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IoT- Application Based on Control and Monitoring System for Single-Phase Induction Motor

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ABSTRACT: The system uses the ESP32S microcontroller which supports built in Wi- Fi and Bluetooth, enabling wireless control and real time monitoring of the induction motor. Sensors includ- ing voltage, temperature, and vibration are integrated to con- tinuously monitor the motor and detect faults like overcurrent, overheating, and abnormal vibrations. The Blynk application allows users to remotely view sensor readings, receive alerts, and control various parameters through a mobile device, improving ease of access and responsiveness. Load and voltage control is achieved using components like a relay module, dimmer, and potentiometer, allowing precise adjustment to enhance motor ef- ficiency and protect against voltage fluctuations Designed for both industrial and home applications, the system provides a reliable, smart solution for extending motor life and reducing maintenance through automated protection and monitoring features

KEYWORDS: IoT ; relay actuation, induction mo- tor, fault detection and real-time monitoring

I. INTRODUCTION

Motors are the most used electrical machines in various sec- tors, including manufacturing, HVAC systems, water treatment plants, and home appliances. Their popularity stems from their simple construction, high efficiency, low cost, and minimal maintenance requirements. However, despite these advantages, induction motors are vulnerable to several operational issues such as phase imbalances, voltage fluctuations, overcurrent, overheating, and excessive vibrations. If not detected and addressed promptly, these anomalies can result in reduced efficiency, unplanned downtimes, or even complete motor failure, leading to significant financial and operational losses. Conventional motor control systems typically rely on manualinspection or basic protection schemes such as thermal relays and circuit breakers. While these methods offer a degree of safety, they lack intelligent decision-making capabilities and fail to provide real-time monitoring, which is crucial for predictive maintenance and timely fault mitigation. Further- more, the absence of remote accessibility makes it difficult for operators to monitor or control motors in distributed or inaccessible locations. Recent advancements in embedded systems and wireless communication have paved the way for intelligent, IoT-based solutions that address these challenges. Microcontrollers like the ESP-32S, which come equipped with integrated Wi-Fi and Bluetooth, enable real-time data acqui- sition, edge processing, and remote control through cloud-connected platforms. When paired with mobile applications such as Blynk, these systems offer a powerful, user-friendly interface for live monitoring, fault notification, and device control, all from a smartphone or tablet. In this paper, design and implementation of an IoT-based Induction Motor Control and Protection System utilizing the ESP-32S microcontroller are presented. The system incorporates a suite of sensors to continuously monitor motor health parameters including current, voltage, temperature, and vibration. It also includes a relay module and dimmer for controlling connected loads, manual switches for local operation, and a potentiometer for voltage tuning. A ventilation

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cooling motor and buzzer alert system further enhance safety by responding to high-load and fault conditions.

- Key features of the proposed system include:
- Real-time monitoring of motor parameters via the Blynk
IoT mobile application.
- Automatic protection mechanisms against overcurrent, overvoltage, overheating, and excessive vibration.
- Manual and remote control options for load management.
- Compact, low-cost, and scalable hardware design suitable for residential and industrial environments. The system aims to enhance motor reliability, reduce maintenance efforts, and support remote diagnostics and control, ulti- mately contributing to the development of smart automa- tion and Industry 4.0 practices. This paper discusses the hardware design, software integration, testing results, and future prospects of the proposed solution.

In India, there are over 1200 IoT firms, with a 5 billion market value, according to a Deloitte assessment. These firms are concentrated on creating IoT solutions for a range of industries, including smart cities, healthcare, agriculture, and transportation. IoT development in India has advanced signif- icantly since its inception, and the nation is now a magnet for IoT startups and businesses. Stojkoska et.al proposed that The adoption of IoT solutions across a range of industries has the potential to revolutionize markets and enhance people's quality of life nationwide. To ensure the widespread adoption and success of IoT in India, there are still issues that must be resolved. In globally, The Internet of Things has been developing quickly over the past few years on a global scale. The IoT describes how numerous gadgets and products are connected to one another, allowing them to communicate and share data online. This expansion is result of a number of industries, including healthcare, manufacturing, transportation, and smart homes.

