive Extended Kalman Filter method for State of Charge estimation. The technique enhanced battery monitoring accuracy under varying operating conditions.

3. METHODOLOGY

- Design an IoT-based Battery Management System (BMS) using a microcontroller and sensors.
- Measure battery parameters such as voltage, current, and temperature in real time.
- Collect and process sensor data to determine battery health and operating status.
- Transmit the monitored data to an IoT platform through a wireless network.
- Continuously monitor for faults such as over-voltage, under-voltage, over-current, and overheating.
- Compare measured values with predefined threshold limits.
- Trigger an alert using a buzzer when abnormal conditions are detected.
- Disconnect the battery output through a relay if the temperature exceeds the safety threshold.
- Display and store battery data for remote monitoring and analysis.
- Test and validate the system under normal and fault conditions to ensure reliable operation.

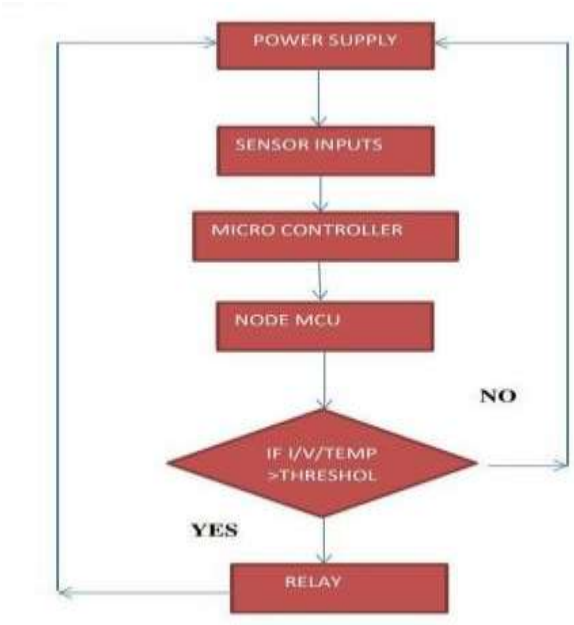


Fig 1: Flowchart of IoT based BMS.

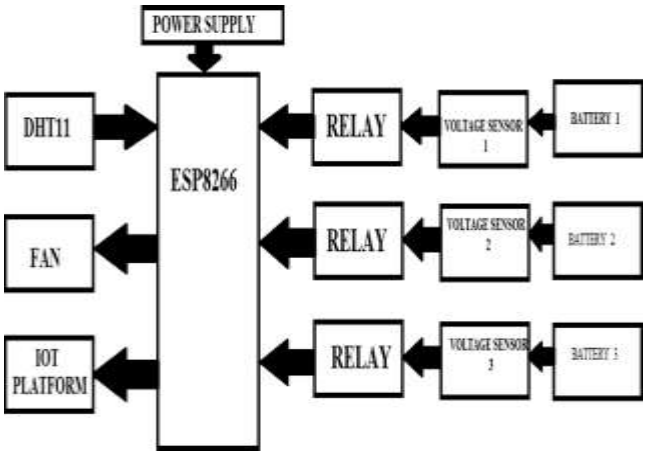


Fig 2: Block Diagram of IoT based BMS.

The proposed Battery Management System (BMS) uses an ESP8266 microcontroller as the central control unit to monitor battery conditions, protect the battery pack, and provide remote monitoring through an IoT platform. The working principle based on the block diagram is described below.

1. Power Supply- The power supply provides the required operating voltage to the ESP8266 microcontroller and all associated components of the system. Once powered, the ESP8266 continuously monitors and controls the entire battery management process.

2. Battery Voltage Monitoring- Three batteries (Battery 1, Battery 2, and Battery 3) are connected to individual voltage sensors. These sensors continuously measure the voltage level of each battery and send the measured values to the ESP8266 through relay interfaces. The microcontroller compares the battery voltages with predefined safe operating limits to determine the charging and discharging status of each battery.

