EV BMS With Charge Monitor and Fire Protection

Prof. G Justin Sunil Dhas, Sarang M, Shanat K S, Sherfin M B, Yadunand Sajith Professor, EEE Department, Vimal Jyothi Engineering College, Kannur, India EEE Department, Vimal Jyothi Engineering College, Kannur, India

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ABSTRACT

The increasing adoption of electric vehicles (EVs) has highlighted the need for an efficient and intelligent battery management system to ensure safety, longevity, and performance. This project proposes an IoT-based EV Battery Management System (EVBMS) that continuously monitors key battery parameters such as temperature, voltage, and current to prevent potential hazards. The system utilizes sensors to detect anomalies, a CO2-based fire extinguishing mechanism for fire prevention, and a cutoff relay to disconnect the battery in case of critical conditions.

Real-time data is transmitted to an IoT platform, enabling remote monitoring and instant alerts for abnormal conditions. Additionally, data logging and visualization provide insights into battery health, helping users take preventive measures. The proposed EVBMS undergoes rigorous testing to optimize performance, minimize false alarms, and ensure reliability. By integrating IoT technology, this system enhances EV safety through automated monitoring, early fault detection, and efficient charge management, ultimately improving the reliability and sustainability of electric mobility.

Keywords: EV Battery Management System (EVBMS), IoT, Electric Vehicles (EV), Battery Safety, Fire Detection, Charge Monitoring, Current Spike Detection, Real-Time Alerts, Data Logging, Remote Monitoring, Automated Protection, Smart Battery Management, Battery Health Monitoring.

1. INTRODUCTION

With the rapid adoption of electric vehicles (EVs), ensuring battery safety and performance has become a critical challenge. The EV Battery Management System (EV BMS) using IoT is designed to enhance battery reliability by integrating real-time monitoring, fire detection, and charge management. This system employs sensors to continuously track temperature, voltage, and current levels, preventing issues such as overheating, overcharging, and current spikes that could lead to failures or fire hazards. In case of abnormalities, automated safety mechanisms, including a CO2 fire suppression system and a cutoff relay, are activated to mitigate risks. The collected data is transmitted wirelessly to an IoT platform, where users receive instant alerts and can access real-time and historical battery performance analytics. By leveraging IoT for continuous monitoring and intelligent decision-making, this system aims to improve EV safety, optimize battery lifespan, and provide users with enhanced control and insights into battery health.

2. LITERATURE REVIEW

According to the authors, a Battery Management System (BMS) in electric vehicles (EVs) plays a crucial role in overseeing the charging and discharging of rechargeable batteries, which helps in optimizing operational costs. The BMS ensures the safety and reliability of the battery, increasing its lifespan by preventing it from entering a harmful state. To monitor the battery's condition, parameters such as voltage, current, and ambient temperature are tracked using various monitoring techniques. Analog and digital sensors, integrated with microcontrollers, are employed for this purpose. The paper also covers important aspects like the battery's state of charge, health, life, and its maximum capacity. By analyzing these methods, the paper provides insights into potential future challenges and solutions. [2]

Rakshitha Ravi discusses how electric vehicle manufacturers are adopting advanced technologies like Artificial Intelligence and the Internet of Things (IoT) to enhance efficiency. Vehicles have become an integral part of everyday life and industrial operations, and considerable efforts are underway to replace combustion engines with electric motors. The integration of IoT is expected to significantly improve EV charging performance and its impact on city planning, thereby simplifying urban living. The paper highlights the ongoing transformation in the automotive and transportation sectors, which is driven by factors like increased computing power and ubiquitous connectivity. Ravi also touches upon the importance of electric vehicles, their historical development, and provides a brief overview of the EV Battery Management System (BMS). [3]