II. LITERATURE REVIEW

Single Phase Induction Motors (SPIMs) are widely used in household and small industrial applications due to their simplicity and ability to operate on a singlephase AC supply. However, these motors are not self-starting and require aux- iliary methods like capacitor start or shaded pole techniques. Despite their advantages, SPIMs are vulnerable to issues like overheating, overcurrent, and voltage fluctuations. Therefore, implementing a proper protection and control system is es- sential. Common protection devices include thermal overload relays, circuit breakers, and voltage sensors. Control systems use components such as contactors, timers, and capacitors to manage motor operation efficiently. comprehensive protection mechanism using components like thermal overload relays, fuses, voltage sensors, and temperature detectors. Additionally, a control circuit is developed to manage starting, stopping, and running conditions using contactors, push buttons, and ca- pacitors. Modern approaches incorporate microcontrollers and IoT technologies to improve safety, performance, and energy efficiency through real-time monitoring and automation. The integration of a mobile app interface (e.g., Blynk), allowing users to remotely monitor motor status, receive fault alerts, and control the motor in real time. This approach supports modern trends in IoT and smart automation, making the system more user-friendly and efficient Maintaining the Integrity of the Specifications

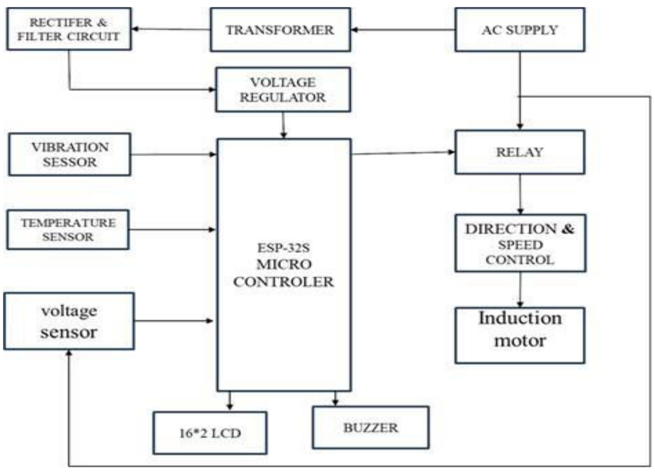

Fig. 1. Fig.1. Block diagram of proposed system.

III. METHODOLOGY

The IoT-based system detects faults by measuring voltage, current, temperature and vibration with the help of the sensors. Such parameters are studied using the microcontrollers and cloud platforms to detect anomaliesA. System Design The hardware network acquires timely information through processing activities to support system fault identification. Operating sensors in real-time enables coordinated monitoring of motor operations to allow for rapid preventive maintenance before system breakdowns occur con- nectivity between the local device and the remote server The detection process utilizes decision-making algorithms that are stored in the cloud.

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TABLE I SPECIFICATIONS OVERVIEW SENSOR

Sl. No	Name of Sensor	Module	Specifications
1	Temperature sensor	DS18B20	Usable temperature range: -55 to 150°C
2	Vibration Sensor	801S	Detection Range: Adjustable, typically 3.3V-5V DC
3	Voltage Sensor	ZMPT101B	Supply: 3V - 5.5V DC. Voltage input range: 0-250 V

TABLE II

SPECIFICATIONS FOR SINGLE PHASE INDUCTION MOTOR

Parameter	Normal Range of Operation
Temperature	125°C
Voltage	220 V
Current	0.5 A
Speed	Up to 2600 rpm
Vibration	900–1100 mm/s

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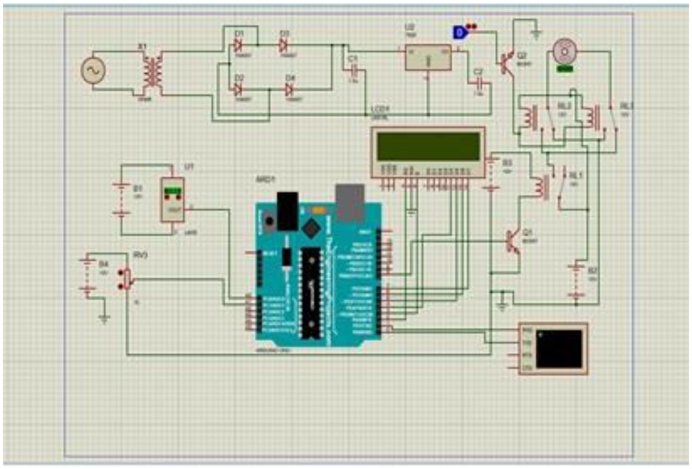

Fig. 2. Simulation Output 1.

