

3-Phase Transmission Line Fault Detector and Identification with Cloud Service

Vageshwari Prabhakar Patil¹, Dr Kiran Donge², Prof. Amol E. Halde³, Prof. Yogesh P. Sushir⁴

¹ Student, Electrical Engineering, Padm Dr. V. B. Kolte College of Engineering Malkapur, Maharashtra, India

² Assistant Professor, Electrical Engineering, Prof. Ram Meghe Institute of Engineering and Research, Badnera, Amaravati, Maharashtra, India

^{3,4} Assistant Professor, Electrical Engineering, Padm Dr. V. B. Kolte College of Engineering Malkapur, Maharashtra, India

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ABSTRACT

Reliable fault detection and identification in three-phase transmission lines are critical for maintaining the stability, safety, and efficiency of modern power systems. This project presents the design and implementation of a 3-Phase Transmission Line Fault Detector and Identification System integrated with Cloud Service for real-time monitoring and analysis. The proposed system continuously measures voltage and current parameters of the three-phase transmission line using appropriate sensors and processes the data through a microcontroller-based control unit. Various fault conditions such as single line-to-ground (LG), line-to-line (LL), double line-to-ground (LLG), and three-phase (LLL) faults are accurately detected and classified based on predefined electrical characteristics and threshold analysis[2].

Upon fault occurrence, the system instantly identifies the fault type and location and transmits the relevant data to a cloud platform using an IoT communication module. The cloud service enables real-time visualization, data logging, and remote access through a web or mobile dashboard, allowing utility operators to monitor system health from any location. Additionally, alert notifications are generated to ensure rapid response and fault isolation, minimizing downtime and equipment damage. The proposed solution enhances power system reliability by enabling remote fault monitoring, faster fault diagnosis, and data-driven maintenance, making it suitable for smart grid and modern power transmission applications[3].

Keywords:- Three-Phase Transmission Line, Fault Detection, Fault Identification, IoT, Cloud Computing, Smart Grid, Voltage and Current Sensors, Real-Time Monitoring, Power System Protection, Remote Monitoring.

1. INTRODUCTION

Three-phase transmission lines form the backbone of modern electrical power systems, enabling the efficient transfer of large amounts of electricity from generating stations to distribution networks over long distances. However, these transmission lines are highly vulnerable to faults caused by factors such as harsh weather conditions, insulation breakdown, equipment aging, tree contact, and accidental human interference. Common faults such as line-to-ground, line-to-line, and three-phase short circuit faults can severely disturb power flow, damage electrical equipment, and lead to prolonged outages if not detected and handled quickly [3].

Traditional fault detection systems rely mainly on protective relays and manual inspections, which often lack real-time monitoring and remote accessibility. These conventional methods may not provide accurate fault classification or immediate alerts, resulting in delayed maintenance and increased downtime. With the advancement of Internet of Things (IoT) and cloud computing technologies, power systems can now be monitored intelligently with greater speed, accuracy, and efficiency [6]. The 3 Phase Transmission Line Fault Detector and Identification with Cloud system is designed to continuously monitor voltage and current parameters of three-phase lines and detect abnormal conditions in real time. Using sensors and microcontroller-based processing, the system identifies the type of fault and transmits this information to a cloud platform through wireless communication modules such as Wi-Fi or GSM. This enables remote monitoring, instant notifications, data logging, and graphical analysis through web or mobile interfaces. By integrating cloud technology, the system enhances reliability, reduces fault response time, improves maintenance efficiency, and contributes to the development of smart and resilient power transmission infrastructure [6].

A 3 Phase Transmission Line Fault Detector and Identification with Cloud is an advanced monitoring system designed to enhance the safety, reliability, and efficiency of electrical power transmission networks [7]. Three-phase transmission lines are essential for delivering high voltage power across long distances, but they are

frequently exposed to operational risks such as short circuits, overloads, insulation failures, and environmental disturbances. These faults can disrupt power flow, damage equipment, and cause significant economic losses if not identified and resolved promptly. This system provides a smart and automated approach to continuously monitor the transmission line parameters and detect abnormal conditions in real time. By using sensors connected to a microcontroller, it analyzes voltage and current values of each phase and determines the presence and type of fault, such as line-to-ground, line-to-line, or three-phase short circuit faults. The integration of cloud technology allows this data to be transmitted to a remote server, where it can be accessed through a web or mobile interface for live monitoring and analysis [10].

