SECONDARY PROTECTION SYSTEM BY USING IOT: A REVIEW

Deepak Baban Gawali[1], Dr. B. N. Chaudhari[2]

[1]PG Student, Electrical Engineering Department PES College of Engineering, Sambhajinagar-431001, Maharashtra, India.
[2]Professor, Electrical Engineering Department PES College of Engineering, Sambhajinagar-431001, Maharashtra, India.

Abstract - *The rapid evolution of modern power systems and the increasing demand for reliable electricity have driven the need for advanced monitoring and protection mechanisms. Traditional protection systems are often limited by the lack of real-time data analysis, automation, and remote accessibility. The emergence of the Internet of Things (IoT) has enabled the development of intelligent solutions for power system monitoring, fault detection, and protection. This review paper presents a comprehensive study of IoT-based techniques used in power generation, transmission, and distribution systems, with a focus on smart grids, transformer protection, and secondary distribution networks. Various approaches discussed in recent literature include wireless sensor networks for power quality monitoring, IoT-enabled transformer fault detection, energy monitoring in photovoltaic systems, and automated load management. The integration of microcontrollers such as ESP32 and Arduino with sensors and cloud platforms has been widely explored to enable real-time data acquisition, remote monitoring, and intelligent decision-making.. Challenges including cybersecurity, latency, scalability, and system reliability are also analyzed. Based on the review, future research directions are identified to develop more efficient, secure, and cost-effective IoT-based power protection systems suitable for smart grid and industrial applications.*

Key Words: Internet of Things (IoT), Smart Grid, Power System Protection, Fault Detection, Energy Monitoring, ESP32, Arduino, Wireless Sensor Networks (WSN), Transformer Protection, Secondary Distribution System, Relay Protection, Load Management, Remote Monitoring, Power Quality, Automation.

1. INTRODUCTION

The modern world relies heavily on continuous and reliable electrical power for industrial, commercial, and residential applications. With the rapid growth of urbanization and technological advancements, power systems have become increasingly complex, requiring efficient monitoring and protection mechanisms. Traditional power protection systems, although effective in basic fault isolation, often lack real-time monitoring, intelligent decision-making, and remote accessibility, which are essential for modern smart infrastructure.

The integration of the Internet of Things (IoT) into power systems has introduced a new paradigm in monitoring, control, and protection. IoT enables the connection of sensors, microcontrollers, and communication networks to collect and transmit real-time data from various components of the power system. This facilitates continuous monitoring of electrical parameters such as voltage, current, temperature, and load conditions, allowing early detection of abnormalities and preventing major failures.

In recent years, IoT-based solutions have been widely applied in Smart Grid environments, transformer protection systems, and secondary distribution networks. These systems utilize embedded platforms such as ESP32 and Arduino, along with cloud computing and mobile applications, to provide real-time visualization, fault alerts, and automated control actions. Features such as relay-based switching, automatic backup power management, and remote accessibility significantly enhance system reliability and operational efficiency.

Despite these advancements, several challenges remain, including data security, communication latency, scalability, and integration with existing infrastructure. Addressing these issues is crucial for the successful deployment of IoT-based protection systems in real-world applications.

This review paper aims to analyze and summarize recent research on IoT-based power monitoring and protection systems. It focuses on various techniques used for fault detection, energy monitoring, and automated control in smart grids and distribution networks. The paper also highlights current challenges and identifies future research directions for developing more robust, efficient, and cost-effective solutions.

2. LITERATURE SURVEY

Recent advancements in the Internet of Things (IoT) have significantly improved the monitoring and protection of modern power systems. Several researchers have explored IoT-based solutions to enhance power quality, fault detection, and system reliability.

Bagdadee et al. [1] proposed a wireless sensor network-based approach for power quality control in smart grids, focusing on real-time monitoring of electrical parameters and improving system stability. Similarly, Cheddadi et al. [2]

developed a low-cost IoT-based energy monitoring system for photovoltaic stations, demonstrating efficient data acquisition and remote supervision capabilities.

Sattar et al. [3] introduced an IoT-based fault detection and protection mechanism for power transformers, enabling early fault identification and minimizing equipment damage. In a related study, Lohith et al. [4] designed an Arduino-based industrial protection system, emphasizing automation and safety in industrial environments.

Security in power systems has also been addressed by Erxia Li et al. [5], who proposed a software-defined perimeter approach to enhance the protection of secondary distribution systems. Furthermore, Alfraidi et al. [6] discussed the application of IoT in residential distribution systems, highlighting improved energy efficiency and smart monitoring capabilities.

Recent works have increasingly focused on automation and intelligent control. Muthuraman et al. [7] developed an IoT-based transformer protection and load-sharing system, integrating automation for efficient power distribution. Similarly, Mnyanghwalo and Kawambwa [8] proposed an IoT sensor node for fault detection and classification in secondary distribution networks, improving diagnostic accuracy.

Joha et al. [9] presented a smart microgrid system incorporating IoT for energy monitoring, management, and protection, demonstrating real-time control and optimization. More recent studies by Prasetyo et al. [10] and Rao et al. [11] further emphasize IoT-based smart protection systems and monitoring frameworks for modern smart grids, highlighting scalability and real-time responsiveness.

