Electric Vehicle BMS with Fire Safety System

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ABSTRACT:

This project presents the design and implementation of an IoT-enabled Battery Management System (BMS) with integrated fire protection for electric vehicles. The system employs an Arduino microcontroller to monitor critical battery parameters such as voltage, current, and temperature in real-time. In addition, smoke and flame sensors are integrated to detect hazardous conditions. When abnormal situations like overheating, smoke, or fire are detected, the system activates an alarm, disconnects the motor through a relay, and triggers a fire extinguisher mechanism to prevent accidents. Furthermore, IoT connectivity via Wi-Fi enables remote monitoring, data logging, and real-time alerts to users, ensuring enhanced safety and proactive maintenance of e-vehicles. The proposed system is low-cost, scalable, and capable of improving battery safety and vehicle reliability.

1.INTRODUCTION:

Electric vehicles (EVs) rely heavily on battery systems, making Battery Management Systems (BMS) a critical component for ensuring efficiency,

often lack integrated fire protection and IoT-enabled monitoring, which are essential for enhancing safety in real-world applications. This project proposes an Arduino based smart BMS that not only measures essential battery parameters but also integrates smoke and flame detection to prevent fire hazards. In case of abnormal conditions, the system responds by triggering alarms, cutting off power supply, and activating a fire extinguisher mechanism. Furthermore, the inclusion of IoT connectivity via Wi-Fi enables real-time monitoring, alerts, and remote diagnostics, thereby providing a comprehensive safety solution for e-vehicles.

2.LITERATURE SURVEY:

1. **Kusekar et al. (2015)** studied the design and development of a low-cost electric car. Their work emphasized mechanical efficiency and highlighted the benefits of electric mobility in reducing fuel costs and pollution.

performance, and safety. A BMS is responsible for monitoring key battery parameters such as voltage, current, and temperature, while also protecting the battery from conditions that may lead to damage or failure. However, conventional BMS solutions

2. **Vignesh et al. (2015)** developed a "Free Energy Bicycle" using a dynamo system for energy regeneration. The study demonstrated the concept of charging batteries using kinetic energy from wheel motion.

3. **Awash Tekle (2014)** examined renewable energy integration into EV battery charging, combining solar and wind power sources for continuous charging.

4. **Patel and Patel (2012)** conducted structural analysis on lightweight chassis designs for EVs, focusing on durability and efficiency improvements.

5. **Ferdous et al. (2011)** explored in-motion charging using wind turbines installed on vehicles, showing how renewable energy can supplement EV power systems

3.METHODOLOGY:

The proposed E-Vehicle Battery Management System with Fire Safety is designed to operate as an intelligent,

autonomous safety controller that monitors the battery pack parameters and executes protection mechanisms when abnormal conditions are detected. The overall methodology involves data acquisition, signal processing, control action, and IoT-based communication. The system functions as a closed-loop control unit where continuous feedback from sensors ensures real-time decision-making.

The central component of the system is the Arduino microcontroller, which acts as the processing and control unit. It receives inputs from multiple sensors, including a voltage sensor, current sensor, temperature sensor (NTC thermistor), smoke sensor (MQ-2), and a flame detector. These sensors are strategically connected to the battery system to measure electrical and thermal parameters at various points. The Arduino continuously samples these sensor outputs, converts them into digital signals through its analog-to-digital converter (ADC), and compares them with the threshold limits programmed in the software.

In the normal operating condition, the measured voltage, current, and temperature values remain within safe limits. However, when a critical condition occurs — such as over-temperature, high current, smoke presence, or flame detection — the system immediately triggers a multi-level response mechanism. The microcontroller sends a control signal to the relay driver circuit, which disconnects the main power supply between the battery and the motor. This isolation prevents further current flow and eliminates the risk of short circuits or thermal runaway. Simultaneously, a buzzer or alarm system is activated to provide an audible alert to the user. To enhance fire response, the system also controls a spray actuator or fire extinguishing module, which releases a suppressant in the battery region.

An important part of the methodology is the integration of IoT technology for remote monitoring and data logging. The Arduino is interfaced with a Wi-Fi module (ESP8266/ESP32) that establishes wireless connectivity with a cloud-based IoT platform. Through this connection, real-time data such as voltage, temperature, and smoke level are continuously uploaded to a web dashboard or mobile application. The IoT server is configured to send instant notifications or email alerts to the user whenever a hazardous situation is detected. This enables proactive safety management even when the vehicle is unattended.