The authors in another study provide a review of battery fires in electric vehicles. Over the past decade, electric vehicles (EVs) have revolutionized the automotive industry globally, driven by advancements in Li-ion battery technology. However, the fire risks associated with these high-energy batteries have raised significant safety concerns. This review specifically focuses on the fire safety issues in EVs linked to thermal runaway and fires in Li-ion batteries. The paper also discusses global safety standards and regulations related to lithium-ion batteries (LIBs), including their characteristics, application, and testing methods to trigger thermal runaway. Recent fire incidents in electric vehicles and energy storage systems are reviewed to help improve safety standards and reduce the risk of failure. [5]

In our research, we also referred to additional sources to gather relevant information for our project. This helped us better understand electric vehicles, the importance of their Battery Management Systems, and the frequency of fire accidents related to them. The information provided valuable insights into how extreme conditions or operational faults can lead to catastrophic events like thermal runaway or fires. Such failures can release toxic gases, cause fires, jet flames, and even explosions. [4]

3. METHODOLOGY

The EV Battery Management System (EVBMS) is designed to enhance battery safety and performance using IoT-based monitoring, fire detection, and charge management. The methodology consists of the following key phases:

1. System Design and Component Selection

Microcontroller: ESP32 or similar for IoT connectivity and real-time data processing.

Sensors:

Temperature Sensor (DS18B20/MLX90614): Monitors battery temperature.

Current Sensor (ACS712/INA219): Detects high current spikes and prevents overload.

Voltage Sensor: Monitors battery voltage to prevent overcharging or deep discharge.

Actuators:

CO_2 Fire Extinguisher System: Triggered when temperature exceeds a set threshold.

Cutoff Relay: Disconnects battery from the load in case of fire risk or abnormal conditions.

2. Data Acquisition and Monitoring

Sensor Data Collection: Real-time data on temperature, current, and voltage is gathered and processed using the microcontroller.

Threshold-Based Triggering:

If temperature exceeds a critical level, the CO_2 fire extinguishing system is activated.

If current spikes beyond a threshold, the cutoff relay disconnects the battery to prevent further damage.

Charge Management: The system regulates charging based on voltage levels to prevent overcharging.

3. IoT Integration and Alerts

Data Transmission: Sensor data is transmitted wirelessly to a Blink IoT platform.

Real-Time Alerts: If an abnormal condition is detected, alerts are sent to the Blink app for immediate user notification.

User Interface: A dashboard displays real-time and historical data trends for monitoring and analysis.

4. Data Logging and Analysis

Local Data Storage: All sensor readings (temperature, voltage, and current) are stored in the microcontroller's memory or an external SD card for further analysis.

Data Visualization: Trends in battery health and performance are displayed in graphs and dashboards to help users detect issues before they become critical.

5. System Testing and Optimization

Simulation and Testing: The system is tested under various conditions to ensure:

Accurate temperature and current detection.

Proper triggering of fire extinguishing and cutoff mechanisms.

Reliable alerts and notifications through IoT.

Performance Optimization: Adjust thresholds and refine the system for minimal false alarms while ensuring maximum safety.

6. Deployment and Implementation

Integration with EV Battery Systems: The final prototype is installed in an EV battery pack for real-world testing.

User Training and Documentation: Guidelines are provided for users on interpreting alerts, handling battery issues, and system maintenance.

