Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 6, May 2026
Paper Id: – IJ2026V6I6 -5 A-E
ISSN 2582-6026

REAL TIME MOTOR FAULT DETECTION AND PROTECTION SYSTEM

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ABSTRACT - In this paper, an ESP32 microcontroller is used to develop and build an Automatic Motor Protection System. A 1 HP single-phase induction motor is shielded by the system from a number of electrical and environmental issues, including as overcurrent, overvoltage, undervoltage, and exposure to rain or moisture. The system uses a voltage sensor and a current sensor (ACS712) to continually check the motor's electrical characteristics. In order to identify moisture that might lead to short circuits or insulation breakdown, a rain sensor is incorporated. The ESP32 initiates a relay to cut off the motor from the power source in order to prevent damage when any parameter beyond the safe operating threshold. LEDs act as visible failure indications, and a 20x4 LCD display shows the current state of every parameter under observation. The suggested method is appropriate for industrial and agricultural applications as it improves motor dependability, lowers maintenance costs, and does away with the need for human monitoring.

***Keyword* : -** ESP32, Motor Protection, Relay, Current Sensor, Voltage Sensor, Rain Sensor, LCD Display, Overcurrent Protection, Motor Fault Detection, Automation

I. INTRODUCTION

Electric motors are extensively utilized in home, commercial, and agricultural settings. One of the most popular motors in small-scale businesses and agricultural water pumping systems is the 1 HP single-phase induction motor. Overcurrent, overvoltage, undervoltage, and single phasing are among the many electrical disturbances that regularly affect motors and can result in irreversible damage if they are not identified and fixed in a timely manner. Additionally, the motor's electrical components and insulation are seriously threatened by exposure to rain and moisture in outdoor settings.

Conventional motor protection techniques rely on mechanical relays, thermal overload devices, or human monitoring, all of which are either labor-intensive or sluggish to react. Microcontroller-based intelligent protection systems are now a viable and affordable option due to the quick development of embedded systems and the Internet of Things. The ESP32 microcontroller is the perfect platform for such an intelligent defense system because of its dual-core CPU, integrated Wi-Fi, and wide peripheral compatibility.

In order to give complete real-time safety for a 1 HP motor, this project suggests an Automatic Motor safety System that combines an ESP32 microcontroller with a current sensor (ACS712), a voltage sensor, a rain sensor, a relay module, a 20x4 LCD display, and LEDs. When a measured parameter exceeds the safe operating threshold, the system automatically trips the relay. Once the fault is fixed, normal functioning resumes. To reduce motor burnout and maintenance costs through automatic fault detection.

II. OBJECTIVE

The ESP32 microcontroller will be used in the design and implementation of an automated motor protection system.

To shield the 1 HP motor from situations involving overvoltage, undervoltage, and overcurrent.

In order to prevent insulation damage, the motor should be disconnected when moisture and rain exposure are detected.

To show motor parameters (voltage, current, and rain status) in real time on a 20x4 LCD screen.

LEDs can be used as visual indicators for both malfunction and regular functioning.

III. LITERATURE SURVEY

The application of digital relay systems for motor protection is covered in a study on microcontroller-based motor protection by R. Muhamad Yusuff et al., which also emphasizes the significance of real-time monitoring for industrial motors. S. Sathish Kumar and T. Bhavani claim that their work on IoT-based motor monitoring shows how embedded platforms may be used to identify voltage and overcurrent problems and remotely notify operators. In their study on automated protection systems,

Pradnya B. Wale and Kamal Sandeep K. discuss how sensors and relay logic are used to shield induction motors from electrical problems in agricultural pump sets. A. Geetha and C. Subramani claim that their study on Arduino-based motor protection shows the efficacy of sensor-based protection and suggests a low-cost embedded system that keeps an eye on temperature and current to prevent motor failure.

P. Anitha and R. Ramesh's work on rain sensor integrated protection systems emphasizes the need of environmental sensing in outdoor motor installations and suggests automated shutdown procedures to avoid failures caused by moisture.

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V. Suresh and M. Arun Kumar claim that their work on ESP32-based Internet of Things applications shows how well the ESP32 works for real-time sensor data collecting and control, which makes it a good platform for protection system applications.

