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Enhancing Fire Protection for Electric Vehicle Batteries

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Abstract - Electric vehicle battery packs need a complex Battery Management System (BMS) for vital parameter monitoring such as voltage, current and state of charge and temperature to ensure safety together with operational efficiency. This research explores the BMS safety mechanisms which include external battery aging notifications through smoke detection followed by alarm sounds and an optimal cooling system along with automatic charging to prevent battery degradation. Short-circuit protection devices in batteries decrease electrical failure risks which can prevent both fires and dead batteries. The system provides continuous power delivery through real-time monitoring and fast maintenance procedures under any possible condition.

Key Words Battery Management System(BMS), Electric Vehicle Battery, Fire Protection, Thermal Management, Smoke Sensor, Short Circuit Protection, Real-time Monitoring, Battery Safety, SOC.

1. INTRODUCTION

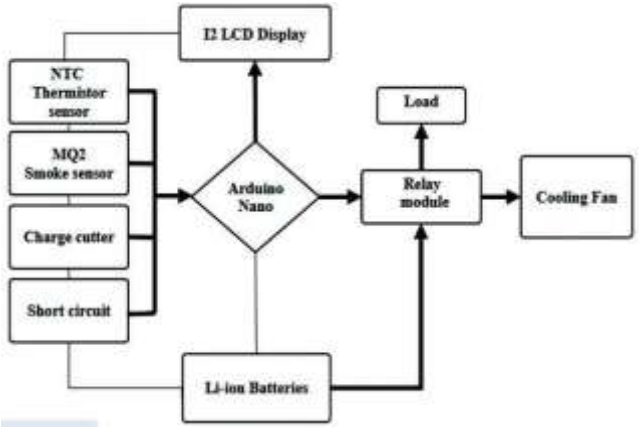
This project introduces advanced features to battery management systems for creating a modern technique to enhance safety from fires in electric vehicle batteries. The system detects potential overheating problems that lead to thermal runaway through continuous monitoring of essential indicators that include voltage, current, temperature and state of charge (SOC). Additional safety measures exist to enhance electric vehicle battery lifespan and performance as well as reliability through the prevention of failures. Four key safety features are installed for electric vehicle battery protection: smoke detectors, short circuit protection, an effective cooling system and automatic charger disconnection systems.

2. EXPERIMENTAL DETAILS

2.1 METHODOLOGY

The primary steps of this methodology start by selecting essential battery metrics containing voltage, current, state of charge and temperature followed by choosing dependable hardware components such as an Arduino Nano for real-time application and NTC thermistor for temperature monitoring along with MQ2 smoke counter for fire detection and protection circuits connected to a 4-channel relay module for power management. The AutoCAD program designs the circuit layout for electrical noise reduction while connecting components through proper GPIO pins to the Arduino system and establishing relay systems for cooling operations and charging operations and load operations. The Arduino program operates as a loop to monitor sensor feedback while running the decision protocol to activate cooling and stop charging based on thresholds and manage alert responses and load disconnects through the I2C LCD display. The system goes through thorough testing and calibration which includes sensor reference instrument comparison and simulation of short circuits and full charging situations in order to determine its effectiveness and operational efficiency. The system enhances battery safety as well as electric vehicle fire protection through continuous improvement of identified weaknesses to achieve superior overall performance.

2.2 BLOCK DIAGRAM



2.3 SIMULATION

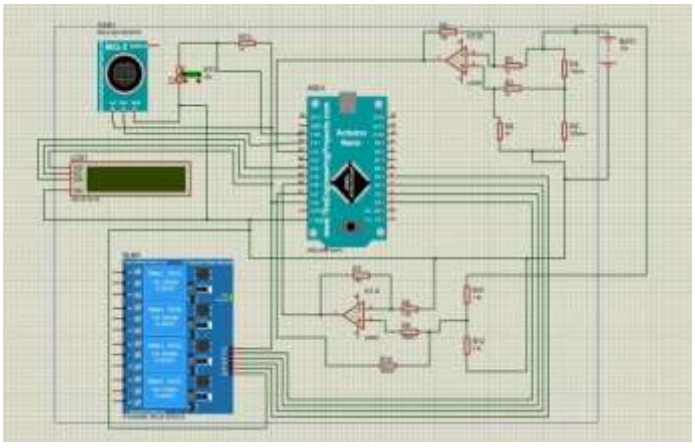


Fig -1: Proteus Simulation of Enhanced Fire Protection for Electric Vehicle Batteries

3. RESULT

All stages of gas detection and safety control system design and implementation and testing proved satisfactory results. The system includes an Arduino Nano microprocessor together with an NTC temperature sensor while the MQ-2 gas sensor joins other operational amplifiers for signal processing functions.