The cloud-based architecture enables instant fault reporting, historical data storage, and remote supervision, allowing maintenance teams to respond quickly and prevent large-scale failures. Overall, this system represents a significant step toward smart grid implementation by improving fault management, minimizing downtime, enhancing operational efficiency, and ensuring a more stable and reliable power transmission infrastructure [10].

1.1 Problem Statement

Transmission line faults in three-phase power systems can lead to power interruptions, equipment damage, and reduced system reliability if not detected and isolated promptly. Conventional fault detection methods often rely on manual inspection or localized protection systems, which may lack real-time monitoring, remote accessibility, and data storage capabilities. Additionally, the absence of centralized data analysis makes it difficult to identify fault patterns and perform predictive maintenance [6]. Therefore, there is a need for an intelligent, automated system that can accurately detect and identify various three-phase transmission line faults in real time and transmit fault information to a cloud platform. Such a system would enable remote monitoring, fast fault diagnosis, timely alerts, and improved operational efficiency, supporting the requirements of modern smart grid infrastructure [7].

1.2. Research Objectives

- To design a system for real-time monitoring of three-phase transmission lines.
- To detect faults accurately in R, Y, and B phases of the transmission line.
- To identify and classify different fault types such as line-to-ground, line-to-line, and three-phase faults.
- To continuously monitor voltage and current parameters of each phase.
- To integrate cloud technology for remote monitoring and data storage.
- To provide instant fault notifications and alerts to maintenance personnel.
- To reduce fault response time and improve power system reliability.
- To minimize power outages and equipment damage by early fault detection.
- To enable remote access to fault data through web or mobile platforms.
- To store historical fault data for analysis and preventive maintenance planning.
- To improve safety in power distribution and transmission systems.
- To reduce dependence on manual inspection and traditional fault detection methods.
- To ensure accurate fault localization for faster repair work.
- To support smart grid implementation and intelligent power management systems.

1.3 Motivation

The growing demand for uninterrupted and reliable electrical power has increased the complexity of modern power transmission networks. Faults in three-phase transmission lines, if not detected and identified quickly, can result in prolonged outages, economic losses, and potential safety hazards. Traditional protection systems operate locally and provide limited fault information, making real-time monitoring and remote decision-making difficult [12].

With the advancement of IoT and cloud computing technologies, it has become possible to monitor power systems continuously, store large volumes of operational data, and analyze faults remotely. Integrating cloud services with transmission line fault detection enables faster response, improved situational awareness, and reduced maintenance time. This project is motivated by the need to develop a cost-effective, intelligent, and scalable solution that enhances fault visibility, supports smart grid initiatives, and enables utility operators to detect, classify, and respond to transmission line faults efficiently from anywhere [14].

1.4 Research Gap

Although several studies have addressed fault detection and protection in three-phase transmission lines, many existing approaches rely on conventional relays or localized monitoring systems that provide limited fault information and lack remote accessibility. Most traditional methods focus primarily on fault detection without accurate fault classification or real-time data visualization. Additionally, many reported systems do not integrate cloud-based platforms, restricting long-term data storage, historical analysis, and predictive maintenance capabilities [10].

Furthermore, existing IoT-based fault monitoring solutions often emphasize data transmission rather than reliable fault identification under varying load and environmental conditions. Issues such as scalability, real-

time alert mechanisms, and seamless integration with smart grid infrastructure remain insufficiently explored [11]. Therefore, there is a clear research gap in developing an integrated, real-time, cloud-enabled three-phase transmission line fault detection and identification system that combines accurate fault classification, remote monitoring, data analytics, and timely alert generation to improve overall power system reliability and operational efficiency [12].

2. LITERATURE REVIEW

The reliability of three-phase transmission lines is critical for the stable operation of modern power systems, yet these lines are frequently affected by various faults such as line-to-ground, line-to-line, and three-phase short circuit faults. Traditional fault detection techniques based on manual inspection and conventional protective relays often suffer from delayed fault identification, limited accuracy, and lack of remote accessibility. To overcome these limitations, researchers have increasingly focused on integrating advanced technologies such as the Internet of Things (IoT), embedded systems, and cloud computing for intelligent fault detection and monitoring [5].

