

IoT Based Electric Vehicle Battery Management System

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Abstract—Ensuring the safety and dependability of high-capacity battery systems has become more difficult as a result of the widespread use of electric vehicles (EVs). The possibility of thermal runaway, which can result in battery overheating, fires, or even explosions, is among the most serious issues. This project suggests an Internet of Things (IoT)-Based Battery Management System (BMS) tailored for electric cars that addresses this problem by emphasizing multi-level safety response and real-time temperature monitoring. The system makes use of a DHT11 sensor to track temperature and humidity levels and an ESP8266 microcontroller for data collection and wireless communication. A mobile application receives the collected data continuously, allowing for remote user monitoring. The BMS reacts using a tiered protection strategy based on the temperature thresholds:

- The user receives notifications and an alarm when the temperature reaches 75°C.
- An air-cooling mechanism is triggered at 80°C.
- A fluid-based cooling system is activated at 85°C.

The system shuts down completely at 90°C to avoid damage or danger, and it automatically restarts when the temperature drops to a safe level. A cooling fan, a fluid pump, relay modules for actuation, copper tubes and aluminium fins for heat dissipation, and auxiliary electronic parts for safety and regulation make up the hardware configuration. In addition to preventing disastrous battery failures, this automated and intelligent system increases user safety and confidence in EV technology. The project intends to establish a new standard for electric vehicle safety and dependability by combining IoT with efficient thermal management.

1.INTRODUCTION

In the global movement to lessen carbon emissions and reliance on fossil fuels, electric vehicles, or EVs, have emerged as a game-changing solution. The use of EVs is growing quickly in the commercial, industrial, and personal sectors due to growing environmental concerns and a move toward sustainable

transportation. Even though EV technology is very promising, there are still a lot of technical obstacles to overcome, especially with regard to the longevity, safety, and performance of the high-capacity lithium-ion battery systems that power these cars. Thermal runaway, a hazardous condition where an excessive accumulation of heat within the battery can result in uncontrollable reactions that cause overheating, fire, or even explosion, is one of the most urgent issues. Despite being statistically rare, these occurrences have happened in real-world situations and pose significant risks to EV users, infrastructure, and public confidence. Inadequate battery management systems that are unable to identify or address early warning indicators are frequently the cause of these incidents. This project presents an Internet of Things (IoT)-Based Battery Management System (BMS) designed especially for electric vehicles in order to address this crucial issue. Real-time environmental monitoring and a dynamic, multi-tiered safety response mechanism are two ways that the suggested system improves battery safety. By providing users with remote monitoring capabilities through a specialized mobile application, it not only responds intelligently to critical battery conditions but also raises user awareness and safety. The system's ability to continuously monitor battery temperature and humidity using a DHT11 sensor forms its basis. An ESP8266 microcontroller processes this data, managing wireless communication in addition to real-time data acquisition.

to mobile or cloud-based platforms. Vehicle owners can view the current battery condition and get immediate alerts in the event of abnormalities using the mobile application, which acts as the user interface.

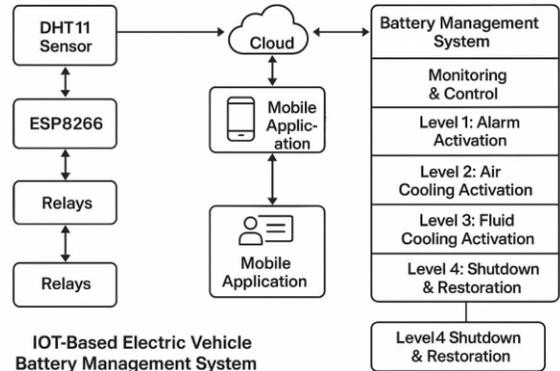
Five response levels make up the battery safety mechanism, which is based on predetermined temperature thresholds:

By emitting an audible alarm and promptly alerting the user, the system gives an early warning signal of potential danger at 75°C.

