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# Design And Construction of a Prototype Arduino-Based Fault Detection System for the Agu-Awka 132 KV Transmission Line Using GSM Feedback.

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***Abstract-* High-voltage transmission systems should be reliable, which can influence the stability of power systems and limit interruptions to energy supply. The Agu-Awka Transmission Company of Nigeria (TCN) substation has an installed capacity of 2 × 60 MVA at 132/33 kV that links the Onitsha–Enugu transmission corridor to the Awka distribution network. Frequent faults such as single-line-to-ground, double-line, and three-phase short circuits within this corridor often result in prolonged outages and equipment damage due to delayed fault detection and reporting. This paper presents the design and construction of a prototype Arduino-based fault detection system for the Agu-Awka 132 kV transmission line with GSM feedback. The system is designed using current and voltage sensors interfaced with ATmega328p microcontroller to monitor line parameters continuously. When the system detects an abnormal condition beyond a specified limit, it gives a signal to isolate the affected phase through the relay. SMS is sent to the control room for corrective action. Results demonstrate fast detection, accurate fault phase identification, and reliable GSM feedback transmission. This low-cost, scalable solution provides a foundation for smart fault monitoring in Nigeria's high-voltage transmission network, enhancing operational reliability and reducing downtime across substations such as Agu-Awka.***

***Index Terms-* Arduino, GSM, Fault Detection, Transmission Line, Electrical Power System.**

## I. INTRODUCTION

In reliability and fast identification of faults in high-voltage transmission lines are required for stability, guaranteed continuity of supply, and protection of equipment. The Transmission Company of Nigeria (TCN) operates the Agu–Awka 132 kV corridor with an installed capacity of 2 × 60 MVA at 132/33 kV. It is critical to ensure electricity to Anambra State. But the frequent occurrence of faults (single line-to-ground, double line, and three-phase) causes long outage duration and stress to the equipment. The delays in locating and restoring these faults are the reasons for such duration and stress to the equipment [1]–[3]. Distance relays, or impedance-based schemes, have been tried and tested but are expensive to deploy in a wide area. Further, they do not provide any remote feedback [4], [5]. Recent studies have focused on using a microcontroller-based fault detector system. It uses local sensing and wireless communication. It consists of a GSM or IoT module to provide real-time alerts to the operator [6]–[9]. Low-cost solutions are developed using platforms like Arduino or ESP32 equipped with sensors that can sense line anomalies and raise alerts using GSM-based feedback. At the same time, significant advancements in data-driven analytics, such as wavelet transforms, traveling-wave (TW) analysis, and sophisticated machine-learning (ML) techniques, have boosted the performance of detection accuracy, fault classification, and localization under significantly more challenging conditions [10]–[13]. More recently, hybrid approaches that merge physics-informed ML models and signal-processing algorithms are being employed for single-ended measurement schemes to reduce hardware complexity with an acceptable performance [14]–[16]. Few studies have been conducted on the development of low-cost, GSM-integrated prototypes for 132 kV transmission lines for Sub-Saharan Africa, which has infrastructural and cost limitations for the installation of advanced monitoring. [17]–[19]. This paper therefore presents a prototype Arduino-based fault detection system for the Agu–Awka 132 kV transmission line, integrating GSM feedback to enable rapid, remote fault reporting. The goal of this system is to show an inexpensive and functioning approach that could be later enhanced with more advanced classification and localization algorithms [20], [21].