4. WORKING PRINCIPLE:

The E-Vehicle Battery Management System with Fire Safety operates as an intelligent electronic safety unit that continuously monitors the condition of the battery and surrounding environment. The system integrates various sensors, control circuits, and an IoT-based monitoring module to provide both automatic protection and remote supervision. The working of the proposed system can be understood through its functional blocks and their interconnections, as illustrated in the system's block diagram.

5.Block Diagram:

The block diagram of the system represents the interconnection of all electronic components that together ensure safe and reliable operation of the electric vehicle battery. The power supply unit provides the required DC voltage for the Arduino controller and all connected sensors. The Arduino microcontroller acts as the central processing unit that collects, analyzes, and responds to sensor data.
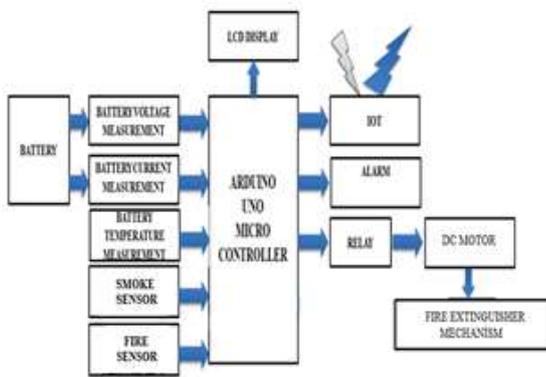
Figure 4.1. BLOCK DIAGRAM

The system includes several key sensors such as the voltage sensor, current sensor, temperature sensor, smoke sensor (MQ-2), and flame sensor. These sensors are connected to the input pins of the Arduino and continuously feed live readings to it. The LCD display module is connected to the output section and displays real-time readings of voltage, current, and temperature to the user. A relay module is also connected to the output section to control the power supply to the motor. The buzzer acts as an audible alarm system that alerts the user in case of a fault or fire hazard.

Additionally, the system includes a fire extinguisher mechanism, which is connected to a DC motor or pump system. When the Arduino detects a fire through the smoke or flame sensors, it triggers the relay to activate this mechanism, thereby releasing extinguishing material to prevent damage. The IoT module (ESP8266) is used for wireless data transmission to a cloud server, enabling remote monitoring and alert notifications through a mobile or web interface.

6. Operation of the System
This Framework gives the accompanying benefits:
Battery Status Observing and Show Charging of Battery according to required input boundaries Temperature observing with auto cutoff. The framework utilizes a li particle Battery, Battery charging and screen framework, Press Buttons, LCD Show, current sensor, voltage sensor, temperature sensor to foster this framework. The framework screens as well as safeguards an EV battery consistently.

We here foster the framework according to a 3S li particle battery. The framework we configuration will not just screen the battery and charge it securely yet in addition safeguard it to stay away from mishaps from happening. The framework when turned on utilizes its charging and observing hardware that permits client to somewhere safe charge the 3S battery.

While charging the voltage sensor is utilized to check voltage and cutoff the progression of current too to the battery utilizing charging hardware. The LCD show likewise shows the ongoing voltage level of battery.
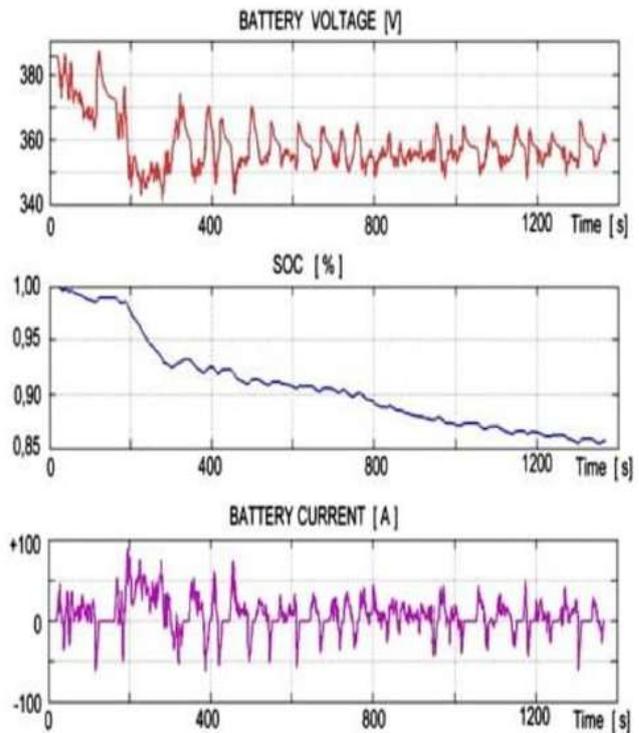
When the battery is completely energized, the framework removes the stock and shows Battery completely energized on LCD Show.