To reduce the temperature rise, an air-cooling system consisting of strategically placed fans is activated at 80°C. The system switches to a fluid-based cooling system, which is more appropriate for managing heat, if air cooling is insufficient at 85°C high heat loads. To prevent thermal explosion or irreparable battery damage, the system fully shuts down the battery at 90°C. As the battery cools to safe operating limits, automatic restoration occurs gradually, reactivating functions as conditions stabilize. This system's hardware implementation has been thoughtfully planned for efficiency and dependability. While copper tubes transport coolant fluids during the active cooling phase, aluminum fins are utilized for passive heat absorption and dissipation. Relay modules, PNP transistors, and MOSFETs manage control and switching functions, guaranteeing accurate and responsive system component actuation. A strong and cohesive hardware structure is ensured by additional components like transformer-based power regulators, cooling fans, and fluid pumps.

This BMS dramatically lowers the risk of catastrophic battery failures by fusing intelligent thermal management with Internet of Things connectivity. It provides an essential safety layer that is frequently lacking or inadequate in many current EV platforms, particularly in models that are more expensive. This system is a critical step in fostering user confidence in electric mobility and goes beyond simple technological advancement. Unlocking the full potential of EVs will require integrating intelligent monitoring and protection systems as battery technology advances. Setting a new standard for safety, openness, and dependability in electric vehicle design, the suggested IoT-Based BMS is a creative and adaptable solution that works with a variety of vehicle models and battery capacities.

2. ARCHITECTURE DIAGRAM



Sensor DHT11

- This sensor measures humidity and temperature.
- It continuously collects environmental data (inside the battery compartment).
- Transmits this information to the microcontroller ESP8266.

ESP8266 Microcontroller

The ESP8266 is a Wi-Fi-capable microcontroller that is used to handle control logic and process sensor data. It uses temperature thresholds to determine how to react after receiving data from the DHT11 sensor. It interacts with relay modules to initiate the following actions:

- Setting off alarms
- Turning on cooling systems
- Starting the system shutdown

Relays

ESP8266-controlled electronic switches and relays.

Used to:

- Turn on an alarm system (such as a buzzer)
- fan for cooling (air cooling)
- Liquid cooling fluid pump
- Complete system shutdown when necessary

Cloud

The ESP8266 uses WiFi to transmit temperature and humidity data to the cloud. This makes it possible to communicate with the user in real time.

Mobile Application:

- connected to the cloud.
- Gets status updates and sensor data.
- Shows the temperature in real time.
- Provides the user with push notifications in emergency situations.

- Enables remote battery health and system behavior monitoring.

Battery Management System

This block breaks down the BMS's logic and operation into five temperature-level-based stages:

Monitoring & control

continuous tracking of temperature and humidity information via cloud and mobile apps.

Level 1: Alarm Set Off ($\geq 75^{\circ}\text{C}$)

- There is an alert (such as a buzzer sound).
- The user's mobile app receives the notification.

Level 2: Activation of Air Cooling ($\geq 80^{\circ}\text{C}$)

- A relay is used to activate a cooling fan.
- Lowers the temperature of the battery.

Level 3: Activation of Fluid Cooling ($\geq 85^{\circ}\text{C}$)

- The fluid pump, a liquid cooling system, is turned on.
- For higher temperatures, more efficient than air cooling.

Level 4: Restoration & Shutdown ($\geq 90^{\circ}\text{C}$)

- In order to avoid overheating or fire, the system automatically shuts down.
- The system automatically returns to normal operation as soon as the temperature falls to a safe level.

Modules

IoT-enabled multi-layered protection is how the Battery Management System (BMS) for electric vehicles guarantees battery safety. To stop dangerous situations like battery explosions, the system makes use of progressive cooling mechanisms, automated alert systems, and real-time monitoring. Six logical modules make up the entire structure, each of which focuses on a distinct safety or control feature of the battery's functioning.

Monitoring & Control

Real-time data transmission and collection are made possible by this module.

