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Real-Time IOT Based Intelligent Protection System for Three Phase Induction Motor

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Abstract: Three-phase induction motors are extensively employed in industrial applications due to their robust construction, operational reliability and high efficiency. However, abnormal electrical conditions, including overvoltage, under voltage and over current, can adversely affect motor performance, resulting in overheating, insulation deterioration and premature equipment failure. To overcome these challenges, this project proposes a real-time Internet of Things (IoT)-based intelligent protection system for three-phase induction motors, integrating continuous electrical parameter monitoring, automatic fault detection and remote supervision.

The proposed system utilizes an ESP32 microcontroller with integrated Wi-Fi connectivity as the central processing and control unit. Voltage and current sensors continuously acquire the motor's electrical parameters, while a 16×2 LCD displays the measured values and operating status locally. The ESP32 processes the sensor data and transmits the information to an IoT application, enabling remote monitoring of motor operating conditions. When the measured parameters exceed predefined protection limits, the controller generates a control signal to activate the driver and relay circuit, which subsequently operates the power contactor to disconnect the motor from the electrical supply. This automatic protective action helps minimize the possibility of motor damage and reduces dependence on continuous manual supervision.

The proposed system integrates real-time monitoring, automatic electrical protection, local status indication and wireless communication into a compact and cost-effective arrangement. It provides a practical solution for improving motor safety, operational reliability and remote monitoring capabilities in industrial motor-driven applications.

Keywords: Three-Phase Induction Motor, Internet of Things (IoT), ESP32 Microcontroller, Real-Time Monitoring, Voltage Sensor, Current Sensor, Overcurrent Protection, Overvoltage Protection, Relay Module, Power Contactor.

I. INTRODUCTION

Three-phase induction motors are among the most widely utilized electrical machines in industrial and commercial applications. Their simple construction, ruggedness, low maintenance requirements and ability to operate under continuous-duty conditions make them suitable for driving pumps, compressors, conveyors, fans and various industrial machinery [1]–[3], [20].

Despite their advantages, induction motors are susceptible to abnormal electrical operating conditions such as overvoltage, undervoltage and excessive current. Prolonged operation under these conditions may cause excessive heating, insulation failure, reduced efficiency and unexpected motor shutdown. Therefore, continuous monitoring and effective protection mechanisms are essential to ensure reliable motor operation and extend equipment service life [6], [7].

Conventional motor protection systems primarily depend on electrical protection devices installed at the motor or distribution level. Although these devices provide essential protection, they may not offer sufficient remote monitoring facilities or real-time visibility of operating parameters. Different diagnostic and condition-monitoring techniques have been developed to identify abnormal motor operating conditions and improve equipment reliability [8], [11].

With advancements in embedded systems and wireless communication technologies, IoT-based monitoring has emerged as an effective approach for remote supervision of electrical equipment. IoT technology enables operating parameters to be acquired, transmitted and accessed through communication networks [9], [10], [13].

To address these limitations, the proposed project develops an IoT-based intelligent motor protection system using an ESP32 microcontroller. The system continuously monitors motor voltage and current through appropriate sensors, processes the acquired information and identifies abnormal operating conditions based on predefined protection limits.

The ESP32 communicates with an IoT application through its integrated Wi-Fi facility, allowing users to monitor motor operating parameters remotely. A 16×2 LCD provides local indication, while a relay-based control arrangement operates the power contactor to disconnect the motor during detected abnormal conditions. The ESP32 hardware and its programming capabilities support the implementation of the proposed monitoring and control functions [4], [5], [16]–[18].

II. LITERATUREREVIEW

Induction motor protection and condition monitoring have been widely investigated to improve the reliability and operational performance of electrical machines. Fitzgerald et al. [1] and Bimbhra [2] explain the operating characteristics and performance of electrical machines, providing the fundamental knowledge required for understanding induction motor operation. Say [3] and Chapman [20] discuss the performance, design and operating principles of alternating-current machines.

Nandi et al. [6] presented a review of condition-monitoring and fault-diagnosis techniques for electrical motors. Their work highlights the importance of monitoring motor operating parameters to identify developing faults and improve machine reliability. Benbouzid [7] investigated induction motor signature analysis as a technique for identifying different motor faults. Bellini et al. [8] discussed advancements in diagnostic techniques for induction machines, emphasizing the importance of effective monitoring methods for detecting abnormal operating conditions.

