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IOT-Based Three Phase Motor Protection System with Remote Monitoring

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Abstract: ***Three-phase induction motors are critical components in industrial applications, yet they remain vulnerable to electrical faults such as over-voltage, under-voltage, overload, and phase failures. Traditional electromechanical protection systems lack precision and remote monitoring capabilities. This paper proposes an advanced IoT-based protection system utilizing the ESP32 microcontroller. The system continuously monitors voltage and current parameters using Potential Transformers (PT) and Current Transformers (CT). Upon detecting anomalies, it triggers a relay to disconnect the motor via a Direct On Line (DOL) starter, preventing catastrophic failure. Furthermore, the system integrates with a cloud platform (Blynk/ThingSpeak) to provide real-time data visualization and alert notifications to maintenance personnel via a mobile application. Experimental results demonstrate that the system effectively detects faults with a response time of less than 200ms, offering a cost-effective and reliable solution for industrial motor protection.***
Keywords: Induction Motor, ESP32, IoT, Motor Protection, Overload, Under Voltage, Remote Monitoring.

I. NTRODUCTION

Three-phase induction motors are the workhorses of modern industry, accounting for nearly 70-80% of all electrical energy consumed in the industrial sector. Their robustness, simplicity, and cost-effectiveness make them ubiquitous in applications ranging from agricultural pumps to complex manufacturing conveyors. However, these motors operate in harsh environments and are susceptible to various power quality issues and mechanical stresses.

Common faults include voltage fluctuations (sags and swells), overloading due to mechanical jams, and phase anomalies such as single-phasing or phase reversal. Research indicates that thermal overloading and voltage unbalance are responsible for a significant percentage of motor failures. A sustained voltage drop increases the current draw to maintain torque, leading to excessive heating (I2R losses) and insulation degradation.

Traditional protection schemes rely on bimetallic thermal overload relays and fuses. While reliable for short-circuit protection, these mechanical devices often suffer from slow response times, lack of precision, and inability to detect complex faults like voltage unbalance effectively. Moreover, they provide no insight into the motor's operational health until a failure occurs.

The advent of the Internet of Things (IoT) allows for a paradigm shift from reactive to proactive maintenance. By integrating microcontrollers and wireless connectivity, it is possible to monitor motor parameters in real-time. This paper presents the design and implementation of a comprehensive protection system using the ESP32 microcontroller, which offers superior processing power and built-in Wi-Fi compared to traditional microcontrollers.

II. LITERATURE REVIEW

Several studies have addressed motor protection. Conventional thermal relays were analyzed in [1], highlighting their inaccuracy due to ambient temperature dependency. Digital relays introduced in the late 1990s offered better precision but were prohibitively expensive for small-scale applications.

Recent advancements utilize microcontrollers like Arduino and PIC. In [2], a GSM-based protection system was proposed, sending SMS alerts upon faults.

However, SMS latency can be high, and it lacks continuous data logging. In [3], a Zigbee-based wireless sensor network was used, which requires a complex gateway infrastructure.

The proposed system leverages the ESP32, which eliminates the need for external communication modules, reducing cost and complexity while enabling high-speed data transmission to cloud platforms via standard Wi-Fi protocols.

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III. SYSTEM ARCHITECTURE

The system comprises three main layers: the Sensing Layer, the Processing Layer, and the IoT/Cloud Layer.

A. Hardware Components

1) ESP32 Microcontroller: The core control unit, featuring a dual-core 32-bit LX6 microprocessor running at 240MHz with built-in Wi-Fi and Bluetooth. Its 12-bit ADC allows for high-resolution signal sampling.

2) Sensing Elements:

- Voltage Sensors (ZMPT101B): Three transformer-based modules used to step down the 230V phase voltages to safe 0-3V analog levels for the ESP32.
- Current Sensors (ACS712-30A): Hall-effect sensors providing an analog voltage output proportional to the current flowing through the motor phases.

3) DOL Starter & Relay: A standard Direct On Line starter is modified. A 5V relay module controlled by the ESP32 is inserted in series with the contactor coil (220V/440V). When the relay opens, the contactor de-energizes, stopping the motor.

Fig. 1. Overall System Architecture

B. Software Architecture

The firmware is developed in the Arduino IDE. It implements a continuous loop that samples voltage and current waveforms to calculate Root Mean Square (RMS) values. These values are compared against pre-set thresholds. Simultaneously, an asynchronous thread handles MQTT/HTTP communication with the cloud server.

IV. PROTECTION MECHANISMS

The system provides protection against four primary faults.

1) *Under Voltage (UV) Protection:* Operating a motor at reduced voltage causes it to draw higher current to drive the load, leading to overheating. The system trips if the line voltage drops below 90% of the rated value (e.g., < 360V for a 415V system) for more than 2 seconds.

2) *Over Voltage (OV) Protection:* Excessive voltage stresses the insulation of the stator windings. The system trips instantaneously if the voltage exceeds 110% of the rated value to prevent insulation breakdown.

3) *Overload (OL) Protection:* This logic mimics the inverse-time characteristic. If the current exceeds the Full Load Current (FLC) by 10%, a timer starts. If the current surges to 200% (e.g., rotor lock), the trip is instantaneous (< 100ms).

4) *Single Phasing:* If any one of the three phase voltages drops near zero while the others remain normal, the system identifies a "Single Phasing" fault and trips immediately to prevent motor burnout.

V. IMPLEMENTATION

The hardware was assembled on a PCB. The ZMPT101B sensors were calibrated using a standard multimeter to ensure accurate RMS readings. The ESP32 connects to the local Wi-Fi network upon startup.

