# IoT-Based Battery Management System for Electric Vehicles

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**Abstract - This paper presents an IoT-Based Battery Management System (BMS) for Electric Vehicles (EVs) to enhance battery safety, performance, and monitoring. The system uses sensors to measure voltage, current, and temperature, which are processed by an Arduino microcontroller. Data is transmitted to the cloud using an ESP8266 Wi-Fi module, enabling real-time remote monitoring through the ThingSpeak platform. An automatic cooling mechanism is implemented using a relay-controlled fan to prevent overheating. The proposed system is cost-effective, reliable, and scalable, making it suitable for EVs and energy storage applications while improving battery life and operational safety.**

## 1. INTRODUCTION

The rapid growth of **Electric Vehicles (EVs)** has transformed the transportation sector by offering an eco-friendly alternative to conventional fuel-based vehicles. EVs rely heavily on rechargeable battery systems, which play a crucial role in determining vehicle performance, efficiency, and safety. However, improper battery usage, overcharging, overheating, and deep discharging can significantly reduce battery life and may lead to hazardous conditions.

To address these challenges, a **Battery Management System (BMS)** is essential. A BMS monitors key battery parameters such as voltage, current, and temperature, ensuring safe and optimal operation. Traditional BMS solutions are limited to local monitoring and lack advanced communication capabilities, making it difficult to track battery performance remotely.

With the advancement of the Internet of Things (IoT), it is now possible to enhance conventional BMS by integrating real-time data communication and cloud-based monitoring. An IoT-based BMS enables continuous tracking of battery parameters, remote access to system data, and timely alerts in case of abnormal conditions. This improves system reliability, reduces maintenance efforts, and enhances user convenience.

In this paper, an IoT-based Battery Management System is proposed using an Arduino microcontroller, sensors, and a Wi-Fi module for cloud connectivity. The system not only monitors battery conditions in real time but also incorporates safety mechanisms such as automatic cooling during overheating. The proposed solution aims to provide a cost-effective, reliable, and scalable approach for modern electric vehicle applications.

## 2. LITERATURE REVIEW

The development of **Battery Management Systems (BMS)** has gained significant attention in recent years due to the rapid growth of Electric Vehicles (EVs) and renewable energy systems. A conventional BMS is responsible for monitoring battery parameters such as voltage, current, and temperature to ensure safe and efficient operation. However, traditional systems are limited in terms of real-time remote monitoring and advanced data analysis.

Several researchers have explored the integration of the **Internet of Things (IoT)** with BMS to overcome these limitations. IoT-enabled BMS allows continuous monitoring of battery parameters and provides remote access to data through cloud platforms. Studies published in IEEE journals highlight that IoT-based systems improve reliability, enable predictive maintenance, and reduce the risk of battery failure.

In one study, an IoT-based battery monitoring system was developed using wireless communication to transmit data to a cloud server, where it was analyzed and displayed in graphical form. This approach allowed users to track battery performance in real

time and receive alerts during abnormal conditions. Another research work focused on implementing smart BMS with temperature control mechanisms, which helped in preventing thermal runaway and improving battery lifespan.

Researchers have also investigated the use of advanced sensors and microcontrollers to improve accuracy and response time. While high-end systems provide better performance, they are often costly and complex. Therefore, there is a need for a **cost-effective and scalable solution** that can be used in educational projects and small-scale EV applications.

This paper builds upon previous research by developing a low-cost IoT-based BMS using Arduino, ESP8266, and commonly available sensors. The proposed system aims to provide real-time monitoring, automatic safety control, and remote accessibility while maintaining simplicity and affordability.

## 3. SYSTEM ARCHITECTURE

The proposed **IoT-Based Battery Management System (BMS)** is designed to monitor, control, and transmit battery parameters in real time. The system architecture consists of multiple interconnected modules that work together to ensure safe and efficient battery operation. The overall system is divided into the following main units:

### 3.1 Sensing Unit

The sensing unit is responsible for measuring key battery parameters. It includes:

- **Voltage Sensor:** Measures the battery voltage using a voltage divider circuit.

- **Current Sensor (ACS712):** Measures the current flowing through the battery and load.

- **Temperature and Humidity Sensor (DHT11):** Monitors battery temperature and surrounding environmental conditions.

