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## ABSTRACT

The rapid adoption of electric vehicles has increased the need for efficient battery management and monitoring systems to ensure safety, reliability, and optimal performance. This project presents a smart Battery Management System based electric vehicle monitoring system designed to continuously track and manage battery parameters in real time. The system monitors critical parameters such as battery voltage, current, temperature, and state of charge using sensors integrated with an embedded controller. These parameters are essential for maintaining battery health and preventing issues such as overcharging, deep discharge, and thermal runaway. The proposed system utilizes a microcontroller to process sensor data and transmit it to a cloud platform using IoT communication technologies. This enables remote monitoring of battery performance through mobile or web applications. The system also includes alert mechanisms that notify users or operators when abnormal conditions are detected, ensuring timely intervention and enhanced safety. Data visualization through graphs and dashboards helps in analyzing battery performance trends and predicting potential faults. The smart BMS improves the efficiency and lifespan of the battery by optimizing charging and discharging cycles. It also enhances vehicle performance by providing accurate information about battery status. The system is cost-effective, scalable, and suitable for various types of electric vehicles. Overall, the project demonstrates an intelligent approach to battery monitoring by combining embedded systems, IoT technology, and real-time data analysis to support the growing demand for sustainable and reliable electric mobility solutions.

**Keywords:** *Battery Management System, Electric Vehicle, IoT, State of Charge, Embedded System, Battery Monitoring, Wireless Communication, Smart Energy*

## I. INTRODUCTION

The increasing demand for sustainable transportation has accelerated the adoption of electric vehicles across the world. Electric vehicles rely heavily on battery systems as their primary source of energy, making battery performance and safety critical factors in overall vehicle efficiency. Unlike conventional fuel-based vehicles, EVs require advanced monitoring systems to ensure that batteries operate within safe limits. Improper battery management can lead to reduced lifespan, performance degradation, or even hazardous conditions such as overheating and thermal runaway. This highlights the importance of implementing intelligent Battery Management Systems.

A Battery Management System is responsible for monitoring, controlling, and protecting the battery pack in an electric vehicle. It continuously measures key parameters such as voltage, current, temperature, and state of charge. These parameters are essential for maintaining optimal battery performance and preventing damage. The BMS ensures that each battery cell operates within safe limits by balancing charge levels and controlling charging and discharging processes. This helps in improving battery efficiency, extending lifespan, and enhancing overall system reliability.

The integration of Internet of Things technology has further improved the capabilities of battery management systems. IoT enables real-time data transmission and remote monitoring of battery parameters. By connecting the BMS to cloud platforms, users can access battery information from anywhere using mobile or web applications. This allows continuous monitoring of battery health and enables predictive maintenance. IoT-based systems also provide data visualization, helping users understand battery performance trends and make informed decisions.

Embedded systems play a crucial role in implementing smart BMS solutions. Microcontrollers are used to collect data from sensors and process it efficiently. These systems are designed to operate in real time and handle multiple inputs simultaneously. The compact design and low power consumption of embedded devices make them suitable for integration into electric vehicles. By combining sensors, microcontrollers, and communication modules, it becomes possible to develop a smart monitoring system that ensures reliable battery operation.

The proposed smart BMS-based EV monitoring system aims to provide a cost-effective and efficient solution for managing battery performance. It integrates sensor technology, embedded systems, and IoT communication to create an intelligent monitoring platform. The system enhances safety, improves battery lifespan, and supports efficient energy utilization. This project contributes to the advancement of electric vehicle technology by addressing key challenges related to battery management and monitoring.

## II. SURVEY OF LITERATURE

1. The study by S. Piller et al. (2001) focused on different techniques for estimating the State of Charge (SoC) of batteries, which is a critical parameter in Battery Management Systems. The paper discussed methods such as voltage-based estimation and coulomb counting. While these methods are simple and widely used, they suffer from inaccuracies due to environmental variations and battery aging. The study emphasized the need for more accurate and reliable estimation techniques. This research forms the foundation for modern BMS systems, including the proposed system, which uses sensor-based monitoring to estimate battery parameters in real time.