3. Temperature Monitoring- A DHT11 sensor is connected to the ESP8266 to monitor the temperature of the battery environment. The sensor continuously sends temperature data to the microcontroller. This allows the system to detect abnormal temperature rises that may affect battery performance or lead to thermal hazards.

4. Relay-Based Protection Control- Relays are used as switching devices between the batteries and the control system. Based on the voltage and temperature readings: If a battery voltage exceeds the safe limit (overcharging condition), the ESP8266 deactivates the corresponding relay to disconnect the battery from the charging circuit. If the battery voltage drops below the minimum safe level (deep discharge condition), the relay disconnects the battery from the load to prevent damage. .During abnormal operating conditions, relays isolate the affected battery to ensure system safety.

5. Cooling Fan Operation- When the DHT11 sensor detects a temperature above the predefined threshold, the ESP8266 activates the cooling fan. The fan dissipates excess heat from the battery compartment, helping maintain the battery temperature within a safe operating range. Once the temperature returns to normal, the fan is automatically turned off.

6. IoT-Based Monitoring-The ESP8266 contains built-in Wi-Fi functionality, enabling communication with the IoT platform. Real-time battery parameters such as: Battery voltages, Temperature, Charging/discharging status, Fault conditions.

7. Fire and Safety Protection- The system continuously monitors battery temperature and voltage conditions. If excessive temperature or abnormal battery behavior is detected, the ESP8266 immediately disconnects the affected battery using the relay and activates the cooling mechanism. This preventive action minimizes the possibility of overheating, thermal runaway, and battery combustion.

4. HARDWARE

Our proposed system uses Temperature sensor, Voltage sensor, Relay and Node MCU. Temperature sensor is used to measure the temperature level of battery then the Voltage sensor is used to measure the voltage level of the battery. The Node MCU is used to continuously upload battery information to an IoT webpage that is available for viewing by the owner or other authorized users.

The list of hardware components that are required are:

- Regulated power supply (RPS)
- Temperature sensor
- Voltage sensor
- Battery
- Relay
- Node MCU

1. Regulated Power Supply (RPS) - Provides a stable and regulated DC voltage to the Node microcontroller, sensors, and relay circuit, ensuring reliable operation of the entire BMS.

2. Temperature Sensor- Monitors the battery temperature continuously. If the temperature exceeds the safe limit, it sends data to the Node microcontroller to prevent overheating and protect the battery.

3. Voltage Sensor- Measures the battery voltage in real time. It detects overvoltage and undervoltage conditions and sends the readings to the Node microcontroller for monitoring and protection.

4. Battery- Acts as the energy storage device. It supplies power to the load and is continuously monitored by the BMS to ensure safe charging and discharging.

5. Relay- Works as an electrically operated switch. It disconnects the battery from the load or charger whenever abnormal conditions such as overvoltage, undervoltage, or overheating are detected.

6. Node microcontroller - Serves as the main controller of the BMS. It receives data from the voltage and temperature sensors, processes the information, controls the relay for battery protection, and sends battery status to the IoT platform for remote monitoring.

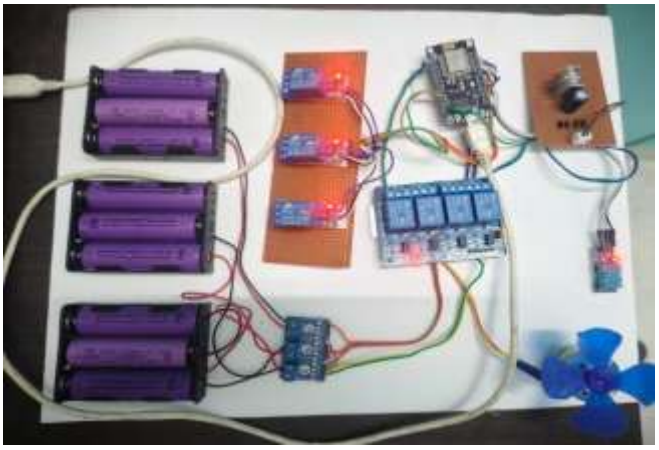


Fig 3: Hardware of IOT Based BMS

5. RESULTS

Observation Table:

