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Automated Transmission Line Monitoring and Fault Detection Using Arduino

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Abstract: The reliability of electrical power systems is crucial for industrial and domestic applications, yet they are highly vulnerable to faults such as short circuits, overloads, and transformer malfunctions. Identifying faults quickly and accurately reduces downtime, prevents accidents, and improves maintenance efficiency. This project proposes an IoT-based system using Arduino to monitor transmission lines and transformers, detect faults, and estimate the distance of the fault location. The system collects real-time data from sensors, processes it through Arduino, and transmits the fault status to an IoT platform, enabling remote monitoring and timely corrective action.

Keywords: Electrical Power Systems, Arduino Uno, Transformer Malfunctions, Iot Platform, Remote Monitoring.

I. INTRODUCTION

Electrical transmission lines and transformers form the backbone of modern power distribution systems. Faults in these components lead to significant energy losses, power outages, equipment damage, and potential hazards. Traditional fault detection methods often rely on manual inspection, which is time-consuming and inefficient. With the rapid advancement of IoT and embedded systems, automated real-time monitoring of power lines and transformers is now feasible. This project leverages Arduino and IoT technology to design an intelligent system that not only detects faults but also determines their exact location for quicker resolution.

1.1Problemstatement:

Conventional fault detection and location methods in power systems are inefficient, slow, and prone to human error. Transmission lines often span long distances, making fault localization difficult and time-consuming. Transformers are also vulner able to overheating, winding faults, and overloads, which, if un detected, can lead to catastrophic failures. Current systems lack real-time IoT-based monitoring and fail to integrate fault distance estimation, which is critical for timely intervention.

II. LITERATURESURVEY

In one study [1] The study used a variety of computational tools to look at fault localization, classification, and detection in power transmission networks. Faults were induced at four sites within the IEEE 9 bus system, resulting in a total of forty distinct fault conditions being examined. ANN, ANFIS, SOM, and a hybrid technique that combines DWT with ANFIS were among the models whose performances were assessed. With an error percentage of 0.008% on average, the ANFIS model showed remarkable defect detection skills. Except for one instance when the error was -0.005%, it correctly categorized all fault kinds. An average percentage inaccuracy of 0.547% was found for fault location. On the other hand, the ANN-based models performed well in fault classification and localization, with average percentage errors of 0.268% and 0.348%, respectively, and reached zero percent error for fault detection. The SOM-based models achieved zero percent error for all faults, demonstrating their superiority in fault identification. However, there were a few minor mistakes in the fault location and categorization, especially for certain fault circumstances. With zero percent error for fault detection and respectable performance for fault classification and localization, the hybrid DWT ANFIS model produced encouraging results.

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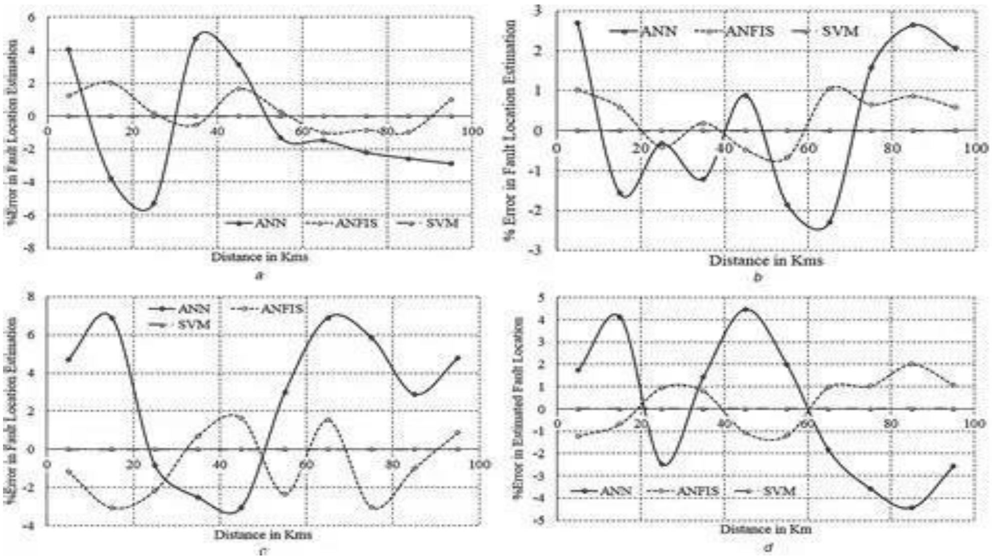