BLOCK DIAGRAM

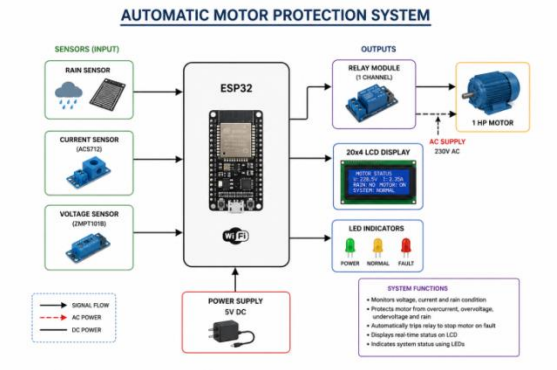

Fig.1 - Block diagram

The Power Supply Unit, Sensor Unit (Current Sensor, Voltage Sensor, Rain Sensor), ESP32 Microcontroller, Relay Module, 1 HP Motor, 20x4 LCD Display, and LED Indicators make up the Automatic Motor Protection System's block diagram. The ESP32 receives continuous input from the sensor unit, interprets the signals, and determines whether to activate the relay to safeguard the motor.

IV. WORKING

The Automatic Motor Protection System works by continuously monitoring the electrical characteristics and ambient conditions of the motor. The ESP32 initializes the LCD display and all attached sensors during power-up.The 20x4 LCD displays the real-time values of current, voltage, and rain sensor status.

The motor's line current is measured by the ACS712 current sensor. The ESP32 signals the relay module to cut the motor off from the supply if the current above the predetermined overcurrent threshold. Similar to this, the voltage sensor keeps an eye on the supply voltage; if it falls below the undervoltage limit or rises over the overvoltage limit, the relay is activated to safeguard the motor windings. When moisture is present on its sensitive surface, the rain sensor senses it. To avoid electric shock and insulation damage, the ESP32 instantly trips the relay and disconnects the motor if it detects wetness. LEDs offer instantaneous visual indication: a red LED denotes a problem situation, whereas a green LED indicates proper functioning. After the problem situation is fixed, the motor can be manually restarted.

ESP32 Microcontroller

Espressif Systems created the ESP32, a powerful, inexpensive, dual-core microcontroller module. It has a dual-core Xtensa LX6 CPU operating at 240 MHz, numerous ADC channels, integrated Bluetooth and Wi-Fi, and an extensive array of digital I/O connectors. The ESP32 serves as the system's central processing unit, receiving analog signals from the voltage and current sensors via its ADC channels, reading the rain sensor's digital output, and regulating the relay and LED indications according to pre-programmed thresholds.

Fig. 2 -ESP32 Microcontroller

RELAY MODULE

The relay is an electrical switch that enables a high-power motor circuit to be switched by a low-power control signal from the ESP32. The 1 HP motor in this project is connected to or disconnected from the AC supply using a single-channel relay module. The relay can manage the AC load of the motor on the switching side and runs on 5V DC from the control side. The relay coil is driven by the ESP32 when it senses a fault state, opening the motor circuit and shielding it from harm.

Fig.3- Relay module

1HP Motor

A 1 HP (746 W) single-phase induction motor, which is frequently utilized in small industrial and agricultural water pumps, serves as the system's load. This motor runs on a 50Hz, 230V AC source. At full load, it draws around 6-7A. When the protection system detects a failure, the motor may be instantly disabled because it is connected to the relay output.

Current Sensor (ACS712)

The ACS712 is a linear current sensor that measures AC and DC current accurately using the Hall effect. This project uses the ACS712-20A version, which has a sensitivity of 100mV/A and

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can measure currents up to 20A. An analog voltage proportionate to the current passing through the motor circuit is produced by the sensor. The ESP32's ADC input receives this analog output. This reading is processed by the ESP32 to see whether the motor current is higher than the safe working limit. whether overcurrent is found, the relay is tripped.