Sr. no.	Time	Voltage(v)	Temperature (°C)
1	19:45	12.02	27.2
2	20:00	12.01	27.2
3	20:15	12.01	27.2
4	20:30	12.00	27.1
5	20:45	11.97	27.0

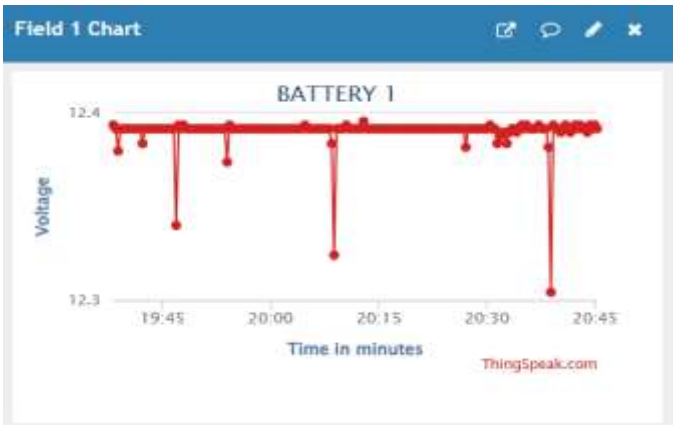


Fig :4 Photocopy of voltage graph of battery 1 without load using IOT

The graph displays Battery 1 voltage variation having no load connection to it, remaining mostly stable around 12.4V throughout the monitoring period. Small fluctuations occur frequently, with a few noticeable sharp drops in voltage at certain time points. These sudden dips suggest temporary disturbances or irregular battery behavior, while overall performance appears consistent and relatively stable during observation.

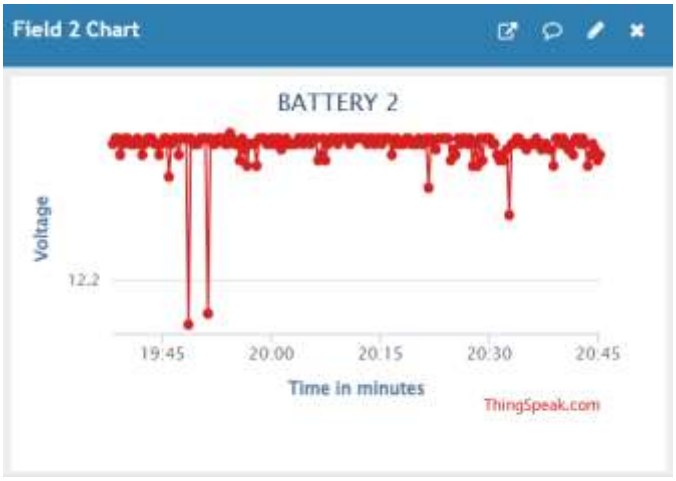


Fig :5 Photocopy of voltage graph of battery 2 without load using IOT

The graph illustrates Battery 2 voltage variation having no load connection to it, remaining generally stable around a constant level during the observation period. Several minor fluctuations and a few significant voltage drops are visible, particularly in the early section. These sudden decreases may indicate temporary disturbances or load effects, while the battery overall demonstrates relatively stable performance.



Fig :6 Photocopy of voltage graph of battery 3 with load (fan) using IOT

The graph represents Battery 3 voltage drop by connecting the 12v load(fan) to it. The voltage shows a gradual declining trend with frequent fluctuations and several sharp drops below the normal operating range. These sudden dips may indicate load-related stress, reduced battery stability, or discharge effects, while overall performance decreases progressively during the monitoring period. The Node MCU plays a vital role in this system, which senses the data from sensors and process the data. The Wi-Fi unit in the Node MCU is used to send the data to the cloud, this data can be monitored continuously from anywhere in the world (where there is an active internet connection).

The graph referring to is a visual representation of data collected from an Internet of Things (IoT) based battery management system -

The x-axis of the graph represents time, while the y-axis represents various parameters related to the battery performance.