Recent studies have explored various automated approaches for real-time monitoring of transmission line parameters using voltage and current sensors combined with microcontroller-based processing units. These systems utilize IoT communication modules such as GSM, Wi-Fi, and LoRa to transmit fault data to cloud platforms, enabling centralized monitoring, fault classification, and historical data analysis. Cloud integration further allows maintenance personnel to access real-time information and alerts remotely, improving response time and system reliability [14].

1. Mussawir Ul Mehmood et al. "Cloud Based IoT Solution for Fault Detection and Localization in Power Distribution Systems" The authors propose a cloud-based IoT framework for detecting and localizing faults in power distribution systems. Current sensing devices send measurements via edge devices using MQTT to a cloud server. This paper presents a cloud-based Internet of Things (IoT) solution for efficient fault detection and localization in power distribution systems. The proposed approach utilizes distributed IoT sensor nodes installed along the distribution network to continuously monitor electrical parameters such as voltage, current, and power quality indices. These sensor nodes transmit real-time data to a cloud platform using wireless communication technologies, enabling centralized data processing and analysis. Advanced algorithms hosted on the cloud are employed to detect abnormal conditions and accurately determine the location of faults, reducing dependency on manual inspection and conventional protection mechanisms. The cloud infrastructure also supports data storage, visualization dashboards, and alert notification services, allowing utility operators to remotely monitor network health and respond rapidly to faults [1].
2. Abhilasha Pawar et al "Transmission Line Fault Detection System Using IoT" This paper presents an IoT-based transmission line fault detection system where sensors deployed along the line measure voltage, current, and temperature and send data to a cloud platform. This paper proposes an IoT-based transmission line fault detection system aimed at improving the reliability and efficiency of power transmission networks. The system employs voltage and current sensors to continuously monitor the operating conditions of transmission lines. A microcontroller processes the acquired data and detects abnormal variations that indicate fault conditions such as line-to-ground, line-to-line, and three-phase faults. Upon fault detection, the system transmits real-time information to a cloud server through an IoT communication module, enabling remote monitoring and data logging. The cloud platform provides visualization dashboards, historical data analysis, and alert notifications to utility personnel, facilitating faster fault diagnosis and response. By integrating IoT technology with conventional fault detection techniques, the proposed system reduces fault detection time, minimizes downtime, and enhances operational safety. The paper highlights the system's cost-effectiveness, scalability, and suitability for smart grid applications, demonstrating its potential for real-time transmission line monitoring and intelligent power system protection [2].
3. D. Sathish Kumar et al. "IoT Based Three Phase Power Monitoring and Failure Using SMS Alerts" The cloud dashboard stores and visualizes phase voltages/currents, enabling remote monitoring and faster restoration of supply. This paper presents an IoT-based three-phase power monitoring and failure detection system designed to enhance the reliability and safety of electrical power distribution. The proposed system continuously monitors three-phase electrical parameters such as voltage, current, and power using suitable sensors interfaced with a microcontroller. Abnormal conditions including phase failure, overvoltage, under voltage, and unbalanced loads are detected through real-time analysis of the measured parameters. When a fault or failure is identified, the system instantly sends alert notifications to authorized personnel using SMS communication via a GSM module, ensuring rapid awareness and response. In addition to alerting, the system can also log power data to an IoT platform for remote monitoring and analysis. The integration of IoT technology enables real-time supervision, improved fault response time, and reduced manual intervention. The paper demonstrates that the proposed

solution is cost-effective, reliable, and suitable for industrial, commercial, and smart grid applications where continuous three-phase power monitoring and timely failure alerts are essential [3].

