Iot Based Smart Battery Management System for E - Vehicle

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***Abstract*—The rapid growth of sustainable transportation has significantly accelerated the adoption of electric vehicles (EVs), placing greater emphasis on efficient and reliable battery systems. However, improper battery management can lead to reduced performance, overheating, and potential system failures, posing safety and operational risks. This paper proposes an advanced Battery Management System (BMS) integrated with Internet of Things (IoT) technology to address these challenges. The system continuously monitors critical battery parameters such as voltage, current, State of Charge (SOC), and State of Health (SOH) at the individual cell level, ensuring optimal performance and longevity. Furthermore, the incorporation of temperature sensing and automatic cutoff mechanisms enhances safety by preventing thermal runaway and other hazards. Real-time data acquisition and remote monitoring through IoT enable predictive maintenance and improved energy efficiency. The proposed solution aims to enhance the reliability, safety, and overall efficiency of EV battery systems, contributing to the advancement of sustainable transportation.[2].**

I. INTRODUCTION

The rapid growth of electric vehicles (EVs) has created a strong demand for efficient, reliable, and intelligent energy storage solutions. At the core of every EV lies the battery system, which directly influences the vehicle's performance, driving range, safety, and overall lifespan. Traditional battery systems, while functional, often lack the capability to monitor and optimize their performance in real-time. This limitation has led to the development of smart battery systems.

Overall, the smart battery system plays a crucial role in advancing electric vehicle technology by improving safety, efficiency, and sustainability.[3]

II. SYSTEM ARCHITECTURE

Sensing: Voltage sensors for cell potential, current sensors for load monitoring, and DHT11 for temperature tracking.
Protection: Relay modules for automatic disconnection during fault conditions.
Microcontroller: Arduino Board for logic processing.
Display: LCD modules and Serial Monitor for local debugging.

III. METHODOLOGY AND IMPLEMENTATION

The implementation involved designing a circuit capable of measuring high-voltage battery parameters while maintaining common ground isolation for safety. The software was developed in the Arduino IDE, focusing on modularity and low-latency data processing.[1]

Parameter Estimation
State of Charge (SOC) is estimated using the Voltage Translation method combined with Current Integration (Coulomb Counting). State of Health (SOH) is derived by
As EV adoption continues to rise, the development of intelligent battery solutions will remain a key factor in shaping the future of mobility.[4]

Safety Algorithm
The safety algorithm functions in a continuous loop:
1. Scan all cell voltages and temperature.
2. If any cell exceeds 4.2V or falls below 3.0V, trigger an alarm.
3. If temperature exceeds 50°C, the relay module disconnects the load automatically.
4. Data is logged to the Serial Monitor and IoT dashboard every 5 seconds.[5]

IV. LITERATURE REVIEW

Existing BMS solutions primarily focus on voltage and temperature monitoring, with limited accuracy in SOC and SOH estimation. Traditional methods such as Coulomb counting suffer from cumulative errors, while model-based approaches require complex computations. Recent advancements include AI-based estimation and IoT-enabled monitoring systems. However, there remains a need for a cost-effective and accurate real-time system.

PARAMETER MONITORING:

Voltage Monitoring

Voltage sensors measure individual cell and total pack voltage. This helps in detecting overvoltage and undervoltage conditions.

Current Monitoring

Current is measured using sensors such as shunt resistors or Hall-effect sensors. It is essential for power calculation and SOC estimation.

Temperature Monitoring

Temperature sensors (e.g., thermistors) are used to detect overheating and ensure safe operation within thermal limits.

State of Charge (SOC) Estimation

SOC represents the remaining battery capacity. It is estimated using methods such as:

Coulomb counting

Open-Circuit Voltage (OCV) method Hybrid techniques for improved accuracy

State of Health (SOH) Estimation

SOH indicates battery degradation over time. It is calculated based on: Capacity fade

Internal resistance changes, Charge-discharge cycle analysis

Thermal Protection and Automatic Cut-off Mechanism

The proposed system incorporates an advanced thermal protection mechanism [11] to ensure battery safety under extreme operating conditions. A predefined temperature threshold of 50°C is set as the critical limit. When the battery temperature exceeds this value, the system automatically disconnects the load or charging circuit using a relay or MOSFET-based switching mechanism.

The display updates dynamically, allowing users to monitor battery performance instantly. Warning messages such as “High Temperature” or “System Cut-off Activated” are also displayed when abnormal conditions occur.

Fault Detection and Alert System

The system is designed to detect multiple fault conditions, including:

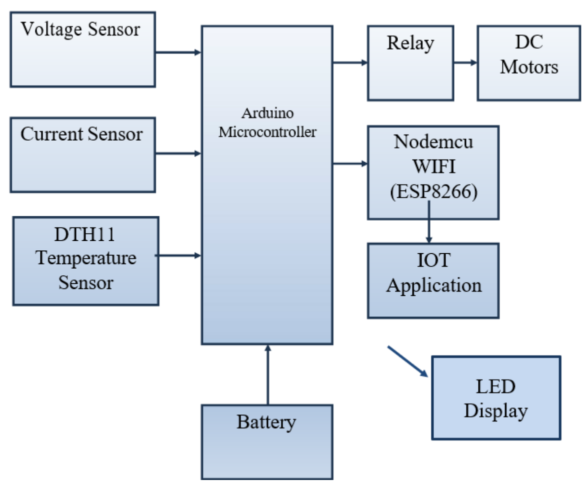
- Over-temperature (>50°C)
- Overvoltage
- Overcurrent
- Deep discharge

When a fault is detected:

- The system triggers a protective cut-off
- A warning is displayed on the LED
- Optional buzzer/LED alerts can be activated

This ensures quick user awareness and prevents further damage to the battery.[6]

BLOCK DIAGRAM



V. RESULTS AND DISCUSSION

The system was tested using a 3S (11.1V) Lithium-ion battery configuration. During the testing phase, the BMS successfully identified unbalanced cell voltages and initiated a safety cutoff when a simulated overheating condition was introduced via the DHT11 sensor.

1. Efficiency Analysis

Integration of IoT allowed for the observation of "Voltage Sag" during high-current draws. This data is crucial for predictive maintenance, as a sudden drop in voltage suggests an aging cell (High Internal Resistance). By identifying these cells early, the BMS prevents the premature failure of the entire battery pack.[8]

2. Comparison with Conventional Systems

Unlike passive BMS units that only balance cells, this IoT-enabled system provides: 1. Historical data logging for warranty verification. 2. Remote alerts for the user via mobile/web interface. 3. Faster response time due to local interrupt-driven safety logic.[10]

VI. CONCLUSION AND FUTURE WORK

This project successfully demonstrates the design and implementation of an IoT-based Battery Management System. The use of Arduino provided a cost-effective and flexible platform for real-time monitoring. The results confirm that cell-level monitoring and automated safety cutoffs significantly reduce the risk of thermal runaway and improve the overall lifespan of EV batteries.

Future Enhancements

Machine Learning:

Implementing AI models to predict Remaining Useful Life (RUL) based on historical discharge patterns.

Active Balancing:

Moving from passive resistor-based balancing to active capacitor-based energy redistribution between cells.

Can-Bus Integration:

For direct communication with the vehicle's Motor Controller and ECU.

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