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Three Phase Monitoring System

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Abstract

The increasing demand for reliable and efficient electrical power distribution has em- phasized the necessity for intelligent monitoring and protection systems. Conventional systems often suffer from limitations such as delayed fault detection, lack of real-time monitoring, minimal automation, and inability to detect unauthorized power usage, which can lead to equipment damage, energy losses, and reduced system reliability. This paper presents an IoT-based three-phase monitoring and protection system designed to con- tinuously observe electrical parameters and ensure safe operation of power distribution networks. The proposed system utilizes voltage and current sensors to measure electrical parameters across all three phases (R, Y, B) and employs an ESP32 microcontroller for real-time data acquisition and processing. The system is capable of identifying various abnormal conditions such as phase failure, overvoltage, undervoltage, short circuit. Upon detection of any fault condition, the system automatically disconnects the load using a relay mechanism to prevent damage to connected equipment. Simultaneously, real-time notifications are transmitted to users through IoT platforms, enabling remote monitoring and quick response. Additionally, the system can be extended to detect irregularities in power consumption, helping to identify potential electricity theft. The proposed solution enhances operational efficiency, improves system reliability, reduces maintenance time, and ensures safety in electrical systems. Its cost-effective and scalable design makes it suitable for industrial, commercial, and residential applications, contributing to the de- velopment of smart and secure power distribution networks.

Keywords: IoT; ESP32; Three-Phase Monitoring; Fault Detection; Smart Grid; Power System Protection.

How to Cite This Article

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Introduction

Electrical power systems play a vital role in modern society, supporting industrial oper- ations, commercial activities, and residential needs. Among various power distribution methods, the three-phase system is widely preferred due to its efficiency, reliability, and ability to deliver high power with reduced losses. However, maintaining the stability and safety of three-phase systems remains a significant challenge due to frequent faults, voltage fluctuations.

In conventional power distribution systems, fault detection and monitoring are often carried out manually or through limited automated mechanisms. These traditional ap- proaches suffer from several drawbacks, including delayed response time, lack of real-time monitoring, and inability to provide remote access to system data. As a result, faults such as phase failure, overvoltage, undervoltage, and short circuit may remain undetected for longer durations, leading to equipment damage, power outages, and financial losses. Another major concern in power distribution networks is electricity theft and unautho- rized usage, which contribute significantly to non-technical losses. Existing systems lack efficient mechanisms to detect such irregularities in real time, thereby affecting the overall efficiency and revenue of power utilities. Additionally, increasing demand for uninter- rupted power supply in industries and smart infrastructures further emphasizes the need for advanced monitoring and protection systems.

With the rapid advancement of Internet of Things (IoT) technology, it has become possi- ble to develop intelligent systems capable of real-time data acquisition, remote monitor- ing, and automated control. IoT-based solutions enable seamless communication between electrical devices and centralized platforms, allowing users to monitor system performance from anywhere and take immediate action in case of abnormalities.

In this context, the proposed IoT-based three-phase monitoring and protection system aims to overcome the limitations of conventional methods by providing continuous mon- itoring of voltage and current parameters, automatic fault detection, and instant alert mechanisms. The system integrates sensors, a microcontroller (ESP32), and communica- tion modules to ensure reliable operation and efficient management of power distribution networks.

The primary objectives of this work include real-time monitoring of three-phase parame- ters, rapid detection of faults, protection of connected loads, and remote access through IoT platforms. By achieving these objectives, the system enhances operational efficiency, reduces maintenance efforts, and contributes to the development of smart and secure electrical infrastructure.

Literature Survey

Researchers have developed many IoT-based systems for three-phase power monitoring, mainly focusing on fault detection, phase monitoring, and automated alerts. Dhilipkumar et al. [1] and Kumar et al. [2] designed GSM-based models that detect interruptions and voltage drops, sending SMS alerts within seconds. Mane et al. [5], Londhe et al. [10], and Shameera et al. [4] built practical systems and added GPS to improve location-based fault reporting. Wi-Fi and cloud-enabled systems extended these ideas by providing dashboards and predictive analysis. Jamshed et al. [3, 11], Kshirsagar and Jain [9], and Egos et al. [6] used ESP32 and ThingSpeak to display phase conditions online, record data, and manage transformer loads. Verma et al. [7] focused on transmission line faults, while Pravallika et al. [8] worked on automatic load transfer to maintain supply during failures. Across these studies, IoT-based monitoring showed clear benefits in detecting faults quickly, sending timely alerts, and improving system visibility. However, most systems remain prototypes. Challenges such as GSM network shutdowns, poor Wi-Fi coverage in rural areas, lack of predictive features, and limited large-scale testing still hinder full adoption.