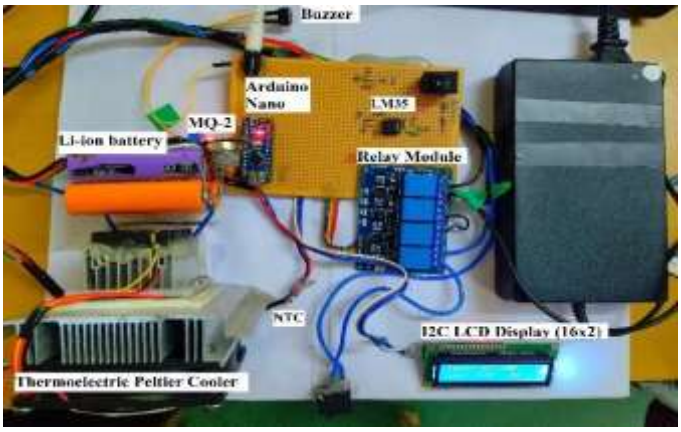


Fig -2: Enhanced Fire Protection for Electric Vehicle Batteries

3.1 LCD STARTUP AND INITIALIZATION

Sets up the LCD display and shows a "System Ready" message so you know the system has powered up correctly.

3.2 TEMPERATURE MEASUREMENT

The device measures temperature using a thermistor before converting it into Celsius and Fahrenheit readings which appear on the LCD display. The device provides an alert when the temperature exceeds 80°F.

3.3 GAS LEAK DETECTION

Checks the gas sensor for dangerous gas levels. High readings from the gas sensor cause the system to trigger a "Gas Leak" warning and play buzzer alarms while controlling a relay for additional safety measures.

3.4 SHORT CIRCUIT & BATTERY MONITORING

Monitors the battery voltage via a sensor. The device warns you about short circuits and battery issues through LED and buzzer signals.

3.5 CHARGE CUTTER CONTROL

Watches the battery charging voltage. At a voltage level of 4.2V the charger automatically pauses its operation to avoid battery damage from overcharging.

3.6 AUDIBLE ALERTS (BUZZER)

Specific audio signals distinctively identify the three different detections (overheating along with gas leaks and short circuits) allowing prompt recognition without needing to directly view the display.

4. FUTURE ENCHANCEMENT

The project consists of sophisticated numerous operating components. The system obtains wireless control and monitoring functions through integration of ESP8266 or ESP32 modules to implement IoT technology. Web interface applications provide real-time gas level tracks to users who can also receive mobile application alerts even when they leave the site. Residential and industrial applications benefit from the sensor array through its inclusion of CO, CO_2 and NH_3 hazardous gas detectors and supplementary types of gas monitors. Lithium-ion batteries together with smart charging technology and a smart energy system and power saving features keep power management continuously active. Through the system users can obtain real-time and historical data by selecting either cloud interface or SD card module for temperature measurements and gas concentration point detection and voltage and current monitoring.Operators utilize gathered information to predict maintenance needs while simultaneously detecting possible risks that might happen. Wearers of portable gas detectors will benefit from automated AI-based alerts which stop hazardous situations due to operational safety measures built from previous data analysis through machine-learning algorithms. Through MQTT and Zigbee protocol connectivity the home automation system enables safety protocols to automatically activate by controlling gas valves and opening windows together with ventilator operation. The essential components of the device feature touchscreen displays instead of basic LCD for users to alter thresholds along with showing historical data and controlling alarms through one simple interface.

5. CONCLUSIONS

An automatic flammable gas monitoring system contains a MQ-2 sensor connected to precision op-amp circuitry for gas detection operations that produces warning signals from buzzers alongside LED indicators. The system activates safety equipment through its relay module to enable external devices which will prevent dangerous gas accumulation at critical measurement areas. Two types of electrical sensors combined with an NTC sensor work together for detecting electrical abnormalities and temperature variations. The system uses a short-circuit detecting device together with an automatic charging cutoff to safeguard equipment from damage and battery overdraft. System updates and maintenance duties stay simple because the modular design structure depends on Arduino Nano together with sensor and amplifier modules alongside relay and display elements. Real-time essential monitoring data including temperature status, current state, voltage status, gas readings and system status shows automatically on the LCD display.

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