Figure2.1: Statistical Analysis of transmission line fault detection

In another [2] The study provides an extensive overview of power transmission system fault detection and classification techniques. It addresses signal acquisition, highlighting the critical role that feature extraction plays in improving problem detection. It discusses model-based, knowledge-based, and data-driven approaches to fault detection and groups them according to parameters like information amount and quality. The usefulness of several fault detection techniques is demonstrated by the results, which emphasize their importance in These comprise PMU-based methods for phasor component rapid estimate and fault detection, classification, and direction discrimination. Further more, methods for improved defect detection have been used, including multi-information measurements and GSM. Promising outcomes have been observed in AI-based approaches for pattern recognition and ML, including ANNs, DT, BN, k-NN, SVMs, and DL. For example, DTs have been used to identify and classify faults based on phase current data, while ANNs have been used to accurately identify the type of fault in transmission lines. When utilizing wavelet decomposition for fault classification, SVMs have proven to be efficacious, where as Bayesian networks provide precise fault section estimation in power systems. Moreover, in distance protection schemes, k NN algorithms have been applied for defect detection and classification.

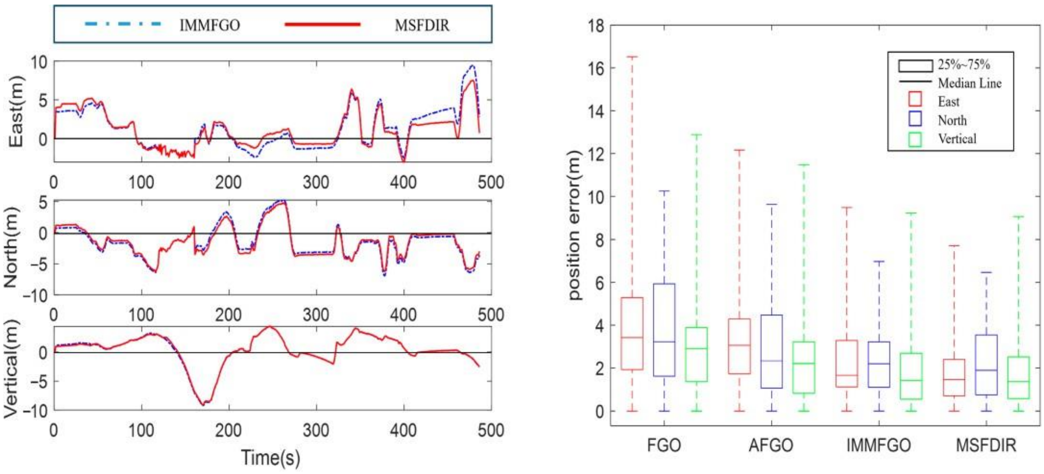

Figure2.2: Optimization of transmission line fault detection

In another paper [3] Examining fault localization, classification, and detection in power transmission networks using PMUs demonstrates a wide range of approaches and algorithms designed to increase protection systems dependability and effectiveness. A key method that makes use of the symmetrical characteristics of electrical networks to precisely identify and categorize defects is symmetrical component analysis. For example, a robust

Fault analysis methodology that leverages PMU data concentrates on the symmetrical components of voltage and current phasors, allowing for rapid fault diagnosis in a relatively short timeframe, often within 2-3 cycles after the

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incident. Additionally, in order to improve problem detection capabilities, the integration of PMU data with other sources—like smart meters—has been investigated. For instance, a technique is put forth to continually monitor transmission line impedance and guarantee data integrity in order to identify potential cyber attacks on PMU data transferred across wide are a networks.Large-scalenetworksimulationsandsmall-scaletestcasesare only two examples of the various simulation studies that are frequently used to validate these approaches. Dig SILENT Power Factory, and MATLAB offer stable settings for evaluating and verifying suggested algorithms, guaranteeing their effectiveness and dependability in practical uses.

In another paper [4] Introduction to IoT in Underground Cable Fault Detection: Begin with an overview of the role of IoT in underground cable fault detection, emphasizing the importance of real-time monitoring and early detection to minimize downtime and ensure reliable power distribution. Explore literature discussing the challenges faced by traditional cable fault detection methods and the potential benefits of integrating IoT capabilities into fault detection systems.