2. The research by J. Vetter et al. (2005) analyzed the factors affecting battery aging and performance degradation. The study identified key issues such as overcharging, deep discharge, and temperature variations that reduce battery lifespan. It highlighted the importance of monitoring battery parameters to prevent damage and improve longevity. The research demonstrated that proper battery management can

significantly enhance battery performance and safety. This directly supports the proposed smart BMS system, which continuously monitors voltage, current, and temperature to prevent such issues.

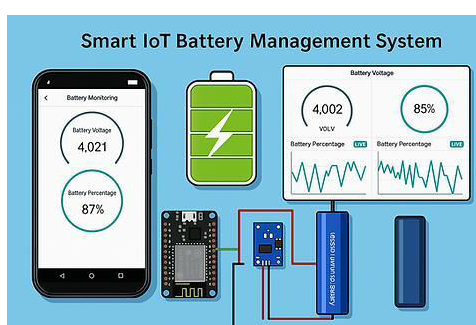
3. The study by Rui Xiong et al. (2013) introduced advanced techniques for estimating battery SoC using Kalman filtering. This method improves accuracy compared to traditional estimation techniques by considering system dynamics and noise. The research demonstrated that advanced algorithms can provide reliable and precise battery monitoring under varying load conditions. However, the method requires higher computational resources and complex implementation. This highlights the gap between high-accuracy systems and cost-effective solutions. The proposed project addresses this by using simpler real-time monitoring techniques suitable for embedded systems.

4. The study by Languang Lu et al. (2013) provided a comprehensive overview of Battery Management Systems. It discussed key functions such as monitoring, protection, cell balancing, and thermal management. The research emphasized that BMS plays a crucial role in ensuring battery safety, efficiency, and reliability in electric vehicles. It also highlighted challenges such as accurate state estimation and system complexity. This work serves as a strong theoretical foundation for the proposed system, which implements real-time monitoring and safety mechanisms using embedded systems and sensors.

5. The research by A. Saxena et al. (2015) focused on analyzing battery degradation and predicting end-of-life conditions. The study used data-driven approaches to evaluate battery performance over time. It highlighted the importance of continuous monitoring and data analysis in predicting failures and improving maintenance strategies. The research demonstrated that real-time data collection and analysis can significantly enhance battery reliability. This aligns with the proposed system, which uses IoT-based monitoring and data visualization to track battery performance and detect potential issues.

6. The study by Luigi Atzori et al. (2010) explored the concept of IoT and its applications in various domains, including energy systems. The research highlighted how IoT enables real-time data collection, remote monitoring, and intelligent decision-making. It emphasized the integration of sensors, communication networks, and cloud platforms to create smart systems. The study also discussed challenges such as data security and network reliability. This research supports the proposed smart BMS system, which uses IoT technology for remote battery monitoring, data visualization, and alert generation.

### III. WORKING METHODOLOGY



The working methodology of the smart BMS-based EV vehicle monitoring system is centered on continuous monitoring and management of battery parameters using sensors and embedded control. The system is equipped with voltage sensors, current sensors, and temperature sensors that are connected to the battery pack. These sensors continuously measure key parameters such as battery voltage, current flow, and temperature. The collected data provides a real-time understanding of battery condition and performance. Accurate sensing is essential for maintaining battery safety and preventing issues such as overcharging, overheating, and deep discharge.

