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Smart Battery Health Monitoring and Protection System for Electric Vehicles

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ABSTRACT - *This paper presents a real-time motor protection and monitoring system designed to improve safety and reliability in electrical motor operations. The system uses an ESP32 microcontroller to continuously monitor key parameters such as voltage, current, and temperature of the motor. Sensors like INA219 current sensor and DS18B20 temperature sensor are used to measure electrical and thermal conditions. The system detects abnormal conditions such as over-current, over-voltage, and overheating, and automatically shuts down the motor using a relay module. An LCD display shows real-time parameter values and system status. An RTC module records time-based events for monitoring purposes. Visual and audible alerts using LEDs and a buzzer notify users during fault conditions. The proposed system provides a low-cost and reliable solution for protecting motors from damage and ensuring safe operation in industrial and domestic applications.*

KEYWORDS - *ESP32, Motor Protection System, Current Monitoring, Voltage Monitoring, Temperature Monitoring, Embedded System, Fault Detection*

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I. INTRODUCTION

Electric motors are widely used in industrial, agricultural, and domestic applications. Continuous operation of motors without proper monitoring can lead to problems such as overheating, over-current, and voltage fluctuations. These conditions can damage the motor and reduce its lifespan. Traditional protection systems often require manual monitoring and may not respond quickly to abnormal conditions.

To overcome these limitations, a smart motor protection system is proposed using an ESP32 microcontroller. The system continuously monitors important parameters such as voltage, current, and temperature of the motor. Sensors are used to measure these parameters in real time, and the data is processed by the ESP32 controller.

When any parameter exceeds the predefined safety limit, the controller automatically stops the motor using a relay and generates visual and audible alerts. The system also displays real-time information on an LCD screen for easy monitoring. This solution provides a reliable, automated, and cost-effective method for motor protection..

II. METHODOLOGY

The proposed system operates by continuously monitoring motor operating conditions using sensors connected to an ESP32 microcontroller. The INA219 sensor measures voltage and current supplied to the motor, while the DS18B20 temperature sensor monitors the motor temperature.

All sensor data is processed by the ESP32 microcontroller. The measured values are compared with predefined threshold limits for voltage, current, and temperature. If any parameter exceeds the safe limit, the system identifies it as a fault condition.

During a fault condition, the ESP32 controller immediately turns off the motor using a relay module to prevent damage. At the same time, a buzzer and red LED are activated to indicate the fault. The system also displays the fault message on the LCD display. When the parameters return to normal conditions, the system allows the motor to operate again

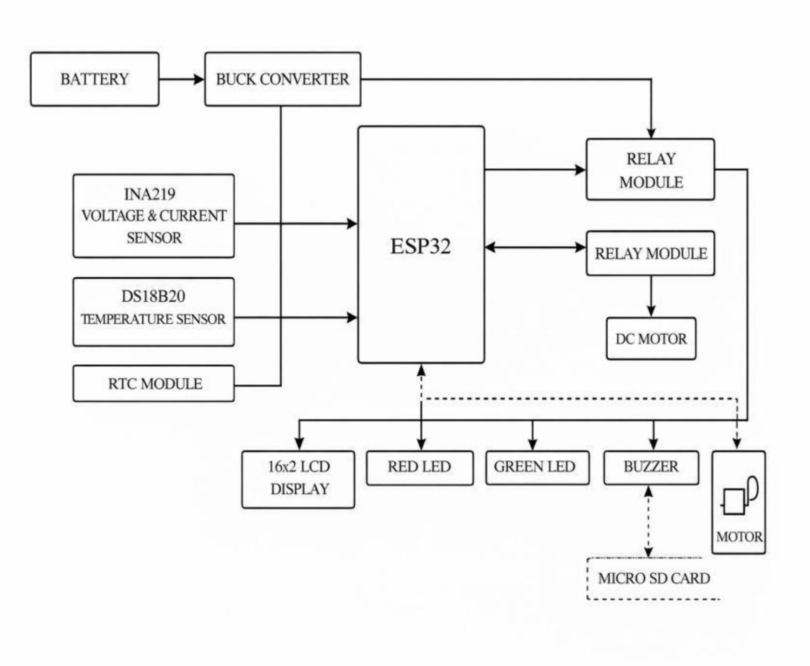

Figure 1. Block Diagram

A. SENSORS USED

The INA219 sensor is used to measure the voltage and current supplied to the motor. This sensor helps in detecting abnormal current or voltage conditions.

The DS18B20 sensor is used to measure the temperature of the motor. It helps in detecting overheating conditions that may damage the motor.

B. MICROCONTROLLER

The ESP32 development board acts as the main controller of the system. It processes sensor data, performs fault detection, controls the relay module, and updates the LCD display. The ESP32 is chosen because of its high processing capability and built-in communication features.

III. HARDWARE DESIGN

The hardware design of the proposed system includes several components such as ESP32 microcontroller, INA219 current sensor, DS18B20 temperature sensor, relay module, LCD display, RTC module, LEDs, and buzzer.

IV. SOFTWARE DESIGN

The software of the proposed system is developed using the Arduino programming environment. The ESP32 continuously reads data from the sensors and processes the values.

The program compares the sensor readings with predefined threshold values. If the voltage, current, or temperature exceeds the limit, the system detects a fault condition and stops the motor by turning off the relay.