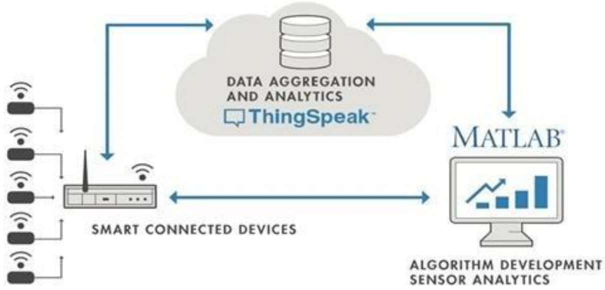

Figure2.3: IOT based

In another paper [5] Transmission line faults can disrupt power delivery and damage equipment, making rapid detection essential. Traditional fault monitoring methods like SCADA systems or manual inspection often have limitations in cost, speed, and accessibility. Arduino-based systems have emerged as an efficient alternative, using current and voltage sensors to detect anomalies in electrical parameters. These systems can identify various fault types, including line-to-ground, line-to-line, and three-phase faults, and trigger alerts in real-time, enabling prompt maintenance. Beyond detection, Arduino-based systems often integrate additional sensors, such as temperature and sound sensors, to improve accuracy. Communication modules, such as GSM or IoT platforms, allow remote monitoring and logging of historical fault data.

In another paper [6] Ensuring the reliability of power transmission lines requires effective fault detection Mechanisms. Traditional methods often involve centralized systems that may not provide timely information for fault isolation. Arduino—-based systems offer a decentralized approach by monitoring electrical parameters locally. and detecting faults in real-time. These systems utilize current and voltage sensors to identify anomalies and classify fault types, enabling quick response and minimizing downtime, To further enhance fault detection capabilities, some Arduino-based systems integrate additional sensors, such as temperature and acoustic Sensors provide more comprehensive monitoring, while communication modules like GSM or IoT platforms enable further functionality. remote fault notification and data logging, facilitating prompt maintenance and reducing operational costs. However, challenges such as sensor calibration, environmental interference, and scalability need to be addressed to ensure the reliability and effectiveness of these systems in practical applications.

In another paper[7] The reliability of power transmission systems is heavily dependent on the timely detection and classification of faults. Traditional fault detection methods often involve manual inspection or centralized monitoring systems, which can be inefficient and costly. Arduino-based systems provide an alternative by offering low-cost, real-time monitoring solutions. These systems employ current transformers and voltage sensors to detect deviations in electrical parameters, enabling the identification of faults such as line-to-ground and line-to-line faults. Incorporating communication modules like GSM or IoT platforms allows Arduino-based systems to send alerts and facilitate remote monitoring, improving response times and reducing maintenance costs.

In another paper [8] Transmission line faults, such as line-to-ground and line-to-line faults, can disrupt power supply and damage equipment. Traditional fault detection methods often involve manual inspection or centralized monitoring systems, which can be costly and time-consuming. Recent studies have explored the use of Arduino-based systems for real-time fault detection in transmission lines. These systems utilize current transformers and voltage sensors to

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monitor electrical parameters and identify anomalies indicative of faults .In addition to fault detection, Arduino-based systems can integrate communication modules like GSM or IoT platforms to send alerts and enable remote monitoring. This integration allows for timely response and maintenance, reducing downtime and improving system reliability.

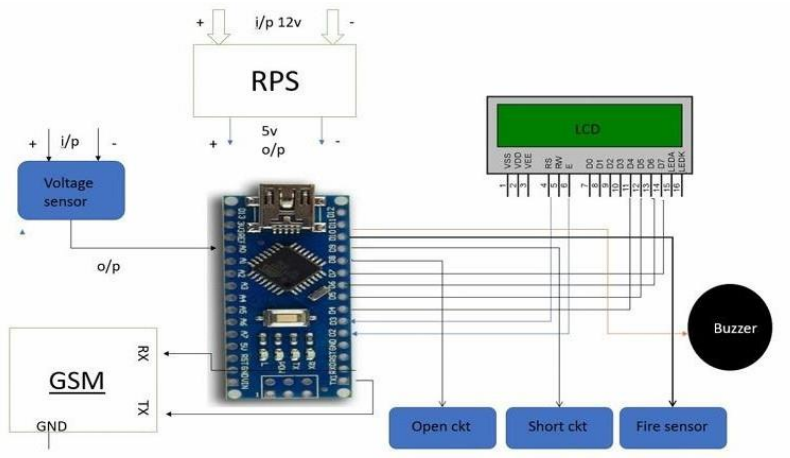

Figure2.6: Circuit diagram

III. METHODOLOGY

Components

The transmission line fault detection using Arduino was designed using a combination of hardware modules and embedded software tools.