However, most existing systems focus on either fault detection or monitoring individually, lacking an integrated solution that combines real-time monitoring, protection, and theft detection in a single platform.

System Overview and Design

The proposed system is designed to monitor and protect a three-phase electrical system using IoT technology.

System Components

- Voltage sensors
- Current sensors
- Microcontroller (ESP32)
- Relay module for load balance
- LCD display for local monitoring
- Wi-Fi module for communication

Software Requirements

- Arduino IDE for programming the microcontroller
- Embedded C++ for code development
- IoT Cloud platform for remote monitoring
- Serial Monitor for debugging and testing
- Mobile application for real-time notifications

System Architecture

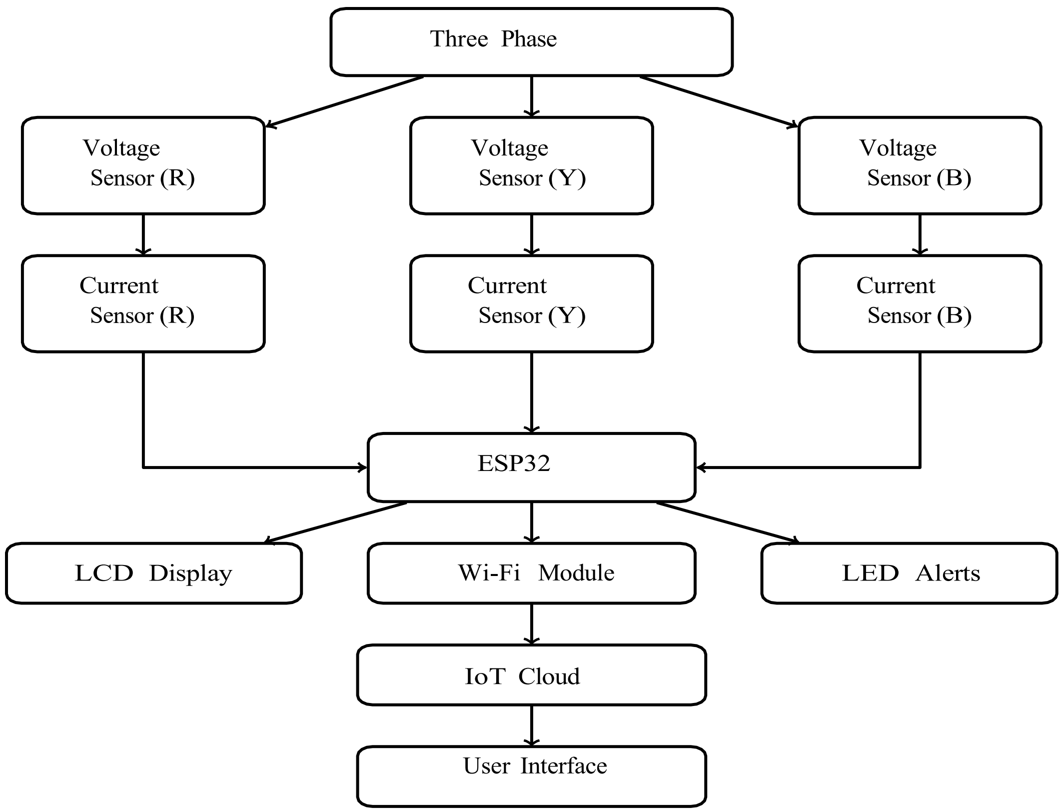

Fig. 1. *IoT-Based Three Phase System Architecture*

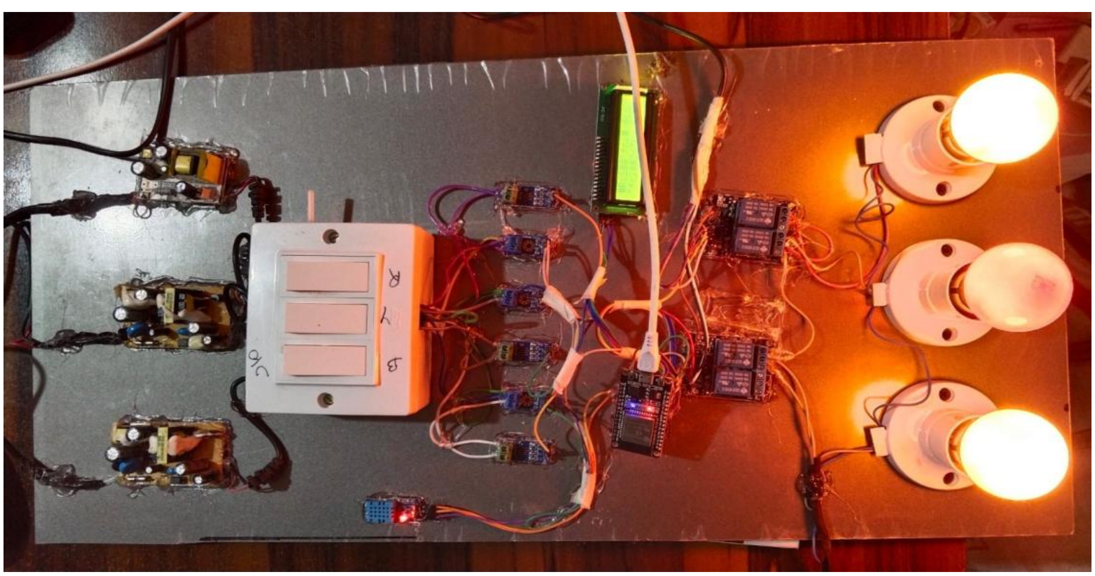

Fig. 2. *Implementation and Design*

As shown in Fig. 2, the system consists of sensors, ESP32 microcontroller, relay module, and IoT platform for monitoring and control.

Methodology

The proposed system is developed to ensure real-time monitoring, fault detection, and protection of a three-phase electrical system using IoT technology. The methodology is structured into functional stages that describe the complete operation of the system.

1. System Initialization: At the initial stage, all system components including voltage sensors, current sensors, ESP32 microcontroller, relay module, and communication interfaces are configured. The threshold values for voltage and current limits are predefined within the microcontroller program.