4. SYSTEM ARCHITECTURE

- **BLOCK DIAGRAM**

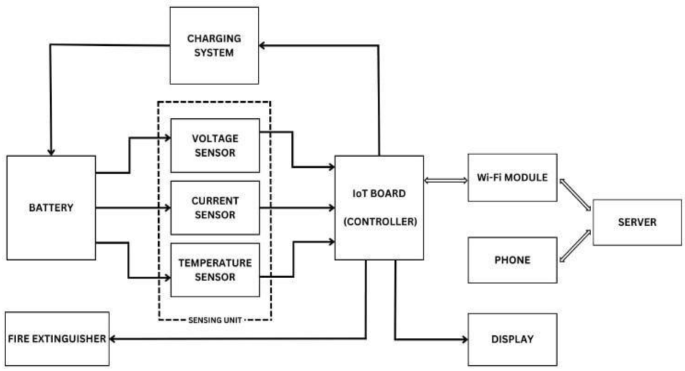

Fig 1. Block Diagram

The block diagram represents an IoT-based Electric Vehicle Battery Management System (EVBMS) designed to enhance battery safety, optimize performance, and enable real-time monitoring. At the core of the system is the battery, which powers the EV and is continuously monitored using a sensing unit consisting of voltage, current, and temperature sensors. These sensors ensure that the battery does not overcharge, experience excessive discharge, or overheat, thereby preventing potential damage or failure. The IoT board (controller) acts as the central processing unit, receiving real-time data from the sensors and making decisions based on predefined safety thresholds. If any abnormal conditions such as overheating or excessive current spikes are detected, the system can trigger appropriate safety mechanisms, including activating a CO_2-based fire extinguisher to prevent fire hazards. The charging system is integrated into the setup to regulate

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battery charging, ensuring efficiency and prolonging battery lifespan.

To facilitate remote monitoring and real-time notifications, the Wi-Fi module transmits data to a server, which processes and stores battery performance metrics for future analysis. Users can access this data via a mobile phone app or a local display, enabling them to monitor battery health, receive alerts, and take necessary actions when needed. This system not only enhances safety and reliability but also provides predictive maintenance insights, reducing the risk of unexpected failures. By leveraging IoT technology, this EV BMS offers an intelligent and automated approach to battery management, making electric vehicles more efficient and secure.

- **SOFTWARE REQUIREMENTS**

1. System Design and Component Selection
Arduino IDE/ESP IDF: Used to program ESP32 microcontroll ers for IoT connections and real-time data processing.
2. Data Collection and Monitoring
Embedded C: Required for programming the ESP32 to proces s sensor data from temperature, electrical and voltage sensors.
Serial Monitor (Arduino Serial Monitor): A debugging tool fo r analyzing real-time sensor data from a microcontroller.
3. IoT Integration and Warnings -
blynk IoT Platform: Provides realtime data transmission and warning messages when anomalies are recognized.
WiFi protocol: Used for wireless communication between ES P32 and the IoT dashboard.
4. Data Protocols and Analysis
Microcontroller Memory/SD Card Support: Used to save temp erature, voltage and current measurements for further analysis.
Data Visualization Tool (Excel/Grafana): Displaying trends r elated to battery health and performance through graphic repre sentation
5. System Testing and Optimization
Simulation Software (Proteus/Matlab): Used for testing and ve rifying systems for temperature hints, current overloads, and Burns recognition.

5. ALGORITHM

Step 1: Initialize variables and set battery current, voltage, and temperature to zero and charging mode to default(Auto) charging mode.
Step 2: Monitor current, voltage, and temperature values from respective sensors for real-time data.
Step 3: Check the status of the battery such as SoH, and SoC and if an abnormality is found send an alert to the user via the IoT modem.
Step 4:Check the individual cell voltage if the voltage levels are unequal activate the cell balancing circuit.
Step 5:Check the battery voltage if it is low send an alert to the user via the IoT modem stating "Battery voltage is low. Please charge the battery.
Step 5.1: Start charging the battery. Enable charging in auto mode and switch to fast charging if needed, once it reaches a particular temperature limit shift to slow
charging.
Step 6: Check the battery voltage if is high and send an alert to the user via the IoT modem stating "Battery voltage is high. Please disconnect the charger."
Step 6.1: Stop charging.
Step 7: Check if the temperature is higher than a specified value if higher then, send an alert to the user via the IoT modem.
Step 7.1: Enable the cooling system.
Step 7.2: Disconnect the charger if the vehicle is undercharging condition.
Step 8: Check the current for fault detection if a fault is detected isolate the circuit.
Step 9: Check for the temperature change and chance of fire.
Step 9.1: If fire is detected send an alert to the user via IoT modem stating "Fire detected. Please take immediate action".
Step 9.2: Turn on the fire extinguisher module.
Step 10: Wait for a specified interval before taking new measurements.
Step 11: Send the data continuously to user via IoT Modem.