Further developments in motor monitoring have incorporated embedded controllers and wireless communication technologies. The integration of IoT into electrical motor monitoring provides remote access to operating parameters and supports improved supervision of industrial equipment [9], [10]. Related studies have also explored IoT-based motor monitoring, control and protection techniques [12], [13].

The ESP32 microcontroller provides an integrated processing and wireless communication platform suitable for developing IoT-based applications. Its hardware architecture and communication capabilities are documented by Espressif Systems [4], [16], [17]. Arduino IDE provides the programming environment required for developing and uploading embedded applications [5], [18]. MQTT is another communication protocol used in IoT environments for exchanging information between connected devices and applications [19].

In addition to electronic monitoring, appropriate electrical switching and protection devices are essential for safely controlling induction motor operation. International standards provide requirements and guidelines for rotating electrical machines and low-voltage contactors and motor starters [14], [15].

Based on these developments, the proposed project integrates voltage and current sensing, ESP32-based processing, LCD indication and relay-operated contactor control. The additional IoT communication facility provides remote access to motor operating information and protection status.

III. OBJECTIVES

1. To design and develop an intelligent protection system for a three-phase induction motor.
2. To continuously monitor motor voltage and current using suitable sensing devices.
3. To implement an ESP32 microcontroller as the central monitoring and control unit.
4. To display real-time electrical parameters and motor protection status through a 16×2 LCD.
5. To establish IoT-based wireless communication for remote monitoring of motor operating conditions.

6. To detect abnormal electrical conditions based on predefined protection limits.
7. To automatically disconnect the motor from the supply during detected fault conditions.
8. To improve motor operational safety, reliability and protection against abnormal electrical conditions.

IV. BLOCK DIAGRAM

The proposed system consists of voltage and current sensors connected to an ESP32 microcontroller. The controller processes the measured parameters and provides information to the LCD and IoT application. During abnormal operating conditions, the controller activates the driver and relay circuit to operate the power contactor and disconnect the motor supply.

The ESP32 serves as the central processing unit, while the wireless communication facility enables remote monitoring of the motor operating condition [4], [16], [17].

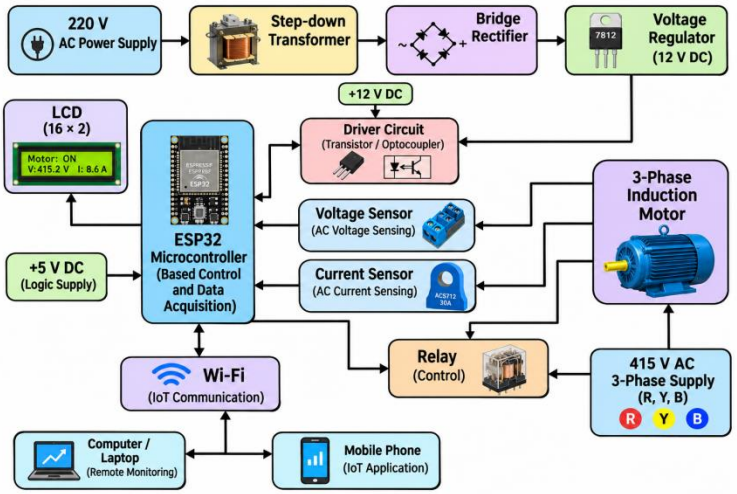

Figure 1: Block Diagram of the Proposed IoT-Based Intelligent Motor Protection System

V. WORKING PRINCIPLE

The proposed system operates based on continuous monitoring of the electrical parameters of a three-phase induction motor. Voltage and current sensors measure the corresponding electrical quantities and provide signals to the ESP32 microcontroller for processing and evaluation. Sensor-based monitoring is an important technique for identifying abnormal motor operating conditions [6]–[8].

Initially, the ESP32 acquires the sensor signals and determines the motor operating condition by comparing the measured values with predefined protection thresholds. The controller executes the monitoring and protection program developed using the Arduino IDE [5], [18].

Under normal operating conditions, the motor remains connected to the three-phase supply through the power contactor. The measured voltage, current and operating status are displayed on the 16×2 LCD. Simultaneously, the ESP32 uses its built-in Wi-Fi connectivity to transmit the monitored information to the IoT application, allowing users to observe the motor condition remotely [4], [9], [10], [16].

If the controller identifies an abnormal electrical condition, such as excessive current or an unacceptable voltage variation, it generates a protective control signal. This signal is supplied to the driver circuit, which activates the relay module. The relay subsequently controls the power contactor, causing it to disconnect the motor from the three-phase supply. The use of an appropriately rated contactor is important for safe motor switching [15].