2. Real-Time Parameter Monitoring: The system continuously monitors electrical parameters such as voltage and current across all three phases (R, Y, B). The sensors convert analog signals into measurable electrical values, which are then fed into the microcontroller for processing.
3. Data Processing and Analysis: The ESP32 microcontroller processes the acquired data and compares it with predefined safe operating limits. The system evaluates the condition of each phase independently to identify any abnormalities in the supply.
4. Fault Identification

   Based on the analyzed data, the system detects various fault conditions including:
   - Overvoltage
   - undervoltage
   - Phase failure
   - Short circuit
5. Protection and Control Mechanism: When a fault is detected, the system activates the relay module to immediately disconnect the load from the supply. This prevents potential damage to electrical equipment and enhances system safety.
6. IoT-Based Communication: The processed data is transmitted to an IoT cloud platform via the ESP32 Wi-Fi module. This enables real-time monitoring of system parameters from remote locations.
7. User Notification and Monitoring: The system provides instant alerts to users through Telegram applications or web dash-boards. The status of each phase, along with fault conditions, is displayed for user awareness and quick decision-making.

Results

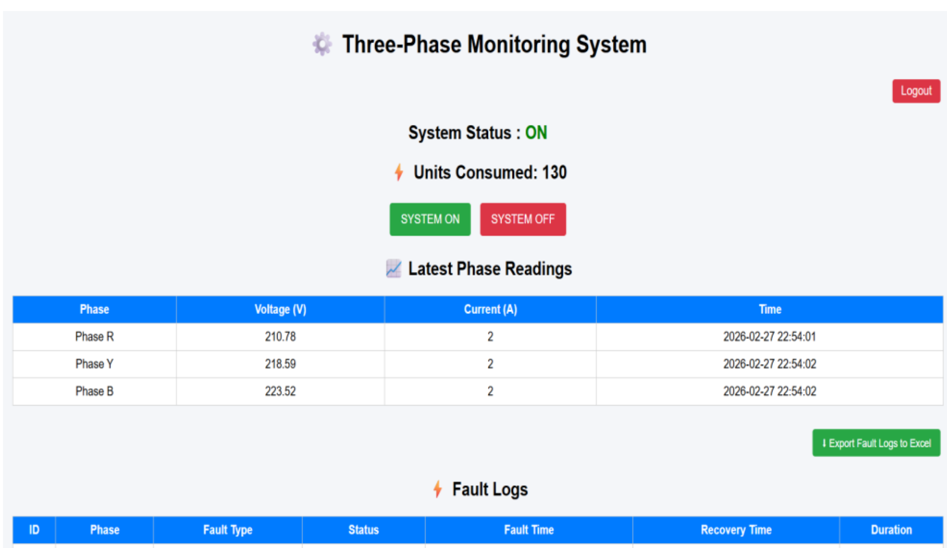

Fig. 3. *Dashboard of IoT-Based Three Phase System*

The proposed IoT-based three-phase monitoring system was successfully implemented and tested under various operating conditions. The performance of the system was eval- uated using real-time data obtained from the web-based dashboard and alert notification system.