When associated with a heap the ongoing sensor monitors current drawn from battery and presentations the boundary on LCD Show. The temperature sensor is utilized to screen temperature of battery while charging as well as releasing.

On the off chance that the battery temperature is seen to stray from standard qualities, the framework naturally removes input as well as result supply and shows the temperature as well as a signal caution on the LCD show. In this way the framework considers a savvy and proficient battery charging as well as security framework

Figure 6.1. LCD DISPLAY
When the system detects any abnormal condition—such as a rise in temperature, presence of smoke, or flame detection—the Arduino immediately executes safety measures. First, it sends a control signal to the relay module, which disconnects the motor from the power source, thereby stopping current flow to prevent

further heating or short-circuiting. Next, the buzzer is activated to produce a loud alarm, alerting the user to the fault.

7. IoT-Based Monitoring

A key feature of this system is its IoT-based monitoring capability, which allows the user to observe system parameters and receive alerts remotely. The Arduino controller is interfaced with a Wi-Fi module (ESP8266/ESP32) that connects the hardware setup to an IoT cloud platform. Sensor readings such as voltage, temperature, current, and gas levels are transmitted in real time to this platform through the internet.

Figure.7.1.INTERNET OF THINGS (IOT)

Users can view the live data on a mobile application or web dashboard, which displays the current operating status of the electric vehicle battery. The IoT dashboard also provides historical data storage, which can be used to analyze trends, identify recurring issues, and perform predictive maintenance.

Time-dependent profiles of HRR and THR of BEV fires and their comparison against ICE and FCEV.
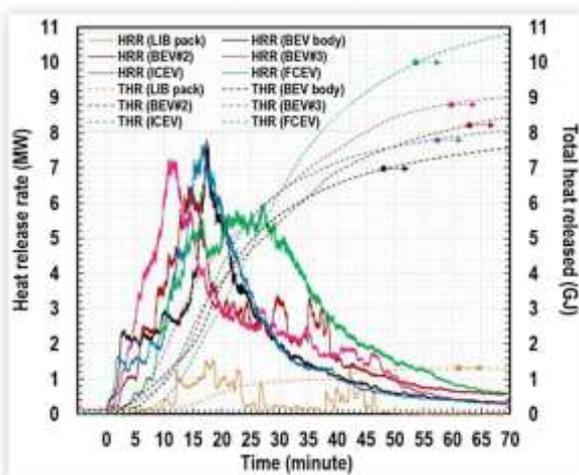
In case of emergency conditions such as smoke or flame detection, the IoT module automatically sends instant notifications or email alerts to the registered user. This ensures that the user is informed of the situation even if they are away from the vehicle. The IoT feature thus transforms the traditional BMS into a smart monitoring system, improving reliability,

accessibility, and user control. The data transmission between the Arduino and IoT server occurs through HTTP or MQTT protocols, which are efficient for low-power and real-time applications. This allows the system to operate continuously without consuming excessive bandwidth or power. Through this integration, the BMS not only protects the vehicle during operation but also provides a continuous record of its performance for further analysis.

8. MATERIAL SELECTION

The selection of appropriate hardware components plays a crucial role in ensuring the system's reliability and performance. The Arduino Uno or ESP32 serves as the core processing unit responsible for reading sensor data and executing control logic. The MQ-2 smoke sensor is used to detect the presence of smoke or flammable gases, while a flame sensor provides rapid response to visible flames or high-temperature radiations. The NTC thermistor measures real-time temperature changes within the battery pack, allowing early identification of overheating conditions.
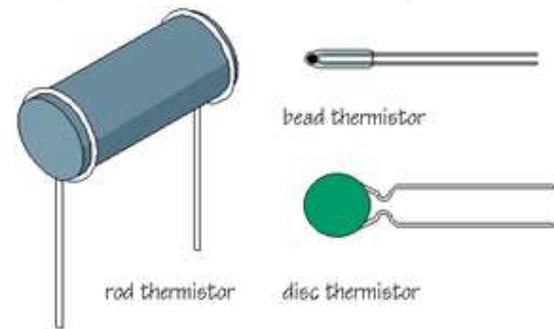

Figure .8.1. Thermistor

A relay module is employed to control high-current circuits such as the motor drive, enabling immediate power cutoff during faults. The buzzer and LED indicators serve as audible and visual alarms to alert users in case of emergencies. An LCD display is integrated to present real-time battery readings, such as voltage and temperature, on the system interface. The system is powered by a 12V rechargeable battery, which also serves as the energy source for testing the EV prototype. The Wi-Fi module (ESP8266 or ESP32) provides the communication link for IoT-based monitoring and remote data visualization. The software implementation is accomplished using the Arduino IDE for programming and Android Studio or web dashboard for interface development.