6. CIRCUIT DESIGN

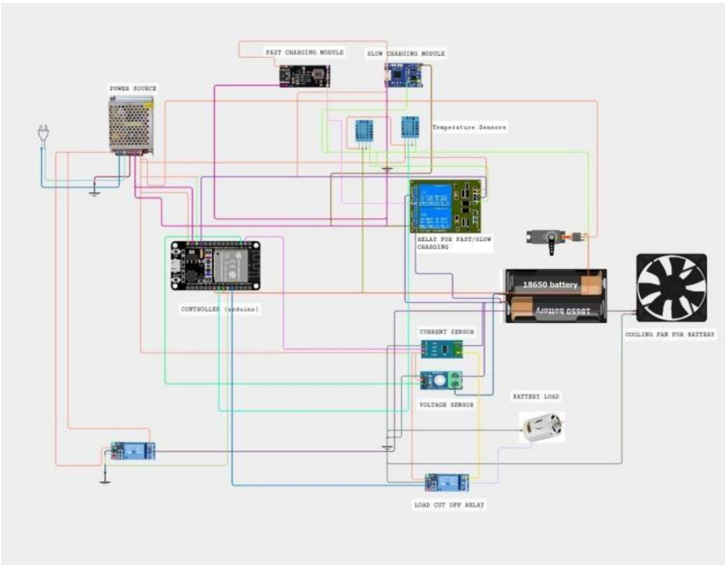

Fig 2. Circuit Diagram

The system is powered by an external power source t hat supplies microcontrollers (ESP32) and other circuit eleme nt energy. The ESP32 acts as a central control unit, processing data from various sensors and controlling the relay for chargi ng and fire prevention. The voltage sensor ensures a proper ch arge value and prevents overload and deep discharge, while th e power sensor detects abnormalities in power consumption. T emperature sensors play an important role in thermal manage ment and activate cooling or fire prevention mechanisms whe n overheating is determined. Depending on the battery conditi on, the microcontroller will select the corresponding load mod e to optimize battery life. Cutoff relays are also integrated into the circuit, isolating the battery in severe failures.In the case o f fire prevention, the design includes a fire delicate module tha t is triggered when excessive heat is detected. A cooling fan is installed to regulate the battery temperature under normal con ditions and prevent overheating.

Additionally, the system features IoT connectivity using a Wi-Fi module, allowing remote monitoring through a cloud server. The circuit transmits real-time battery health data to a mobile application or web interface, ensuring users receive instant alerts in case of issues.