The developed system provides a user-friendly interface for monitoring electrical param- eters such as voltage, current, and system status. As shown in Fig. 3, the web dashboard displays real-time phase readings for all three phases (R, Y, B), along with system status and energy consumption. The system successfully detected abnormal conditions such as phase failure and voltage fluctuations. When a fault occurred, the system immediately updated the status to OFF and disconnected the load to prevent equipment damage. Additionally, the system recorded fault logs including phase, fault type, fault time, and recovery duration, which can be exported for further analysis.

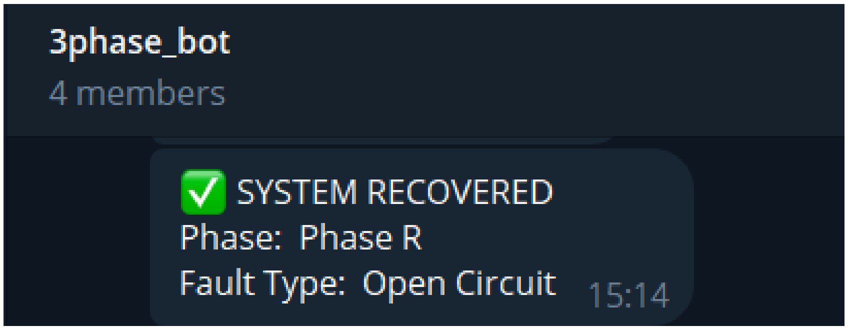

Fig. 4. *IoT Alert Notification for Fault Detection*

Furthermore, real-time alerts were generated and sent to the user via the IoT platform. As illustrated in Fig. 4, an alert notification was triggered when an overvoltage condition was detected in Phase Y, displaying the voltage value (255.3 V) along with the timestamp. This demonstrates the system's capability to provide instant notifications for critical faults.

The system also allows manual control through the dashboard, enabling users to turn the system ON or OFF remotely. The integration of IoT ensures continuous monitoring and quick response to faults, thereby improving system reliability.

The system demonstrated consistent performance under both normal and fault condi- tions, validating its reliability for real-time monitoring and protection applications.

Overall, the results confirm that the proposed system effectively performs real-time mon- itoring, rapid fault detection, automatic protection, and instant alert generation, making it suitable for modern smart power distribution applications.

Applications

The proposed IoT-based three-phase monitoring and protection system has a wide range of applications in modern electrical and industrial environments where reliability, safety, and real-time monitoring are essential.

- Industrial Power Systems: The system can be used in industries to monitor heavy machinery and three-phase motors, ensuring protection against faults such as overvoltage, phase failure, and load imbalance.
- Residential Buildings: It provides reliable monitoring of household three-phase connections, preventing damage to appliances and ensuring uninterrupted power supply.
- Commercial Establishments: Suitable for malls, offices, and commercial com- plexes where continuous power and equipment safety are critical.
- Electrical Substations: The system can be integrated into substations for real- time monitoring of distribution lines, improving fault detection and reducing down- time.
- Smart Grid Systems: It supports smart grid infrastructure by enabling remote monitoring, automation, and efficient energy management through IoT integration.
- Power Theft Detection: The system can be extended to detect unauthorized power usage, helping utility providers reduce non-technical losses.
- Agricultural Use: The system can be effectively used in agricultural fields for monitoring and protecting three-phase water pumps and irrigation motors.

Overall, the proposed system is highly beneficial in environments that require continuous monitoring, quick fault response, and enhanced electrical safety.

Conclusion

This paper presents the design and implementation of an IoT-based three-phase mon- itoring and protection system aimed at improving the reliability, safety, and efficiency of electrical power distribution. The system continuously monitors voltage and current parameters of all three phases and detects abnormal conditions such as phase failure, overvoltage, undervoltage, and load imbalance.

The integration of an ESP32 microcontroller with IoT technology enables real-time data acquisition, remote monitoring, and instant fault notifications through a web-based dash- board and alert system. The automatic relay-based protection mechanism ensures im- mediate disconnection of the load during fault conditions, thereby preventing damage to electrical equipment.

The experimental results demonstrate that the system performs accurate monitoring un- der normal conditions and effectively detects and responds to faults with minimal delay. The inclusion of features such as fault logging, energy monitoring, and remote control enhances the overall functionality of the system. Furthermore, the system proves to be highly beneficial in various applications including industrial systems, commercial establishments, residential setups, and agricultural fields, particularly for protecting irrigation pumps from electrical faults.

Overall, the proposed system offers a cost-effective, scalable, and efficient solution for modern smart power distribution networks, contributing towards improved energy man- agement and system reliability.

Future Work

The system can be further improved by incorporating advanced technologies:

- Integration of artificial intelligence for predictive fault analysis
- Development of a dedicated mobile application
- Implementation of automatic load balancing
- Enhanced security for data transmission
- Integration with smart grid infrastructure

These improvements will make the system more intelligent, efficient, and adaptable to future power systems.

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