SYSTEM IMPLEMENTATION The relationship with re- spect to normal range of operation among sensor parameters (temperature, vibration, current, voltage, speed) is analyzed through Pearson correlation coefficient [10] Single-phase in- duction motor operation is improved alongside maintenance costs reduction when IoT-based fault detection systems use hardware monitoring with real-time control capabilities. A. Software Simulation for Data Collection Figure 2 depicts the simulation architecture that is used to detect faults in proteus. Quantitative simulation results were also obtained besides the descriptive ones. Indicatively, at 230 V, current increased to 6.0 A which caused a relay shut off in less than 1.5 seconds. Any vibration of more than 60 Hz sounded LCD warning. Correct actuation of relays is to be ensured by graphical output (Fig. 3). This set-up draws similarity to the actual implementation of the hardware, which can be used to check the fault detection logic of the system in advance, prior to the physical implementation. Multiple simulation scenarios were carried out: • Normal Operation: The monitored parameters (current, voltage, vibration) were kept in safe operating limits. • Overcurrent Fault: The motor current was artificially increased beyond the threshold, trig- gering the relay to disconnect the motor, as shown in Figure

3. The LCD showed a message of• Normal Operation: The monitored parameters (current, voltage, vibration) were kept in safe operating limits. • Overcurrent Fault: The motor current was artificially increased beyond the threshold, triggering the relay to disconnect the motor, as shown in Figure 3. The LCD showed a message of

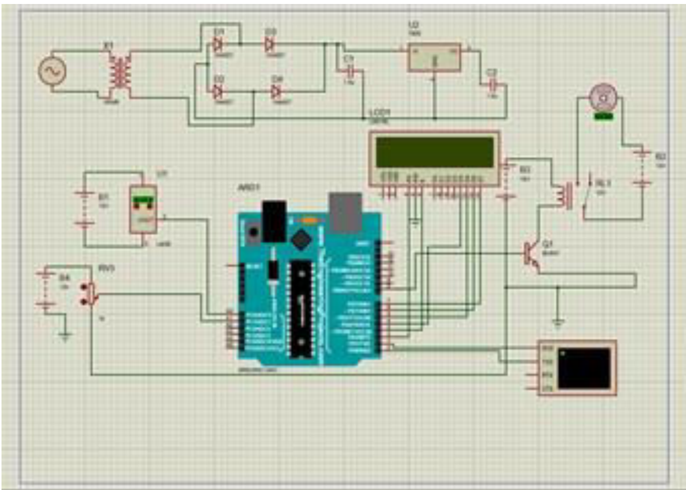

Fig. 3. Simulation Output 2.

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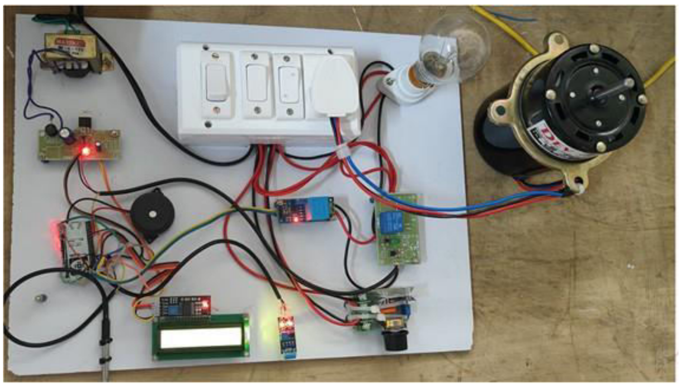

Fig. 4. Working Model.

IV. SIMULATION

Proteus is a simulation and design software used mainly for electronics and embedded systems projects. It allows users to create circuit diagrams, simulate how the circuits work, and even test microcontroller code within the virtual hardware. This means you can design everything from simple led blink circuits to complex automation systems withoutPhysically building them first. Proteus supports many pop- ular microcontrollers like arduino, pic, avr, and arm, and lets you visualize how sensors, motors, relays, and displays will behave with your program. It's a powerful tool for students, engineers, and hobbyists because it helps in finding mistakes early, experimenting with designs safely, and saving both time and components before actual hardware implementation The thresholds mentioned below in Table III are specific to the Proteus simulation environment and differs from the hardware setup thresholds. They were adjusted to enable rapid triggering of fault conditions for demonstration and verification purposes within the virtual setup The simulation results confirm that the proposed design effectively detects abnormal motor behavior and executes appropriate safety measures in real time. The immediacy of the relay working with a 1-2 second breach of a threshold and visible LCD danger warnings shows the potential of the system to avoid the possible damage to the motor.