Table -1: Comparison table

Author & Year	**Method Used**	**Parameters Monitored**	**Advantages**	**Limitations**
Bagdadee et al. (2019)	Wireless Sensor Network (WSN) with IoT	Voltage, Power Quality	Real-time monitoring, improved grid stability	Limited fault protection mechanisms
Cheddadi et al. (2020)	IoT-based energy monitoring (PV systems)	Voltage, Current, Energy	Low-cost, remote monitoring	Focus only on solar systems
Sattar et al. (2021)	IoT-based transformer protection	Voltage, Temperature	Early fault detection, reduces damage	Limited scalability
Lohith et al. (2021)	Arduino-based industrial protection	Basic electrical parameters	Simple and cost-effective	No cloud or remote monitoring
Erxia Li et al. (2023)	Software-defined perimeter security	Network/System security	Strong cybersecurity approach	Does not monitor electrical parameters
Alfraidi et al. (2022)	IoT in residential distribution	Energy usage, load	Smart energy management	Limited industrial application
Muthuraman et al. (2024)	IoT transformer + load sharing	Voltage, Load	Automation and load balancing	Complex implementation
Mnyanghwalo et al. (2024)	IoT fault detection node	Fault signals	Accurate fault classification	Limited parameter monitoring
Joha et al. (2024)	Smart microgrid IoT system	Voltage, Current, Power	Real-time monitoring + control	Higher system cost
Prasetyo et al. (2025)	IoT-based smart protection	Electrical parameters	Improved system protection	Limited automation
Rao et al. (2025)	Smart grid monitoring using IoT	Multiple parameters	Scalable and efficient	Security concerns

3. RESEARCH GAPS

The review of existing IoT-based power protection systems reveals several important gaps. Most systems primarily focus on monitoring and lack complete protection mechanisms. Automatic switching between primary and secondary power supplies is rarely implemented, and many studies monitor only limited parameters such as voltage and current while ignoring temperature and load-related faults. To monitor protective devices is our moto and take N.A (Preventive). Additionally, integrated fault handling, real-time response, and decision-making capabilities are often insufficient. Issues related to cybersecurity, system reliability due to internet dependency, and lack of cost-effective scalable solutions are also observed.

To address these limitations, the proposed system utilizes an ESP32-based IoT platform for real-time monitoring of voltage, temperature, and fault conditions. It incorporates automatic relay-based switching to manage primary and secondary power supplies, ensuring continuous operation and improved protection. The system also enables remote monitoring, making it a more efficient, reliable, and integrated solution compared to existing approaches.

4. CHALLENGES AND ISSUES

Despite the advantages of IoT-based power protection systems, several challenges still exist:

- Cybersecurity Risks: IoT systems are vulnerable to hacking, data breaches, and unauthorized access, which can affect power system safety.
- Network Dependency: These systems rely heavily on internet connectivity. Network failure can interrupt monitoring and control operations.
- Latency Issues: Delay in data transmission can affect real-time fault detection and response.
- Scalability: Expanding the system for large-scale applications like smart grids can be complex and costly.
- Cost and Maintenance: Although IoT systems are relatively low-cost, maintenance and sensor calibration increase overall expenses.
- Integration with Existing Systems: Traditional power systems are not fully compatible with IoT-based solutions, making integration difficult.

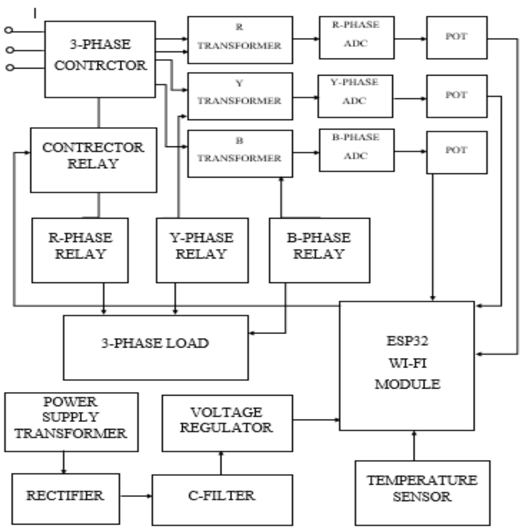

Fig.1: Block diagram

The proposed system is an ESP32-based three-phase load protection and monitoring system designed to ensure reliable operation of industrial loads. The three-phase supply consisting of R, Y, and B phases is connected through a three-phase contactor, which controls the power delivered to the load. Each phase voltage is stepped down using individual transformers and converted into digital signals through ADC circuits. These signals are monitored by the ESP32 microcontroller, which continuously checks the voltage levels of all phases. Potentiometers are used for calibration and setting reference values. Based on the measured voltages, the ESP32 controls the phase relays and contactor relay to protect the load from phase failure, under-voltage, over-voltage, or unbalanced voltage conditions. A temperature sensor is also connected to the ESP32 to monitor system temperature and provide thermal protection. The power supply section consists of a transformer, rectifier, capacitor filter, and voltage regulator that provide a stable DC supply to the control circuitry. Additionally, the ESP32's Wi-Fi capability enables remote monitoring and control of the three-phase system, making it suitable for industrial automation and smart power management applications.

5. CONCLUSIONS

This paper presents the conceptual design of an IoT-based primary and secondary power supply protection system aimed at improving the safety and reliability of electrical loads. The selected topic addresses critical challenges such as voltage fluctuations, thermal faults, and load failures that commonly occur in power distribution systems.

Based on an extensive review of existing literature, it is observed that many current systems focus mainly on monitoring rather than integrated protection and automatic backup supply management. The proposed concept intends to overcome these limitations by incorporating multi-fault detection, relay-based load isolation, and intelligent supply switching using an ESP32 microcontroller. Although the system has not yet been implemented, the proposed approach demonstrates strong potential for real-time fault detection, enhanced operational safety, and improved power continuity. The topic is technically feasible, relevant to current IoT and smart grid research trends, and suitable for further development in the implementation and testing phases.

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