Following the protection operation, the corresponding fault or protection status is indicated on the LCD and communicated to the IoT application. IoT communication protocols such as MQTT can support the exchange of information between connected devices and monitoring applications [19].
Once the abnormal condition has been rectified, the motor can be restarted according to the control logic implemented in the system.
Thus, the proposed arrangement combines electrical parameter sensing, microcontroller-based decision-making, automatic switching and wireless communication to provide an integrated motor monitoring and protection solution.

VI. COMPONENTS USED

The major hardware and software components employed in the proposed system are described below.

1. ESP32 Microcontroller

The ESP32 acts as the central processing and control unit of the proposed system. It receives voltage and current sensor signals, processes the measured parameters, executes the programmed protection logic and communicates with the IoT application through its integrated Wi-Fi facility. Its technical specifications and communication capabilities are documented by Espressif Systems [4], [16], [17].

2. 16×2 LCD Display

The LCD provides local information regarding the motor's operating condition, measured electrical parameters and system protection status.

3. Voltage Sensor

The voltage sensor measures the electrical supply voltage associated with the motor and provides a corresponding signal to the ESP32 for monitoring and protection purposes.

4. Current Sensor

The current sensor measures the current drawn by the induction motor. The measured current is processed by the controller to identify excessive current conditions. Voltage and current monitoring are important parameters in electrical motor condition assessment [6], [7].

5. Driver Circuit

The driver circuit provides the necessary interfacing between the low-power control output of the ESP32 and the relay control circuit.

6. Relay Module

The relay module receives control signals and operates the contactor control circuit during normal and abnormal operating conditions.

7. Power Contactor

The power contactor performs the main switching operation by connecting or disconnecting the three-phase electrical supply to the induction motor. The selection and application of contactors and motor starters are addressed in IEC 60947-4-1 [15].

8. Adapter

The adapter provides the required low-voltage DC supply to the control and monitoring electronics.

9. Three-Phase Induction Motor

The induction motor is the electrical machine being monitored and protected by the proposed system. Its operating characteristics and performance are described in standard electrical machinery literature [1]–[3], [20].

10. Arduino IDE and USB Cable

The Arduino IDE is used to develop, compile and upload the control program to the ESP32 microcontroller. The USB cable provides the programming interface [5], [18].

11. IoT Application

The IoT application receives the motor operating information transmitted through the ESP32's Wi-Fi connection and provides a remote monitoring interface for users. Wireless IoT communication supports remote monitoring and data exchange between connected devices [9], [10], [13], [19].

VII. APPLICATIONS

The proposed IoT-based intelligent protection system can be utilized in the following applications:

1. Industrial three-phase induction motor monitoring and protection.
2. Water pumping systems and industrial pumping stations.
3. Industrial fans and ventilation systems.
4. Conveyor belts and material-handling equipment.
5. Air compressors and motor-driven machinery.
6. Manufacturing and automated production facilities.
7. Industrial process control systems.
8. Remote monitoring of electrical motor installations.
9. Small- and medium-scale industrial applications requiring wireless motor supervision.

VIII.ADVANTAGES

The major advantages of the proposed system are:

1. Continuous monitoring of motor voltage and current parameters.
2. Automatic disconnection of the motor during detected abnormal conditions.
3. Remote monitoring through IoT-based wireless communication.
4. Local display of operating parameters and protection status.
5. Reduced requirement for continuous manual supervision.
6. Improved motor operational safety and reliability.
7. Compact and cost-effective system architecture.
8. Integration of sensing, processing, protection and communication functionalities.
9. Improved visibility of motor operating conditions for maintenance personnel.

IX. CONCLUSION

The proposed real-time IoT-based intelligent protection system provides an integrated solution for monitoring and protecting three-phase induction motors against abnormal electrical operating conditions. The implementation of voltage and current sensors enables continuous acquisition of motor electrical parameters, while the ESP32 microcontroller performs data processing, protection decision-making and wireless communication.

The 16×2 LCD provides local indication of measured parameters and system status, whereas the integrated Wi-Fi facility enables remote monitoring through an IoT application. When predefined protection limits are exceeded, the controller activates the driver and relay circuit to operate the power contactor, thereby disconnecting the motor from the electrical supply.

The integration of real-time sensing, automatic protection and remote monitoring provides a practical and economical approach to improving induction motor operational safety and reliability. The proposed system can be effectively utilized in industrial applications where continuous motor supervision and automatic protection are essential.

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