4. Sneha Tibude et al. "Automatic Fault Detection in Transmission Line Using IOT" This paper introduces an automatic fault detection system for transmission lines using Internet of Things (IoT) technology to improve power system reliability and response time. The proposed system employs voltage and current sensors installed on transmission lines to continuously monitor real-time electrical parameters. A microcontroller-based processing unit analyzes the sensed data to detect abnormal conditions indicative of faults such as line-to-ground, line-to-line, double line-to-ground, and three-phase faults. Once a fault is detected, the system automatically transmits fault information to a cloud platform through an IoT communication module. The cloud service enables real-time visualization, data storage, and remote monitoring via a web or mobile interface. Alert notifications are generated to inform utility operators immediately, allowing quick fault isolation and corrective action. The paper highlights that integrating IoT with transmission line monitoring reduces fault detection time, minimizes power outages, and enhances system efficiency, making the solution suitable for smart grid and modern power transmission applications [4].
5. Roy "Implementation of Cloud Server Utilised Transmission Line Fault Detection Using AI-IoT" This paper presents the implementation of a cloud server-based transmission line fault detection system that integrates Artificial Intelligence (AI) with Internet of Things (IoT) technologies for intelligent power system monitoring. The proposed system uses voltage and current sensors deployed along transmission lines to collect real-time electrical data, which is transmitted to a cloud server through IoT communication modules. AI-based algorithms hosted on the cloud analyze the incoming data to automatically detect, classify, and predict transmission line faults such as line-to-ground, line-to-line, double line-to-ground, and three-phase faults. The use of machine learning models improves detection accuracy under varying load conditions and reduces false alarms compared to conventional threshold-based methods. The cloud platform also provides real-time dashboards, historical data storage, and analytics for fault trend analysis. Upon fault detection, instant alerts are generated and sent to utility operators via web or mobile applications, enabling rapid fault isolation and maintenance decisions. The paper demonstrates that the AI-IoT-based cloud solution enhances fault detection speed, scalability, and reliability, supporting the development of intelligent and smart grid-enabled transmission systems [5].

3. PROPOSED METHODOLOGY

The proposed methodology involves the development of a 3-phase transmission line fault detection and identification system integrated with cloud services for real-time monitoring and analysis. Voltage and current sensors are deployed on each phase of the transmission line to continuously acquire electrical parameters under normal and faulty conditions [21]. The sensed signals are processed by a microcontroller-based unit, where fault detection logic is implemented using threshold comparison and phase imbalance analysis to identify different fault types such as line-to-ground, line-to-line, double line-to-ground, and three-phase faults. Upon fault occurrence, the system immediately classifies the fault and initiates local indications or protective actions. Simultaneously, the fault data and real-time measurements are transmitted to a cloud platform through an IoT communication module. The cloud service enables centralized data storage, real-time visualization, historical analysis, and remote access through web or mobile dashboards. Automated alert notifications are generated to inform utility operators, enabling faster fault diagnosis, reduced outage time, and improved reliability of the three-phase transmission system [21].

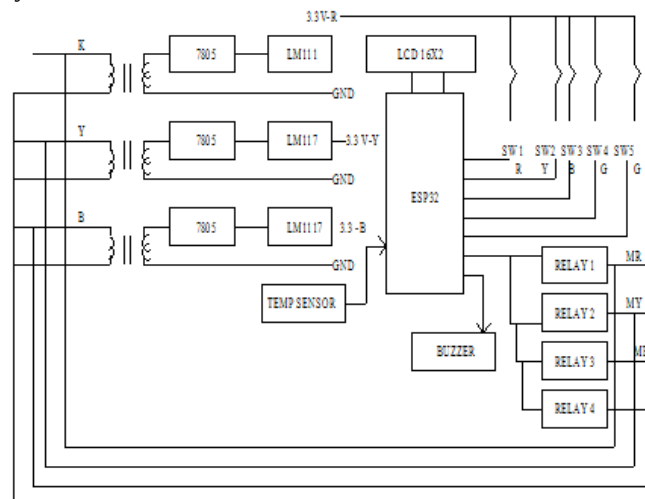


Fig 1: Block diagram

The proposed 3 Phase Transmission Line Fault Detector and Identification with Cloud system uses an ESP32 controller as the central intelligent unit to continuously monitor the health of all three phases (R, Y, B). Each phase is tapped through a potential transformer and regulated using a 7805 and LM1117 stage to obtain a safe, isolated 3.3 V signal for the ESP32. By sampling these regulated phase voltages and the connected temperature sensor, the ESP32 detects abnormalities such as phase loss, over/under-voltage, unbalance, or overheating and then identifies the corresponding faulted phase and fault type. The detected status and fault information are displayed locally on a 16×2 LCD, while an audible buzzer is activated to alert nearby personnel. At the same time, the ESP32 drives relay modules to isolate the faulty phase or load (MR, MY, MB) and protect the system from further damage. Using its in-built Wi-Fi capability, the ESP32 also uploads real-time measurements and fault reports to a cloud server, where data can be viewed through a web or mobile application and stored for analysis and maintenance planning. Thus, the proposed system provides automatic fault detection, clear identification, local protection, and remote cloud-based monitoring for three-phase transmission lines [22].