7. WORKING & IMPLEMENTATION

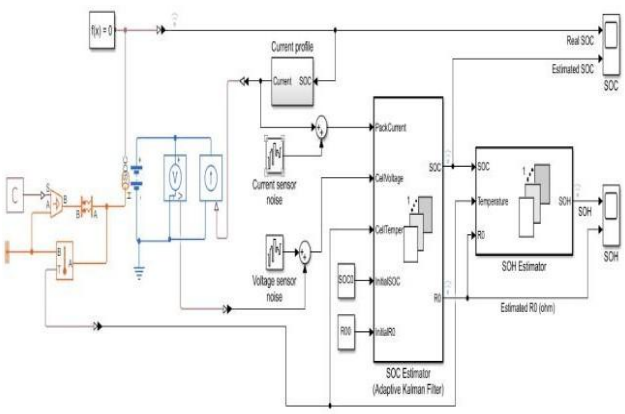

Fig 3. SOC And SOH Simulation Diagram

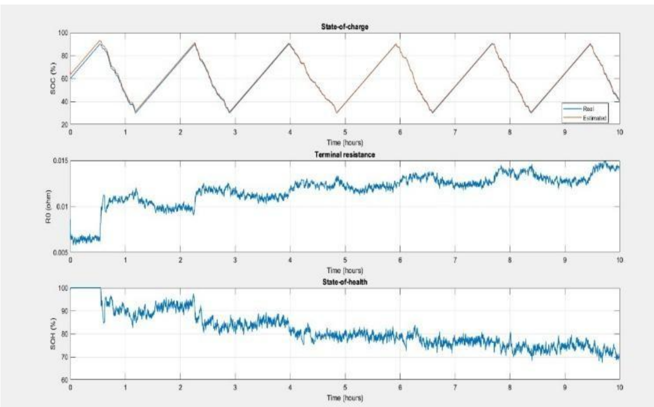

Fig 4. Graphical representation of Terminal Resistance, SOH, Time

The EV Battery management machine (EVBMS) with price monitoring and fireplace protection is designed to decorate the protection and efficiency of electrical car batteries with the aid of continuously tracking critical parameters including voltage, cutting-edge, and temperature. The machine employs an ESP32 microcontroller to technique sensor facts in actual time and make clever decisions based on predefined safety thresholds. whilst peculiar conditions like overheating or excessive current waft are detected, the system turns on protection mechanisms, together with a cooling fan, cutoff relay, and CO2 hearth extinguisher.Moreover, the rate management module guarantees premier charging by means of switching between speedy and sluggish charging modes, decreasing the chance of overcharging and lengthening battery lifespan. IoT integration permits users to screen battery health remotely via a mobile utility, imparting actual-time alerts and historic information visualization. The machine is carried out the usage of hardware components like sensors, relays, and a servo motor, along side software gear along with Arduino IDE and Blink IoT for programming and facts logging. After rigorous testing and calibration, the system is included into an EV battery % for actual-world assessment. The successful deployment of this task ensures enhanced battery protection, progressed reliability, and predictive maintenance abilties, making it a realistic solution for modern-day electric motors.

8. FUTURE SCOPE

The destiny scope of the EV Battery management device (EV BMS) with charge monitoring and hearth safety is significant, with ability advancements in protection, efficiency, and clever power management. Integrating synthetic intelligence (AI) and gadget learning can beautify predictive maintenance, permitting early detection of battery problems to prevent failures. The machine may be further stepped forward with the aid of incorporating wireless charging era, making EV charging extra handy and green. moreover, the integration of smart grids could permit dynamic charging based on electricity demand, reducing strain on energy networks and selling renewable energy usage. future traits may focus on **stable-kingdom batteries, which provide better strength density and stepped forward protection in comparison to traditional lithium-ion batteries. better hearth suppression structures, consisting of superior cooling mechanisms and automated extinguishing devices, can similarly minimize fireplace risks. expanding IoT competencies will allow actual-time facts sharing with manufacturers and provider centers, making sure timely software updates and proactive renovation. those advancements will make a contribution to sustainable mobility, enhancing battery overall performance, lowering environmental effect, and making EVs extra reliable for substantial adoption.

9. CONCLUSION

Through the integration of electric car (EV) Battery control and Motoring with hearth safety making use of IoT gives a good sized advancement in electric powered car generation, improving each protection and performance elements. through using IoT-primarily based answers, we've created a comprehensive system that now not simplest efficiently manages the EV's battery however additionally guarantees the protection of passengers, the vehicle, and its surroundings. thru meticulous research and cautious thing choice, we've advanced a sophisticated gadget structure that seamlessly integrates battery management, motor control, and hearth safety mechanisms. The implementation of IoT technology permits actual-time tracking and manage of the EV system, bearing in mind proactive management of battery fitness, motor efficiency, and hearth chance mitigation. furthermore, the inclusion of fireplace protection measures adds a further layer of safety, addressing issues associated with thermal runaway and capacity hearth hazards associated with high-energy lithium-ion batteries. fast detection and suppression systems, coupled with IoT connectivity, make sure swift reaction to any emerging fireplace threats, safeguarding both the vehicle and its occupants.

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