Fig.4 - Current Sensor

VOLTAGE SENSOR

The voltage sensor module (ZMPT101B) detects AC voltage levels using a precision voltage transformer. It reduces the high AC supply voltage to a safe analog signal that the ESP32's ADC can read. The predetermined safe operating range is compared to the observed voltage. The ESP32 triggers the relay to disconnect the motor and stop winding insulation failure if the supply voltage increases over the overvoltage threshold or falls below the under voltage threshold.

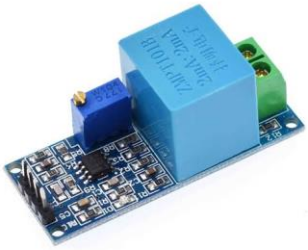

Fig.5 - Voltage sensor

RAIN SENSOR

An LM393 comparator circuit and a printed circuit board with exposed copper traces make up the rain sensor. The resistance decreases and the sensor generates a LOW digital output signal when moisture or droplets cross the copper wires. The ESP32 reads this signal. The rain sensor is installed close to the motor panel in agricultural pump outside installations. The ESP32 instantly trips the relay when it detects rain or moisture, reducing the possibility of electric shock and motor winding damage from moisture intrusion.

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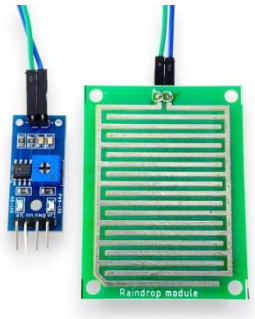

Fig.6- Rain sensor

20x4 LCD Display

A 20x4 character LCD display (with I2C interface) is used to present real-time motor operating parameters to the user. The four rows display: motor current (Row 1), supply voltage (Row 2), rain sensor status (Row 3), and overall system status – Normal/Fault (Row 4). The I2C interface reduces the number of wiring connections to just two data lines (SDA and SCL), simplifying the hardware design. The LCD is powered by 5V from the system power supply and is interfaced with the ESP32 via the I2C protocol.

LED Indicators

The visual indications are two LEDs. When the motor is operating normally, a green LED that is attached to an ESP32 output pin stays ON, signifying that all parameters are within safe bounds. When any failure condition—such as overcurrent, overvoltage, undervoltage, or rain—is detected, a red LED that is attached to another ESP32 output pin goes on. The red LED stays on until the issue is fixed and the system is reset, assisting operators in promptly identifying a fault state without having to view the LCD display.

V. ADVANTAGES AND APPLICATION

• Offers automated real-time protection against rain, moisture, overvoltage, undervoltage, and overcurrent.
• Considerably prolongs the 1HP motor's service life and lowers motor burnout.
• Removes the requirement for ongoing manual motor parameter monitoring.
• All important operational parameters are instantly visible on the 20x4 LCD display.
• Even from a distance, LED indicators offer a prompt visual fault alert.
• It is appropriate for small-scale industrial and agricultural application due to its low cost and simplicity of installation.
• Future extensions for remote monitoring and warnings are made possible by the ESP32's Wi-Fi

functionality.
• Prevents fault escalation, which lowers maintenance and repair expenses.

APPLICATION

• Water pumping systems used in agriculture where motors are subjected to the elements, including rain.
• Small-scale industrial applications that need for ongoing motor operating monitoring.• Automatic motor protection for home water supply systems.
Irrigation control systems requiring automatic disconnection during rainfall.

VI. CONCLUSION

Motor protection in chemical and food processing industries where moisture is present.
The ESP32 microcontroller-based Automatic Motor safety System effectively illustrates how embedded systems may offer dependable, real-time safety for electric motors. When a failure situation is detected, the system automatically disconnects the motor from the supply. It does this by efficiently monitoring the motor current, supply voltage, and environmental factors including moisture and rain. The system is straightforward and easy to operate thanks to the incorporation of LED indications and a 20x4 LCD display.
The use of the ACS712 current sensor and ZMPT101B voltage sensor ensures accurate and continuous electrical parameter monitoring, while the rain sensor adds an important environmental protection layer, especially for outdoor agricultural installations. The relay provides a reliable switching mechanism to protect the 1HP motor from damage. The project can be further extended to include GSM or Wi-Fi-based remote alerts using the ESP32's built-in connectivity, making it a comprehensive IoT-enabled motor protection solution for industrial and agricultural environments.

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