The graph shows trends or patterns in the voltage values, providing insights into the battery's electrical behavior. For example:

Charging and Discharging Events: The graph may show the voltage values during charging events, indicating how the battery voltage increases over time as it is charged. It may also show the voltage values during discharging events, representing how the battery voltage decreases during EV operation as energy is drawn from the battery.

Voltage Profiles: The graph may show the voltage profiles of the battery during different stages of operation, such as during startup, normal operation, and shutdown. This can help identify any abnormal voltage behaviors, such as voltage spikes or drops, which may indicate issues with the battery's performance or health.

Voltage Range: The graph may show the voltage range of the battery, indicating the upper and lower limits of the acceptable voltage levels. Monitoring the battery voltage.

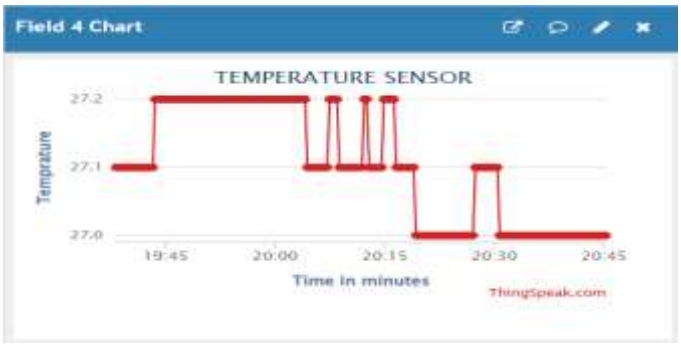


Fig 7 : Photocopy of temperature graph using IOT

The graph presents temperature sensor readings over time, showing relatively stable values between 27.0°C and 27.2°C during the monitoring period. Minor fluctuations occur initially, followed by a slight decrease and stabilization around 27.0°C. The small variations indicate consistent environmental conditions and stable sensor performance with no significant temperature changes observed.When the selected parameter is battery temperature, the graph displays the real-time temperature of the battery pack at different time intervals. The x-axis of the graph represents time, while the y-axis represents the battery temperature in degrees Celsius (°C). By continuously plotting temperature values, the graph illustrates how the battery temperature varies during operation, charging, or discharging conditions.

The temperature monitoring graph helps in analyzing the thermal behavior of the battery pack and provides insights into its operating condition. Under normal circumstances, the temperature values remain within a safe operating range and show gradual variations according to the battery load and environmental conditions. Sudden increases or abnormal fluctuations in temperature may indicate excessive current flow, internal battery faults, poor ventilation, or potential thermal issues. Continuous monitoring of temperature is essential because excessive heat can negatively affect battery performance, reduce battery lifespan, and create safety risks. Therefore, a predefined threshold value is set within the monitoring system. If the battery temperature exceeds this safe threshold level, the system automatically triggers an overheating alert. The alert mechanism notifies the user or operator immediately so that corrective actions can be taken, such as reducing load conditions, stopping charging operations, or inspecting the battery system for possible faults.

6. ADVANTAGES & DISADVANTAGES

Advantages

1. Real-time Monitoring: Continuously monitors battery voltage and temperature using sensors.
2. Remote Access: The Node MCU enables users to monitor battery status from anywhere through the Internet.
3. Battery Protection: The relay disconnects the battery during overvoltage, undervoltage, or overheating conditions, preventing damage.
4. Improved Battery Life: Proper monitoring and protection increase battery lifespan.
5. Low Cost: The system uses affordable components such as Node MCU, sensors, and relay, making it economical.
6. Easy Maintenance: Faults can be detected quickly, reducing maintenance time and cost.
7. Energy Efficiency: Prevents unnecessary charging and discharging, improving battery performance.
8. User-Friendly: Real-time battery parameters can be displayed on a mobile application or IoT dashboard.