The given block diagram illustrates a three-phase transmission line fault detection system controlled by an ESP32 microcontroller, which serves as the central processing and communication unit. The three phases, namely R (Red), Y (Yellow), and B (Blue), are stepped down using individual transformers. Each phase output is regulated using a 7805 voltage regulator followed by an LM1117 to obtain stable 3.3V supply levels suitable for the ESP32 and associated circuitry [21]. These regulated voltages from the three phases are monitored and used to analyze line conditions. The ESP32 continuously receives input signals from the three phases and a temperature sensor, enabling it to detect abnormal conditions such as voltage fluctuation, overheating, or phase failure. A 16x2 LCD display is interfaced to show real-time system status, phase information, and fault messages. Additionally, multiple switch inputs (SW1 to SW5) are connected for manual control, testing, or system configuration related to the R, Y, B, and ground phases. For fault protection and isolation, the ESP32 controls four relay modules (Relay 1 to Relay 4) which are responsible for disconnecting the affected phase or load during fault conditions [16]. A buzzer is also connected to provide audible alerts when a fault is detected. The outputs marked as MR, MY, and MB indicate motor or load connections for each respective phase, which are controlled through the relays. Overall, this block diagram represents an intelligent system that monitors three-phase power lines, detects faults such as phase loss or abnormal voltage, isolates faulty sections using relays, alerts users through a buzzer and LCD display, and prepares data for cloud-based monitoring using the ESP32's IoT communication capabilities. This enhances system safety, reduces downtime, and improves reliability of power transmission networks [22].

4. LIMITATIONS

- The accuracy of fault detection and identification depends heavily on the precision and reliability of voltage and current sensors; sensor errors or failures can affect system performance.
- The system relies on continuous internet connectivity for cloud communication; network latency or connectivity loss may delay data transmission and alert generation.
- Threshold-based fault identification methods may be less effective under highly dynamic load conditions or during transient disturbances.
- Cloud services may introduce data security and privacy concerns, requiring robust encryption and authentication mechanisms.
- The initial deployment cost may be higher due to the integration of IoT hardware, sensors, and cloud infrastructure.
- Scalability to very large transmission networks may require additional computational resources and optimized data handling strategies.
- The system may have limited fault location accuracy if sensor placement is sparse along long transmission lines.

5. CONCLUSION

The 3 Phase Transmission Line Fault Detector and Identification with Cloud system provides a reliable and intelligent solution for real-time monitoring and protection of three-phase power transmission lines. By continuously analyzing voltage and temperature parameters, the system effectively detects and identifies faults such as phase loss, voltage imbalance, and short circuits, ensuring quick and accurate fault recognition [10]. The integration of relay-based isolation and buzzer alerts enhances safety by preventing further damage and providing immediate local indication of fault conditions. Cloud connectivity further strengthens the system by enabling remote monitoring, real-time fault reporting, and secure data storage for future analysis. This reduces response time, improves maintenance efficiency, and minimizes power outages. Overall, the proposed system enhances the reliability, safety, and efficiency of power transmission networks and serves as a strong foundation for future integration with smart grid technologies and advanced automated power management systems [11]. The 3-Phase Transmission Line Fault Detector and Identification system integrated with cloud services provides

an effective and intelligent solution for real-time monitoring and protection of modern power transmission networks. By continuously measuring voltage and current parameters of each phase, the system accurately detects and classifies various fault conditions such as line-to-ground, line-to-line, double line-to-ground, and three-phase faults. The integration of IoT communication and cloud platforms enables remote monitoring, centralized data storage, real-time visualization, and timely alert generation, significantly reducing fault response time and power outage duration [14].

The proposed system enhances operational reliability, supports data-driven maintenance, and aligns with smart grid requirements. Despite certain limitations related to connectivity and sensor dependency, the overall approach offers a scalable, cost-effective, and efficient framework for intelligent transmission line fault management, contributing to improved safety and stability of power systems [6].

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