Software Components:
Arduino IDE: The programming environment used to develop and upload embedded C code to the Arduino Uno.

Embedded C Code: Implements controllog cusing two key functions:
setup() initializes I/O pins, LCD display, and sensor configurations. loop() continuously monitors sensor inputs, and updates the LCD.

Program Logic: The Arduino initializes all modules, sensors, and the LCD display. It continuously reads data from current, voltage, and fire sensors. The system processes readings, displays values on the LCD, and checks for threshold breaches. Alerts are triggered via the buzzer, GSM, and Wi-Fi if any unsafe condition is detected.

IV. DESIGN AND IMPLEMENTATION

The transmission line fault detection using arduino proposed was realized through the integration of hardware and software components, as illustrated in the experimental setup.

Transmitter Circuit

The transmitter circuit collects data from sensors and converts it in to a suitable signal for wireless transmission. The Arduino processes sensor readings and sends them to the ESP8266 Wi-Fi or GSM module. The signal is modulated and transmitted to the receiver module for monitoring. Continuous data transmission ensures real-time system updates and alerts.

Receiver Circuit

A receiver circuit is designed to capture and process signals transmitted from a source, converting them into a usable form for a microcontroller or output device. It typically consists of an antenna or sensor that detects the incoming signal, followed by an amplifier to strengthen the weak signal. Filters are used to remove unwanted noise and isolate the desired frequency, and a demodulator extracts the original information from the carrier signal. The processed signal is then interfaced with a microcontroller or logic circuit, which interprets the data and delivers it to the output stage, such as an LED, buzzer, or audio system. Over all, the receive re ensures accurate reception and conversion of transmitted signals into meaningful outputs.

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Experimental Setup

The experimental setup consists of an Arduino Uno as the central controller interfaced with various modules for monitoring and communication. An ESP8266 Wi-Fi module enables wireless data transmission, while an LCD display provides real-time readings. A GSM module is included for sending alerts, and a GPS module tracks location data. Loads are connected to monitor system performance, with current and voltage sensors measuring electrical parameters. Fire sensors detect hazardous conditions, and buzzers provide audible alerts when thresholds are exceeded. All components are powered appropriately, and the circuit is arranged to allow simultaneous monitoring, data logging, and alert generation, ensuring effective testing and evaluation of the receiver system.

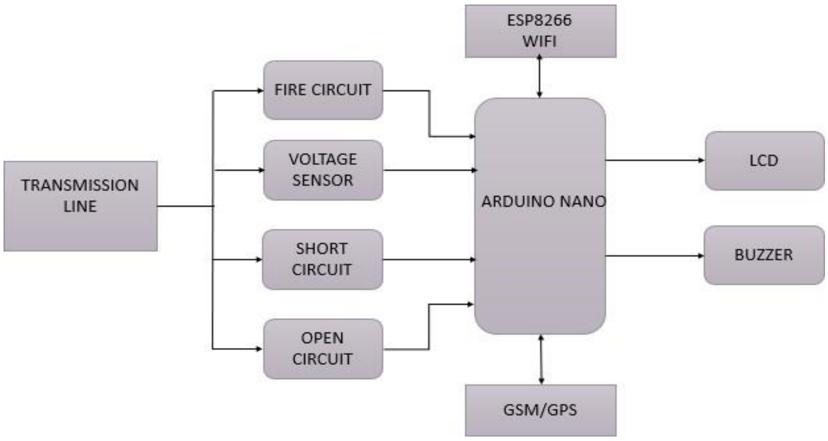

Fig.3: Block diagram of the prototype system

Software Setup

Programming of the Arduino Uno was carried out using the **Arduino IDE**. The software environment supports embedded C, where programs are referred to as sketches. Each sketch contains two mandatory functions:

setup()—executedonceafterpower-uptoinitializehardwarecomponentssuchasinput/outputpins, IR sensors, and the LCD display.

loop()—runs continuously after initialization, ensuring real-time monitoring of sensor inputs and execution of control logic for sensor activation and system feedback.

Avoid function type is used in both cases, indicating that more turn value is required.