Disadvantages

1. Internet Dependency: Remote monitoring requires a stable Wi-Fi or Internet connection.
2. Limited Accuracy: Low-cost voltage and temperature sensors may have small measurement errors.
3. Power Consumption: The Node MCU and sensors consume a small amount of battery power continuously.
4. Security Risks: IoT systems may be vulnerable to cyberattacks if proper security measures are not implemented.
5. Limited Protection Features: This basic BMS monitors only voltage and temperature and may not include current sensing or cell balancing.
6. Relay Wear: Mechanical relays have a limited lifespan due to repeated switching operations.

7. Wi-Fi Range Limitation: Monitoring is affected if the Node MCU is outside the Wi-Fi coverage area.
8. Not Suitable for Large Battery Packs: The prototype is mainly designed for small-scale or educational applications and may require additional hardware for industrial battery systems.

7. FUTURE SCOPE

- Improved battery management algorithms: With the advent of artificial intelligence and machine learning technologies, there is a lot of scope for developing better algorithms to manage the life of electric vehicle batteries. These algorithms can predict battery aging, optimize charging cycles, and improve energy efficiency.

- Advanced energy storage technologies: There is a growing need for energy storage technologies that can provide higher energy density and longer cycle life for electric vehicle batteries. Research is underway to develop solid-state batteries, which are expected to offer higher energy density and faster charging times.

- Battery recycling: Proper recycling of electric vehicle batteries is crucial to prevent environmental damage. Several research projects are focused on developing more efficient and sustainable battery recycling methods.

- Enhanced thermal management systems: Thermal management is a critical issue for electric vehicle batteries as overheating can damage them. Advanced thermal management systems that can provide better cooling and heating for batteries can improve their performance and prolong their lifespan.

- Integration with smart grid technologies: As electric vehicle adoption increases, it becomes important to integrate EVs with smart grid technologies. Battery management systems can be used to monitor the energy consumption of EVs and optimize their charging cycles to minimize the impact on the grid.

- Improved safety features: Electric vehicles need to be equipped with advanced safety features to prevent battery fires and other accidents. Battery management systems can be enhanced to provide better monitoring of battery temperature, voltage, and current, to detect any potential hazards early and prevent accidents from occurring.

8. CONCLUSION

The IoT-based Battery Management System (BMS) provides an effective solution for monitoring and managing battery performance through real-time data acquisition and communication. The system continuously tracks important battery parameters such as voltage, temperature, and operational status to ensure safe and efficient battery usage. Experimental results indicate that battery voltage decreases during the discharge process, while temperature gradually increases with prolonged operation. Through IoT technology, the collected data can be remotely monitored and analyzed for improved system control. The proposed system enhances battery reliability, enables early fault detection, reduces maintenance requirements, improves battery lifespan, and supports efficient energy utilization, making it suitable for various smart energy and industrial applications. The increasing demand for electric vehicles (EVs) due to the depletion of fossil fuels has made battery technology and battery management systems (BMS) essential components of modern transportation. Since the performance, reliability, and safety of an electric vehicle depend entirely on its battery, continuous monitoring and proper management of battery parameters are necessary for efficient operation. The proposed IoT-based Battery Management System provides an effective solution for monitoring battery performance in real time. By continuously measuring important parameters such as voltage, current, temperature, and state of charge, the system helps maintain the battery within safe operating limits. The integration of IoT technology enables remote monitoring, allowing users and operators to access battery information from anywhere through an internet-connected device. A significant advantage of the proposed system is its ability to detect abnormal battery conditions and degraded battery performance at an early stage. When any parameter exceeds the predefined threshold value, the system generates notifications and alerts, enabling timely corrective actions. This feature helps prevent battery damage, improves operational safety, and reduces the possibility of unexpected failures. Furthermore, the inclusion of temperature monitoring and protection mechanisms enhances battery safety by reducing the risk of overheating and fire hazards. The collected data can also be stored and analzed for predictive maintenance and performance evaluation. Overall, the IoT-based Battery Management System improves battery efficiency, extends battery life, enhances vehicle safety, and reduces maintenance costs. Therefore, it represents a reliable and intelligent solution for future electric vehicles and energy storage applications, supporting the growth of sustainable and environmentally friendly transportation systems.

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