A. Hardware Setup for Data Collection

The real-time fault detection system in Figure 4 employs five sensors which include a temperature sensor, current sensor together with vibration sensor as well as voltage sensor and speed sensor to monitor a single-phase induction motor. The sensors track essential parameters of temperature, current and vibration and speed as well as voltage to recognize potential device failures. A system which hosts operations using Ar- duino Uno, controls several LCD displays and a relay module along with a transmitter offers powerful real-time detection solution.

B. Parametric Considerations

The chosen motor runs within its specified operational zones to maintain peak operational performance and reliability. Table IV establishes the operational limits for essential parameters such as temperature alongside voltage, current, speed and vibration. The established baseline values will function as warning indicators to identify possible equipment malfunc- tions. The detection of faults relies on established threshold limits for monitored variables to execute immediate preventive maintenance actions before motor failures occur, based on industry criteria and performance analysis as demonstrated in Table IV. The threshold values were carefully selected to prioritize early fault detection and motor safety. For exam- ple, although the motor operates safely between –25°C and 70°C, 32°C is used as an early fault threshold to enable timely preventive actions. This conservative limit helps detect issues like poor ventilation, mechanical friction, or emerging electrical faults before serious damage occurs. The value is aligned with typical ambient temperatures (25–30°C), so any rise without increased load suggests abnormal conditions. It was also validated through system testing and accounts for the Arduino's 1–2 second response delay—ensuring the relay reacts promptly and improves overall system reliability in real- time applications.

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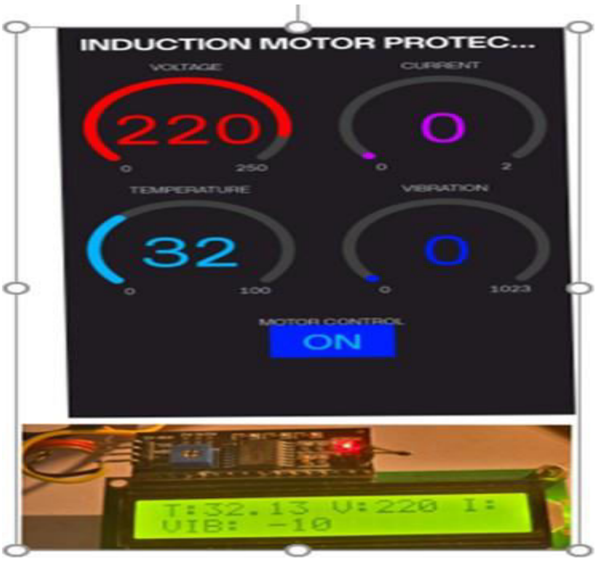

Fig. 5. Installation message send to customere.

Fig. 6. High Temterature.

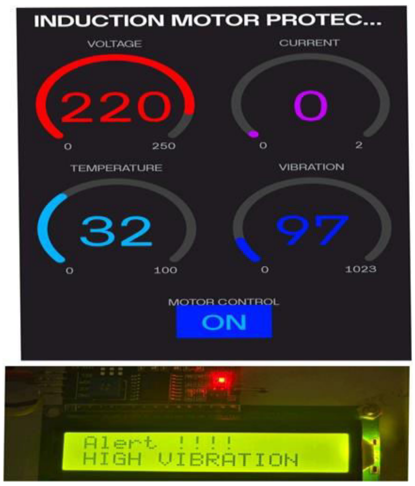

Fig. 7. High Vibration.