For the IoT interface, the Blynk platform was chosen. Virtual pins V1, V2, and V3 were mapped to Phase R, Y, and B voltages respectively. A notification widget was configured to push alerts to the user's smartphone when the "Fault_Flag" variable is set to HIGH in the code.

Fig. 2. Circuit Diagram of the Protection Unit

VI. RESULTS AND DISCUSSION

The system was tested on a 1HP three-phase induction motor. A 3-phase variac was used to simulate voltage faults.

A. Voltage Protection Test

The voltage was gradually reduced. At 180V (phase voltage), the system detected the fault. The LCD displayed "Under Voltage" and the motor tripped. The response time was measured to be approximately 1.5 seconds (including programmed delay to avoid nuisance tripping).

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TABLE I: TEST RESULTS FOR VOLTAGE FAULTS

CONDITION	SET LIMIT	MEASURED	ACTION
Normal	200V-250V	230V	No Trip
Under Voltage	< 180V	175V	Trip
Over Voltage	> 260V	265V	Trip

B. Overload Test

Mechanical load was applied to the shaft. As current rose from 2.0A (Rated) to 2.8A, the system allowed operation for 10 seconds before tripping. At 4.5A (simulated lock), trip occurred in 150ms.

C. IoT Performance

The data visualization on the Blynk app showed a latency of ~1 second. Alerts were received on the smartphone within 3 seconds of the fault occurrence, validating the efficacy of the remote monitoring feature.

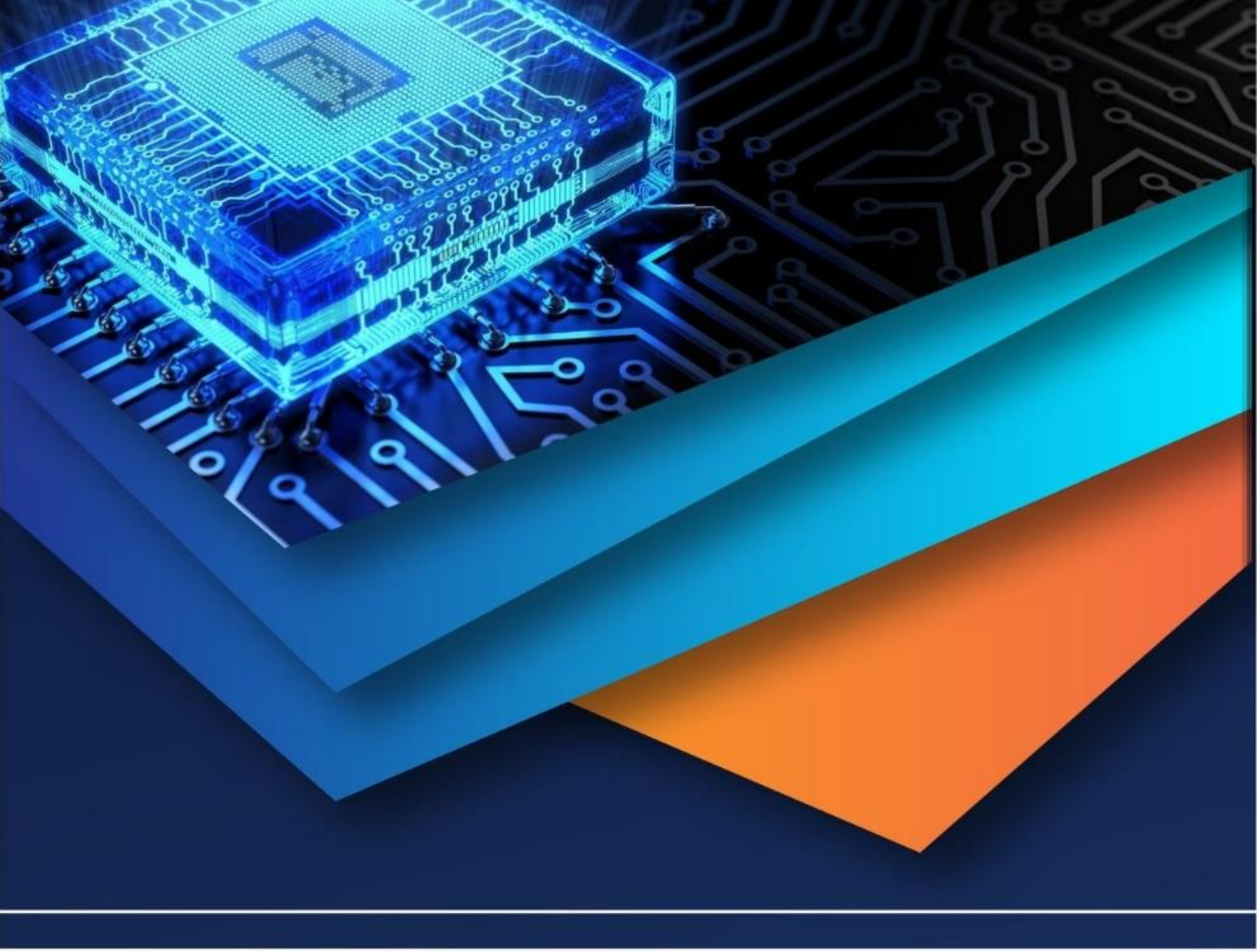
VII. CONCLUSION

This paper presented an IoT-based solution for three-phase motor protection. The system successfully integrates robust protection logic with modern communication capabilities. Compared to traditional bimetallic relays, the proposed system offers higher accuracy, faster response times for critical faults, and the significant advantage of remote data logging. This technology is highly applicable in agriculture and remote industrial sites where manual monitoring is difficult. Future work involves integrating Machine Learning algorithms on the cloud to predict bearing failures based on current signature analysis.

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