Parts: ESP8266 Wi-Fi Module, DHT-11 sensor

Functions:

- Continuously checks the temperature and humidity of batteries
- Transmits information to a cloud dashboard or mobile app.
- Establishes the foundation for automated reactions.

Alarm and Notification System

When the temperature reaches 75°C , this module is turned on. buzzers and mobile app notifications are components.

Functions:

- Triggers both digital and audio alerts
- Instantly alerts users to dangerous situations

Air Cooling Activation

This is the initial automated cooling step, and it is activated at 80°C .

Parts: Features of a high-speed air-cooling fan.

Function:

- Uses forced air to lower battery temperature.
- Combined with switching relay units Design feature: When air cooling, aluminum fins improve heat rejection.

Fluid Cooling Mechanism

Engaged at 85°C , this is a secondary, more efficient cooling stage.

Components: Pump, Copper Tubes, Fluid Reservoir

Functions:

- Circulates coolant over heated surfaces
- Dissipates heat more effectively.

Complete Shutdown Mechanism

The shutdown starts right away when the temperature reaches 90°C .

Parts: MOSFETs, Relay Transistors (PNP547)

Functions

- Cutting the battery's power supply
- Preventing fire or explosion

3. METHODOLOGY

The design, development, and implementation of an Internet of Things (IoT)-based Battery Management System (BMS) for electric vehicles is the main goal of this project's methodology. The primary objective is to improve EV battery safety and dependability by

continuously monitoring their thermal conditions and initiating multi-level protective measures to stop thermal runaway or overheating. The method combines software elements like IoT platforms and mobile apps with hardware elements like sensors, microcontrollers, and actuators.

Hardware configuration, sensor integration, firmware development, cloud connectivity, mobile monitoring, and system testing are all covered in detail in this chapter. Modern EV safety standards require real-time monitoring, automation, and user awareness, all of which are emphasized by the methodology.

Overview of System Design

Three main layers make up the structure of the suggested system:

Sensing and Control Layer: The sensing and control layer is in charge of gathering data from sensors and using a microcontroller to make decisions.

Communication Layer: Wirelessly sends sensor data to a mobile app and cloud platform.

Action Layer: carries out safety functions like setting off alarms, turning on cooling systems, or turning off the battery when necessary.

To guarantee precise operation, quick reaction times, and smooth user interaction, every element in these layers has been carefully chosen and integrated.

Implementation of Hardware

Integration of Sensors:

A DHT11 sensor is used by the system to continuously measure humidity and temperature. The ESP8266 microcontroller, which is connected to this sensor, reads and processes the data. The DHT11 was selected due to its affordability, ease of use, and adequate accuracy for this use case.

Actuation and Microcontroller:

The ESP8266 serves as the control unit in addition to gathering sensor data. Temperature readings are compared to predetermined threshold values. According to the findings, it uses relay modules to control multiple actuators:

A warning buzzer (activated at 75°C)

A fan that cools air (activated at 80°C)

A cooling pump that uses fluid (activated at 85°C)

System shutdown (safety triggered at 90°C)

In reaction to rising temperatures, these processes are intended to happen gradually and intensify.

Cooling Mechanisms

Two types of cooling systems are implemented:

Air Cooling: A fan is activated to dissipate heat through airflow, assisted by aluminum fins.

Fluid Cooling: A pump circulates coolant through copper tubes, absorbing and removing heat more efficiently.

Programming with Arduino ID

The entire logic of the system is written in **Arduino C/C++** using the Arduino IDE. Key functions include:

- Reading sensor data
- Comparing temperature values with thresholds
- Activating/deactivating relays for cooling and alarms
- Sending data to the mobile application.

Reaction Plan

To stop battery failures, a multi-level safety response strategy is used:

Level 1-Alert (75°C): Sounds a buzzer and notifies the user via mobile device.

Level 2-Air Cooling (80°C): Uses air flow to lower temperature by turning on a high-speed fan.

Level 3-Fluid Cooling (85°C): To quickly cool the battery, a fluid pump is turned on to circulate coolant.