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TABLE III

OPERATING CONDITIONS AND SYSTEM STATUS

Condition	Current (A)	Voltage (V)	Vibration (Hz)	System Status
Normal Operation	0.5	230	50	Running Normally
Over Current	5.0	230	52	Shutdown Triggered
Abnormal Vibration	2.8	230	60	Warning Displayed

V. RESULT ANALYSIS

A. Actuation and Remote Control

Actuation and remote-control system development enabled users to monitor and control the system from any location. Remote control features through IoT-based communication protocols allow data transmission from and to mobile applications and cloud servers, and generate email alerts. The testing found remote actuation worked properly for system functions activation or deactivation through a 1-2 second delay, which meets requirements for real-time monitoring. This rapid 1–2 second relay actuation is highlighted as one of the key contributions of this work. The successful implementation of this method appears in Figure 2, which shows the Proteus schematic for remote control design

B. Sensor Data Display

The main functionality of the system involves real-time data acquisition from temperature, voltage, current, speed, and vibration sensors, followed by their demonstration on multiple platforms for easy monitoring access. The LCD output system with website data visualization serves as an optimal method to present sensor readings. The system operates under stable conditions, according to Figure 5 in which all systems function without any detected faults. The data received additional ac- cessibility through its presentation on the Adafruit IO website as well as on the LCD screen. All measured data points lay within ±2 of accuracy which confirmed the accuracy of the sensors used. The system's real-time output appears through both a mobile-friendly interface and LCD screens.

C. Figures and Tables

The system underwent testing by subjecting it to undervolt- age or overvoltage, over current, over-temperature, excessive vibration and abnormal speed. The system demonstrated ef- fective capability in detecting faults by producing alerts that appeared on the LCD display, as well as through website notifications and email alerts. The system responded in 1-2 seconds to the threshold violation with the actuation of remote email alert in 5 seconds. The ability to swiftly respond is one of the contributions that this proposed framework makes. The system data shows excellent performance at measuring temperature, current and speed data because the actual mea- surements matched expected values closely as can be seen from Fig. 10. The recorded deviations in voltage and vibration measurements exceeded acceptable values thus necessitating more calibration measures or noise reduction filters to improve sensor accuracy [11] to predict motor failures could signifi- cantly reduce downtime and optimize maintenance schedules. Expanding the system with cloud-based data logging and analytics [12] would enable long-term trend analysis and automated reporting, improving decision-making processes. Implementing edge computing [13] for localized real-time fault detection would enhance reliability in environments with limited internet connectivity. These upgrades aim to transform the system into a robust, intelligent industrial solution.

TABLE IV

THRESHOLD VALUES FOR SELECTED MOTOR

Parameter	Fault Condition (While Operating)
Temperature	$> 32^{\circ}C$
Voltage	< 170 V, > 230 V
Current	> 1.0 A
Speed	> 1500 rpm

Vibration	> 1100 mm/s

D. Scalability discussion

Although tested on a single-motor laboratory setup, the system's architecture can be extended to multiple motors in industrial environments. Each motor can function as an individual node on the cloud dashboard, enabling centralized supervision. Incorporating NB-IoT/3GPP connectivity would further enhance scalability and applicability in large-scale production.

TABLE V

COMPARISON OF EXPECTED AND MEASURED PARAMETERS

Parameter	Expected Range	Measured Value	Deviation	Remarks
Temperature	−25 to 70°C	32°C	+6.67%	Acceptable
Voltage	220 V	165 V	-25%	Under-voltage detected
Current	0.55 A	1.10 A	-4.17%	Acceptable
Speed	1500 rpm	1492 rpm	-0.53%	Acceptable
Vibration	900–1100 mm/s	1150 mm/s	+4.55%	High vibration detected

E. Limitations

The current system relies on fixed fault detection thresholds, which work well in controlled settings but may not generalize under varying industrial loads or environments. Future work should incorporate predictive analytics or adaptive thresholds to enable more robust and intelligent fault detection.

VI. CONCLUSION AND FUTURE WORK

The IoT-based smart monitoring system for single-phase induction motors has been successfully implemented in lab environments, demonstrating reliable real-time sensor data acquisition, remote tracking, and automatic fault detection. The results obtained under test conditions are promising, with precise anomaly identification, rapid response times, and error- free operation. In industrial settings with higher operational complexity and data variability, the system's performance is expected to be even more impactful. The integration of instant email/mobile alerts and accessible dashboards for parameters like temperature, voltage, current, and vibration positions it as a practical tool for industrial motor monitoring. Future enhancements will prioritize scalability and adaptability. In- tegrating machine learning (ML) algorithms

VII. ACKNOWLEDGMENT

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