These sensors continuously collect real-time data from the battery system and send it to the microcontroller.

### 3.2 Control Unit

The control unit consists of the **Arduino Uno microcontroller**, which acts as the brain of the system. It performs the following functions:

- Reads and processes sensor data

- Compares values with predefined safety limits

- Controls output devices such as relay and display

- Sends processed data to the communication module

### 3.3 Communication Unit

The communication unit uses the **ESP8266 Wi-Fi module** to enable IoT connectivity. It transmits sensor data from the Arduino to the cloud platform (**ThingSpeak**) using internet communication protocols. This allows:

- Remote monitoring of battery parameters

- Real-time data visualization

- Alert generation for abnormal conditions

### 3.4 Actuation Unit

The actuation unit includes a **relay module and a 12V cooling fan**. When the temperature exceeds a predefined threshold:

- The Arduino activates the relay

- The relay switches ON the cooling fan

- The fan reduces battery temperature, ensuring safe operation

### 3.5 Display Unit

A **16×2 LCD display** is used to show real-time battery parameters such as voltage, current, and temperature. This provides a simple and user-friendly local interface for monitoring.

## 3.6 Cloud Platform

The system uses the **ThingSpeak IoT platform** for cloud-based data storage and visualization. It provides:

- Real-time graphical representation of data
- Historical data logging
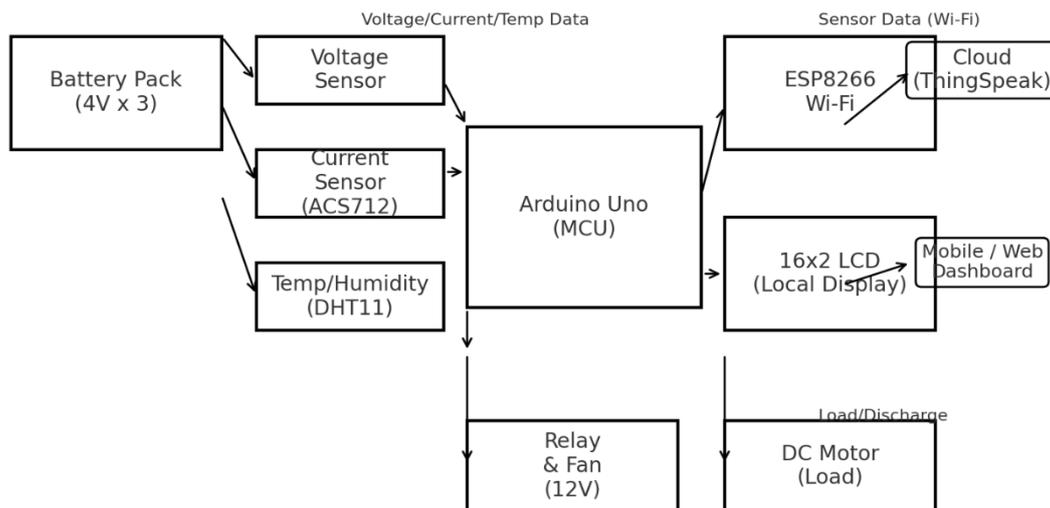- Remote accessibility from any location



Fig 1: Block diagram of BMS

## 4. WORKING PRINCIPLE

The **IoT-Based Battery Management System (BMS)** operates by continuously monitoring key battery parameters and taking appropriate actions to ensure safe and efficient operation. The system integrates sensors, a microcontroller, and an IoT communication module to achieve real-time monitoring and control.

Initially, the battery pack supplies power to the system and the connected load. The **voltage sensor** measures the battery voltage using a voltage divider circuit, while the **ACS712 current sensor** measures the current flowing through the circuit. At the same time, the **DHT11 sensor** monitors the temperature and humidity of the battery environment. These sensors generate analog and digital signals corresponding to the measured values.

The collected data is sent to the **Arduino Uno microcontroller**, which processes the input signals using programmed logic. The microcontroller continuously compares the measured values with predefined safety thresholds. If all parameters remain within safe limits, the system continues normal operation.

When the system detects abnormal conditions, such as excessive temperature or overcurrent, it immediately takes corrective action. For example, if the temperature exceeds a set limit, the Arduino activates the **relay module**, which turns ON the cooling fan to reduce the temperature. This prevents overheating and protects the battery from potential damage.