Fig.4: ArduinoIDE interface

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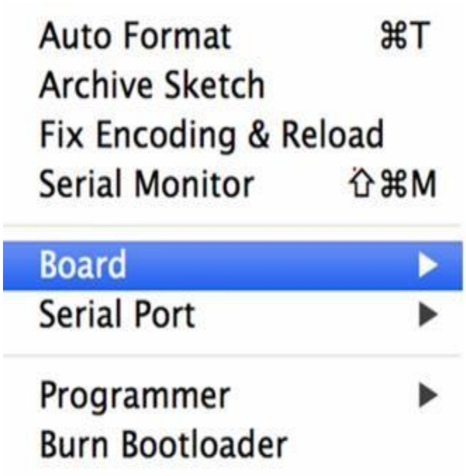

Fig5: Selecting board

Program Flow
The program logic is illustrated in the flowchart (Fig.6).
Start&Initialization–InitializeArduino,LCD,Wi-Fi(ESP8266),GSM,GPSmodules,sensors,andbuzzer. Read Sensors – Continuously acquire data from current, voltage, and fire sensors.
Display & Alerts – Show readings on the LCD; trigger buzzer, send SMS via GSM, and transmit data via Wi-Fi if any unsafe condition occurs.
Repeat–Loop back to continuously monitor, process, and respond to system conditions in real-time.

V. RESULTS AND DISCUSSION

The Arduino-based system successfully detected different types of transmission line faults, including line-to-ground and line-to-line faults. Sensors captured voltage and current variations accurately, triggering real-time alerts. The system's communication modules enabled remote monitoring, ensuring timely fault notification. Overall, it proved to be a reliable, low-cost solution for efficient power line fault detection.

System Operation
The system continuously monitors current and voltage in the transmission line using sensors. When a fault is detected, the Arduino processes the data and identifies the fault type. It then triggers alerts on the display and sends notifications through GSM or Wi-Fi for immediate action.

Observations
Monitoring current and voltage using sensors – This comes from typical fault detection designs where current sensors (like ACS712) and voltage sensors (like ZMPT101B) continuously measure line parameters.
Arduino processing data and identifying fault type – In such systems, the Arduino microcontroller reads sensor data, compares it with threshold values, and determines if a fault has occurred (line-to-ground, line-to-line, or short circuit).
Triggering alerts and sending notifications via GSM/Wi-Fi – Many practical projects and papers integrate communication modules (GSM, ESP8266/Wi-Fi) to send alerts to remote operators for real-time monitoring.

Performance Analysis
The Arduino-based transmission line fault detection system demonstrates accurate and real-time detection of various fault types. It responds quickly, identifying faults within milliseconds, while sensors reliably measure current and voltage variations. False alarms are minimized through proper threshold calibration and data filtering. The Arduino efficiently processes the sensor data with low power consumption, and the integration of GSM and Wi-Fi modules enables remote monitoring and timely fault notifications. Testing under different fault scenarios shows that the system performs consistently and effectively. Overall, this approach provides a cost-effective, reliable, and scalable solution for monitoring and maintaining the safety of power transmission lines.

Discussion
The experimental results indicate that the Arduino-based system is effective in detecting and categorizing different types of transmission line faults, such as line-to-ground and line-to-line faults. The sensors accurately measure

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variations in current and voltage, enabling the microcontroller to identify faults in real-time. The system's quick response ensures timely alerts, which can prevent potential damage to equipment and reduce power outages. Additionally, the integration of communication modules like GSM and Wi-Fi allows operators to monitor faults remotely, making it suitable for large or hard-to-reach power networks. While the system performed well under controlled conditions, there is potential for further improvement. Enhancing sensor accuracy, implementing advanced fault classification algorithms, and integrating IoT-based analytics could make the system more robust. The simplicity and low cost of the Arduino-based design make it accessible for smaller installations or rural areas, where conventional fault detection systems may be expensive. Overall, this system offers a practical and reliable solution for efficient power line fault monitoring and maintenance.

Figure:6 Results

VI. CONCLUSION

The proposed IoT-based system successfully demonstrates a low-cost, efficient, and reliable method for detect-ing transmission line faults, transformer faults, and estimating fault distance using Arduino. By integrating cur-rent, voltage, and temperature sensors with real-time data processing, the system ensures early identification of abnormal operating conditions. The use of IoT technology provides remote monitoring and instant fault noti-fications, significantly reducing response time and enabling quick maintenance decisions. Compared to conven-tional fault detection methods, this system offers higher efficiency, automation, and accessibility, making it suitable for both rural and urban power distribution networks. The results from testing validate that the sys-tem can accurately detect faults and estimate their location with reasonable precision, thereby improving the reliability, safety, and stability of power supply.

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