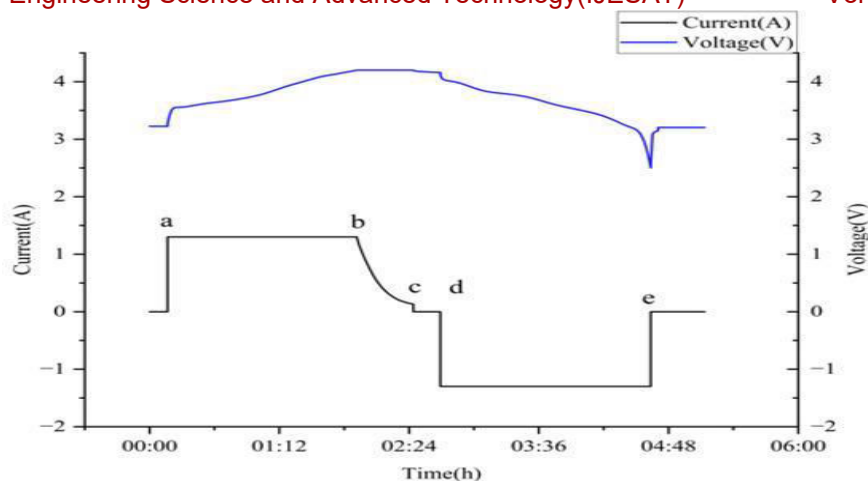
The microcontroller acts as the central processing unit of the system. It receives data from all sensors and processes it using predefined algorithms. The system calculates important parameters such as state of charge based on voltage and current measurements. Threshold values are set for each parameter to ensure safe operation. If any parameter exceeds the safe limit, the system identifies it as a fault condition and triggers appropriate actions such as alerts or system shutdown. This ensures the protection of the battery and enhances system reliability.

The communication module enables the transmission of data to an IoT cloud platform for remote monitoring. Wireless technologies such as Wi-Fi or GSM are used to send real-time data to the cloud. Users can access this data through mobile or web applications, allowing them to monitor battery performance from any location. This feature is particularly useful for fleet management and electric vehicle monitoring, where continuous tracking of battery status is required.

The system also includes an alert mechanism that notifies users when abnormal conditions are detected. For example, if the temperature exceeds safe limits or if the battery voltage drops below a threshold, the system generates alerts. These alerts can be sent as notifications through mobile applications or messaging services. This helps in taking timely action to prevent damage to the battery or vehicle.

Overall, the working methodology involves the integration of sensors, microcontroller, communication modules, and cloud platforms to create an intelligent monitoring system. The system continuously collects and processes data, transmits it for remote monitoring, and ensures safe operation of the battery. This approach improves battery efficiency, enhances safety, and supports reliable electric vehicle performance.

#### **IV. IMPLEMENTATION**



**Fig.1 Battery Voltage Analysis Graph**

The implementation of the smart BMS-based EV monitoring system begins with the integration of hardware components such as sensors, microcontroller, communication module, and battery pack. Voltage sensors are connected across the battery terminals to measure the battery voltage, while current sensors are used to monitor the flow of current during charging and discharging. Temperature sensors are placed near the battery cells to detect heat variations. All sensors are interfaced with the microcontroller using appropriate analog and digital input pins, ensuring accurate data acquisition.

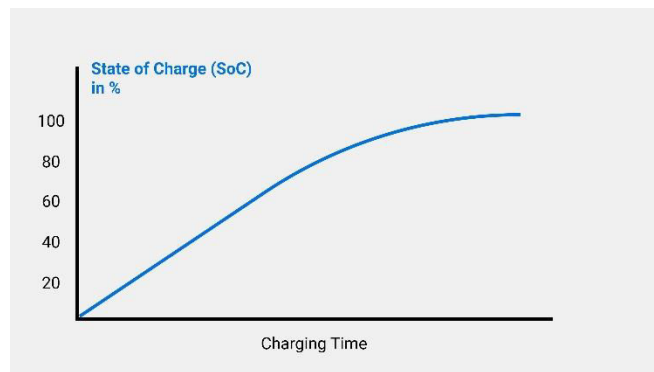
The microcontroller is programmed using embedded C or Arduino IDE to continuously read sensor values and process the data. The program includes algorithms for calculating parameters such as state of charge and monitoring threshold limits. When sensor values exceed predefined limits, the system identifies abnormal conditions and initiates protective actions. The software is designed to ensure real-time performance and efficient data processing, enabling quick response to changes in battery conditions.

The communication system is implemented using wireless technologies such as Wi-Fi or GSM. The microcontroller transmits sensor data to an IoT cloud platform, where it is stored and analyzed. Users can access the data through a mobile or web interface, allowing remote monitoring of battery performance. The system also supports data logging, enabling historical analysis of battery usage and performance trends.