Simultaneously, the processed data is transmitted to the cloud using the **ESP8266 Wi-Fi module**. The data is uploaded to the **ThingSpeak platform**, where it is displayed in graphical form for real-time monitoring. Users can access this data remotely from any location, allowing continuous supervision of the battery system.

Additionally, a **16×2 LCD display** shows real-time values of voltage, current, and temperature locally, providing immediate feedback to the user.

Thus, the system works in a continuous cycle of data acquisition, processing, decision-making, and communication, ensuring efficient battery management, improved safety, and enhanced reliability for electric vehicle applications.
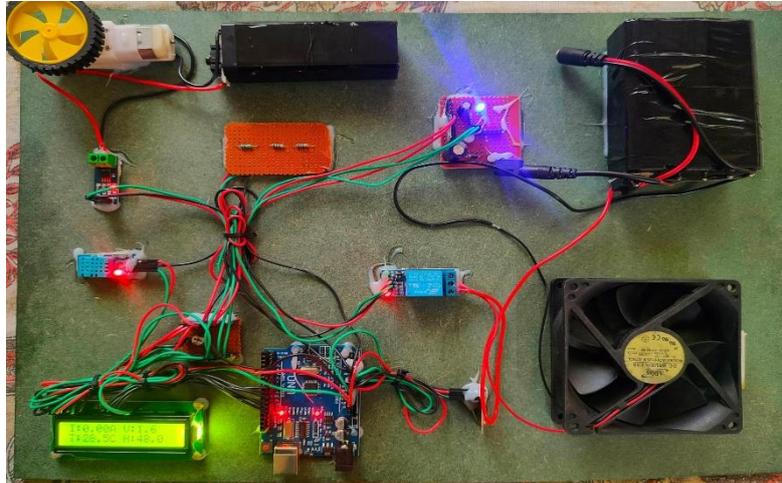


Fig 2:  Project image

## 5. RESULTS AND DISCUSSION

The proposed **IoT-Based Battery Management System (BMS)** was successfully designed and tested using a 12V battery setup and a DC motor as a load. The system was evaluated under different operating conditions to analyze its performance in terms of monitoring accuracy, response time, and safety features.

During testing, the **voltage sensor** provided stable and accurate voltage readings of the battery, while the **ACS712 current sensor** effectively measured the load current under varying conditions. The **DHT11 sensor** monitored temperature changes, especially when the system was operated for longer durations or under higher loads.

The **Arduino Uno microcontroller** processed the sensor data efficiently and displayed real-time values on the LCD. The integration with the **ESP8266 Wi-Fi module** enabled successful transmission of data to the ThingSpeak cloud platform. The data was visualized in the form of graphs, allowing easy tracking of voltage, current, and temperature variations over time.

One of the key observations was the system's ability to respond to abnormal conditions. When the temperature exceeded the predefined threshold, the relay was activated automatically, turning ON the cooling fan. This resulted in a noticeable reduction in temperature, demonstrating the effectiveness of the thermal protection mechanism.

The system also showed good reliability in continuous operation. There were no major delays in data transmission, and the IoT platform updated readings at regular intervals. However, slight variations in sensor readings were observed due to the use of low-cost sensors, which can be improved using high-precision components.

Overall, the results confirm that the proposed system provides:

- Accurate and real-time monitoring of battery parameters

- Effective thermal management through automatic cooling

- Reliable data transmission and visualization using IoT

- Improved safety and operational efficiency

Fig 3: Result of the project

## 6. ADVANTAGES

The proposed **IoT-Based Battery Management System (BMS)** offers several advantages over conventional battery monitoring systems. By integrating sensing, control, and IoT communication, the system improves safety, efficiency, and usability in electric vehicle applications.

- Real-Time Monitoring
- Enhanced Safety
- Remote Accessibility
- Automatic Control System
- Cost-Effective Design
- Improved Battery Life
- Easy Implementation and Scalability
- User-Friendly Interface

## 7. CONCLUSION

This paper presents a cost-effective and efficient IoT-based Battery Management System for Electric Vehicles. The system successfully monitors battery parameters in real time and ensures safety through automated control mechanisms. The integration of IoT enhances accessibility and enables remote monitoring, making it a promising solution for future smart EV systems.

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