Level 4-Shutdown (90°C): To avoid risks like fire or explosion, the system shuts down.

Restoration Phase: The system gradually recovers from a temperature drop below safe thresholds by ceasing air cooling first, followed by fluid cooling, and then returning to normal operation.

This multi-layered strategy prevents sudden shutdowns unless absolutely required and guarantees effective battery protection.

Monitoring on the Go and User Engagement

The Blynk platform powers the mobile app, which gives users access to an intuitive dashboard with real-time temperature and humidity readings. Even when they are not in the car, users are warned when the battery reaches dangerously high temperatures. This

increases user confidence and makes battery health more transparent.

Among the app's primary features are:

- Real-time display of humidity and temperature
- Alerts and warnings
- System status visual indicators (cooling mode, shutdown, etc.)
- Tracking for automatic recovery after the battery cools

Validation and Testing

To verify the operation of every part and the entire system, a number of tests were carried out. These comprised:

Unit Testing: DHT11, relays, fans, pumps, and alarms are all tested separately.

Integration testing: Verified that every part (sensor → controller → actuators) interacted as intended.

Threshold testing involves raising the temperature artificially to 75°C, 80°C, 85°C, and 90°C to see if the system reacts correctly.

Restoration Testing: Confirmed that, without human assistance, the system returns to normal after cooling.

Network Recovery: To guarantee auto-reconnection and system stability, Wi-Fi disconnection and power loss scenarios were tested.

Every test case demonstrated that the system functions as intended and is capable of managing EV battery situations in the real world.

4. CONCLUSION

Thermal management is one of the most important issues in electric vehicle safety, and the IoT-Based Electric Vehicle Battery Management System (BMS) created in this project offers a clever and workable solution. Making sure high-capacity lithium-ion batteries are safe and long-lasting is crucial as the number of electric vehicles on the road keeps growing. In order to meet that need, this project uses Internet of Things (IoT) technology to combine automated, multi-stage safety responses with real-time temperature and humidity monitoring. The battery is constantly shielded from overheating and possible damage thanks to the implementation of a multi-level protection strategy that includes alarm alerts, air cooling, fluid cooling, and emergency shutdown. Additionally, by

adding a layer of dependability, the automatic restoration mechanism makes the system intelligent and self-sustaining.

Relay modules, fans, pumps, copper tubes, aluminum fins, and other hardware were skillfully integrated to provide effective cooling, and the Blynk app functioned as an intuitive user interface for alerts and real-time system interaction. In addition to being modular and reasonably priced, the entire system can be modified to accommodate different kinds of electric cars and battery setups.

By integrating remote user interaction, automated thermal response, and Internet of Things connectivity, the suggested BMS improves the safety of electric vehicles. It lays a solid basis for future developments like state-of-charge tracking, AI-based prediction, and integration with intelligent charging infrastructure. This solution has a lot of potential for practical application, particularly in developing nations and mid-range EV models where dependability and cost are important factors.

5. FUTURE IMPLEMENTATIONS

Several potential future improvements could be taken into consideration in order to further increase the Battery Management System's safety, effectiveness, and intelligence:

Integration of Machine Learning:

Use AI algorithms to forecast battery failures and adjust system response according to usage trends.

State-of-Charge and Health Monitoring: Include tools to gauge the battery's level of charge and general condition to help users better manage its lifespan.

GPS-Based Heat Mapping: This technique, which is particularly helpful for fleet management, uses GPS to monitor and examine overheating trends in particular locations.

Improved Mobile App Dashboard: Add analytics, data history, and real-time graphs to the app to improve user engagement and maintenance scheduling.

Blockchain for Data Security: Use blockchain technology to protect sensor and event data, guaranteeing tamper-proof logs for diagnostics and warranties.

Voice Assistant Support: Integrate Alexa or Google Assistant to enable voice commands for control and status updates.

Wireless Charging Sync: Adapt charging rates dynamically according to battery temperature by integrating with wireless charging systems.

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