Graphical analysis is used to evaluate the performance of the system. The battery voltage graph shows variations during charging and discharging cycles, helping to identify battery efficiency and capacity. The temperature graph represents changes in battery temperature over time, indicating thermal behavior under different operating conditions. These graphs provide valuable insights into battery health and performance.

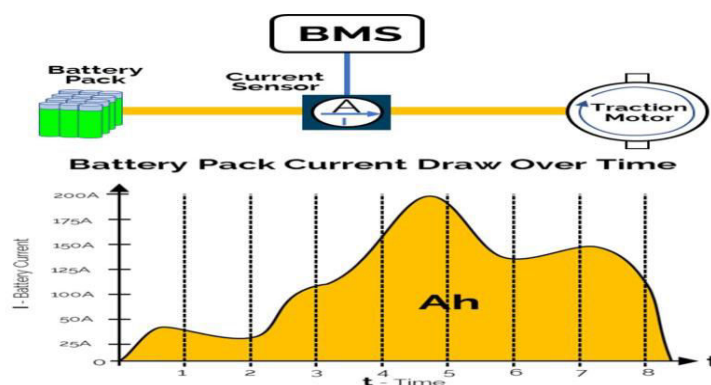
The overall implementation demonstrates the successful integration of hardware and software components to create an intelligent battery monitoring system. The system ensures accurate data collection, efficient processing, and reliable communication. It provides a scalable and cost-effective solution for monitoring and managing battery systems in electric vehicles, enhancing safety and performance.

## V. RESULT AND ANALYSIS



**Fig. State of Charge (SoC) Analysis Graph**

The state of charge analysis graph represents the variation of battery charge level over time during charging and discharging cycles. The graph shows a gradual increase in SoC during charging and a steady decrease during discharging, reflecting normal battery behavior. The system continuously calculates SoC based on voltage and current measurements, providing accurate information about the available energy in the battery. During testing, the system demonstrated consistent tracking of charge levels, enabling efficient battery usage and preventing deep discharge conditions. The graph helps in understanding battery performance and planning charging schedules effectively. Minor fluctuations may occur due to load variations and measurement accuracy. This analysis confirms that the system can reliably monitor battery charge levels and support efficient energy management in electric vehicles.



**Fig. Battery Current Analysis Graph**

The battery current analysis graph illustrates the variation of current flow during charging and discharging operations. The graph shows positive current values during charging and negative values during discharging, indicating energy flow direction. Sudden spikes in current may occur due to changes in load or acceleration of the vehicle. The system continuously monitors current to ensure that it remains within safe limits, preventing damage to the battery. During testing, the system successfully detected abnormal current

conditions and generated alerts when thresholds were exceeded. The graph provides valuable insights into power consumption patterns and helps in identifying inefficiencies in the system. This analysis demonstrates that the current monitoring feature enhances battery safety and improves overall system performance.

## VI. CONCLUSION

The smart BMS-based EV vehicle monitoring system provides an effective and reliable solution for managing and monitoring battery performance in electric vehicles. The system integrates sensors, embedded controllers, and IoT communication to continuously track important parameters such as voltage, current, temperature, and state of charge. By analyzing these parameters in real time, the system ensures safe operation of the battery and prevents critical issues such as overcharging, deep discharge, and overheating. The implementation demonstrates that the system can accurately monitor battery conditions and provide timely alerts when abnormal situations occur.

The integration of IoT technology enables remote monitoring and data visualization, allowing users to access battery information from anywhere. This improves convenience and supports better decision-making regarding battery usage and maintenance. The graphical analysis of battery parameters helps in understanding performance trends and identifying potential faults. The system also contributes to extending battery lifespan by optimizing charging and discharging cycles.

Overall, the proposed system is cost-effective, scalable, and suitable for various electric vehicle applications. It enhances safety, improves energy efficiency, and supports sustainable transportation. Future improvements may include the integration of advanced algorithms for more accurate state estimation and predictive maintenance, further enhancing the reliability and performance of electric vehicle battery systems.

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