9. SYSTEM ARCHITECTURE

The system architecture can be described in three major sections: input, processing, and output. The input section consists of sensors responsible for detecting

electrical and environmental parameters such as voltage, temperature, smoke, and flame. The processing unit, which is the Arduino or ESP32 microcontroller, acts as the brain of the system. It processes incoming signals, evaluates them against predefined thresholds, and executes decisions based on logical conditions. The output section comprises the relay control unit, alarm module, and IoT communication system.
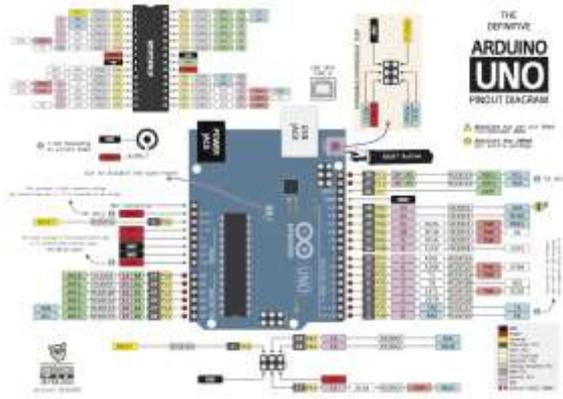

Figure.9.1 Arduino Uno Pin Diagram

When a hazardous condition is detected, the Arduino sends signals to the relay circuit to disconnect the motor, thus preventing current flow and reducing the risk of fire escalation. Simultaneously, the alarm is triggered to alert nearby users, and the IoT module sends real-time notifications to the cloud platform. This architecture allows for continuous monitoring, immediate response, and remote data access. The block diagram effectively illustrates the flow of signals from sensors to microcontroller and from microcontroller to actuators and communication systems. The integration of IoT further ensures that the user can supervise and control the system remotely, providing a robust safety network for electric vehicles.

10.APPLICATIONS

The developed system can be deployed across multiple sectors within the electric vehicle ecosystem. It can be integrated into electric vehicle manufacturing units to enhance inbuilt safety features. Public EV charging stations can adopt this system to prevent battery overheating and short circuits during high-load charging operations. Similarly, EV maintenance and service centers can use this system for diagnostic testing and safety verification of battery packs. Furthermore, it can be utilized in battery recycling and energy storage plants where monitoring of thermal and fire-related parameters is critical to avoid accidents. In addition, the system holds potential for applications in hybrid electric vehicles and laboratory research setups

that focus on IoT-enabled BMS development and safety studies.

The versatility and scalability of the system allow it to be customized for various types of electric vehicles and stationary energy systems, making it a valuable addition to the growing EV safety infrastructure.

11. ADVANTAGES

The IoT-enabled BMS with integrated fire safety offers multiple advantages over conventional systems. It ensures continuous real-time monitoring of battery parameters with improved accuracy and responsiveness. The system's automated control actions help prevent fire-related disasters without human intervention. Its IoT-based interface facilitates remote access and notifications, enabling early detection of faults even when the vehicle is not in use. The design is compact, energy-efficient, and cost-effective, making it suitable for small and large-scale EV manufacturers. The use of open-source components such as Arduino and Wi-Fi modules ensures easy customization and upgradability, promoting further innovation in EV safety technologies.

12. Conclusion

The proposed IoT-based Battery Management System with Fire Safety represents a significant step toward achieving safer and smarter electric mobility. The system effectively combines data acquisition, control automation, and wireless communication into a single integrated framework. By continuously monitoring the voltage, temperature, and current parameters of the battery, along with real-time smoke and flame detection, the system provides immediate preventive actions against potential fire hazards. The inclusion of IoT connectivity allows for remote supervision and predictive maintenance, reducing the risk of accidents and system failures.

Overall, the project demonstrates a practical, low-cost, and scalable approach to EV battery safety management. Its successful implementation contributes to improving user confidence in electric vehicles while addressing one of the key challenges in EV adoption—battery-related fire incidents. The system can serve as a foundation for future developments in autonomous safety monitoring and intelligent vehicular systems.

13. References

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