The software also updates the LCD display to show real-time sensor values and fault messages. The RTC module is used to display the current time for monitoring and logging purposes.

A. FLOW CHART

The software flow begins with system installation and peripheral configuration. The ESP32 initiation RFID reader module and the TFT display. The door sensor input pin is configured. Bluetooth scanning parameters are utilized a system wait for an RFID tag to the scanned when a tag is detected, the tag ID is ready by the controller the system. The current access location. Authorization rules of the scanned inmate or loaded. The in time and out time conditions are verified. Working area eligibility is checked if the location is a work zone. If all conditions are satisfy access is granted. The green led is turned on the TFT display shows and authorized message. This system waits for door open confirmation use in the red switch. If any condition fails, access is denied the red led and buzzer are activated. The TFT display shows a warning messages. The violation events is recorded. Bluetooth scanning updates zone information is parallel this system returns to the waiting state for the next scan.

B. ALGORITHM

The access control algorithm starts when an RFID tag is scanned. The system reads the unique ID tag .it check whether the tag ID excess in the authorized inmate list. The current access point is identified. The permitted location list for the inmate is retrieved the algorithm verifies weather the scanned location is allowed the current time is combined with the allowed in time and out time if the access point is a working area, eligibility is verified if all conditions are true the algorithm generate an access allowed signals. The green led is activated the TFT display shows the access approval message. The algorithm waits for door open confirmation door open and close events are monitored. If any rules is violated, access is denied. The red led is activated the buzzer is turned on the event is stored in a system log. The algorithm updates Bluetooth based zone data. The algorithm monitors abnormal condition the system repeats the process continuously.

C. COMMUNICATION PROTOCOLS

The proposed system uses standard wired communication protocols for reliable data exchange between components. The INA219 current and voltage sensor, RTC module, and LCD display communicate with the ESP32 microcontroller using the I²C communication protocol, which allows multiple devices to share the same data lines efficiently. The DS18B20 temperature sensor communicates with the controller through the One-Wire protocol, enabling accurate temperature measurement using a single data line. Output devices such as the relay module, LEDs, and buzzer are controlled using digital input/output pins of the ESP32. These communication protocols ensure stable, fast, and efficient data transfer between sensors, controller, and output devices, enabling real-time monitoring and protection of the motor system..

V. RESULT AND DISCUSSION

The developed system was tested under different operating conditions to verify its performance. During normal conditions, the system successfully displayed voltage, current, temperature, and system status on the LCD display.

When the temperature exceeded the predefined limit, the system automatically stopped the motor and activated the buzzer and red LED. Similarly, when abnormal voltage or current conditions were introduced, the system detected the fault and shut down the motor immediately.

The experimental results confirm that the proposed system effectively protects the motor from overheating, over-current, and voltage fluctuations. The system operates reliably and provides real-time monitoring of motor conditions.

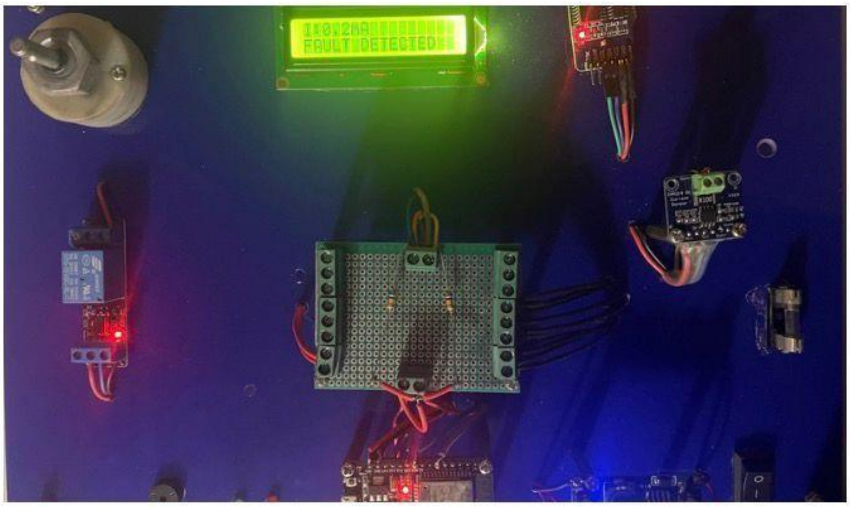

Figure 2

VI. CONCLUSION

This paper presented a real-time motor protection and monitoring system using an ESP32 microcontroller. The system continuously monitors voltage, current, and temperature parameters and detects abnormal conditions automatically.

By integrating sensors, relay control, LCD display, and alert mechanisms, the system provides a reliable and cost-effective solution for motor protection. The experimental results demonstrate that the proposed system improves motor safety and reduces the risk of damage caused by electrical faults.

VII. FUTURE IMPROVEMENTS

In future work, the system can be entered to support a larger number of access points and multiple jail blocks. The centralized server are cloud platform can be indicated to stored long term access and movement records advanced analytics can be added to detect abnormal behavior patterns and repeated violations trends. Mobile are web based dashboards can be introduced for remain monitoring by security Administrator. Biometric verification can be combined with RFID to further entrance identities authentication. Bluetooth zone accuracy can be improved by deploying additional becomes for final indoor localization's system can also been indicated with existing surveillance and prison management systems for comprehensive security management.

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