## II. LITERATURE REVIEW

Fault detection systems using microcontrollers are cheap compared to conventional protection devices. Tarun et al. [1] developed an Arduino–GSM system that could detect when currents in the transmission lines went above normal levels. Subsequently, these devices will send out an alert via SMS. The GSM model developed by [2] is capable of detecting single- and multi-phase faults. Jadhav et al. [3] expands upon this concept and use IoT and GPS modules to monitor a large area. They study by [13] and [14] gave an Arduino based prototype which uses relay actuation for faulty phase isolation and sending of SMS. It has been established that GSM-integrated fault detection is feasible, but most studies are confined to small-scale or laboratory demonstrations. For a long time, traveling-wave techniques and classical impedance based dispatching fault location schemes have been used for transmission line fault location. Aker et al. [4] introduced a method based on multiresolution analysis with a Naïve Bayes classifier to detect faults in lines compensated by STATCOM with high effectiveness. Liu et al. [17] proposed a superior TW position algorithm relying on decomposition ICEEMDAN-NTEO for noise improvement. Similarly, Özdemir et al. [5] applied a ML-based approach for TW feature extraction to determine the fault location on a 400 kV line, with errors less than 30 m. Because of their strong immunity to noise, wavelet-based methods are popular in fault diagnosis since they capture transient features. Pratap Singh et al. [6] used both discrete wavelet transform (DWT) and artificial neural network (ANN) for fault classification in the DFIG–TCSC connected lines. Dhole et al. [12] in their work suggested deep neural network (DNN) trained wavelet derived features for accurate fault location. The automated fault detection and classification can be done using various machine-learning approaches, namely SVM, KNN, and random forest algorithms. The study in [7], provided a thorough review of ML approaches for power-line fault analysis. A recent paper by Chowdary et al. [9] used machine-learning classifiers on transmission-line data to accurately predict the type of fault. In the same way, Yang et al [8] emphasize lines connected to inverter-based generators (IBGs), with a machine learning (ML) based approach for compensating fault currents reduction. Rai et al. [10] used deep convolutional auto-encoders in high-impedance fault (HIF) detection. When synchronized multi-end measurement is not available, you can use single-ended or physics-informed ML. Wang et al. [11] proposed a machine-learning-based approach for fault diagnosis using only single-end measurements Bera et al. [15] introduced a hybrid intelligent protection scheme that combines fuzzy logic and ML for PV-integrated lines. Xing et al. [16] validated a physics-informed, data-driven model for single-ended fault location using field data. The reviewed literature highlights that most Arduino–GSM prototypes [1]–[3], [13], [14], [20] focus on detection and SMS alerting, while advanced TW, DWT, and ML algorithms [4]–[8], [11], [12], [17]–[19],[21] require expensive sensors or computing hardware.

### 2.1 Transmission Line Faults and Protection Methods

Transmission lines are the backbone of electrical power systems as energy is transmitted from generating stations to the distribution systems via them. Nonetheless, these lines may get faulty due to lightning strikes, insulation failure, pollution, mechanical damage, and human interference. If faults in transmission lines are not detected and isolated on time, the system may become unstable, equipment may be damaged and outages may get prolonged. Two general classes are symmetrical and asymmetrical faults. With symmetrical faults like three-phase short circuits, all phases are affected equally. Even though this kind of fault is not very common, it is the worst type of fault. This is because high magnitude currents flow and it puts a lot of stress on the system. Asymmetrical faults occur far more frequently than symmetrical faults, these single line-to-ground (SLG) and line-to-line (LL) and double line-to-ground (DLG) fault together make up over 80% of the fault which occur into the network at high voltages [22], [23].

Several studies have looked into fault behaviors and the relevant protection strategies. Das et al. [24] examined fault currents in a 132 kV transmission system, discovering that most disturbances are due to overvoltage transients and flashover due to weather conditions. As per [25], the implementation of distance relays, overcurrent protection and differential relays are traditionally used to protect transmission lines. However, these schemes are expensive to install and maintain. Ghosh and Lubkeman [26] noted that impedance-based techniques are dependable; however, they are of little value when the grid is weak or remote. In particular, variations in line impedance undermine the accuracy of fault location.

Several researchers have built inexpensive detection and classification systems in light of these obstacles. The researchers in [27] presented a microcontroller-based system that allows real-time fault monitoring which uses local sensing to supplement conventional elays. Basically, this paper [28] added GSM technology to fault detection networks in substations for faster remote response. Recent improvements in digital signal processing have led to the utilization of discrete wavelet transform (DWT) and traveling wave (TW)analysis for fault classification and location with high accuracy [29],[30]. Moreover, machine learning and data-driven hybrid intelligent protection schemes are now popular for providing self-adaptive responses to varying grid conditions [31].

In developing regions, like Sub-Saharan Africa, Agu--Awka 132 kV transmission line's high-voltage corridors mainly rely on manual fault reporting and mechanical isolation. Using wireless communication as well as microcontroller-based fault detection systems can help bridge the gap between conventional and intelligent protection schemes and thus can help in achieving better reliability at a low cost. These systems can serve as early-warning mechanisms, reducing downtime and enhancing the operational efficiency of transmission networks.

## III. SYSTEM MODELING AND METHODOLOGY

The proposed system includes a microcontroller, a GSM module, voltage and current sensors, transistor drive, relay and the utility loads. The system was modeled and simulated using proteus software. The complete system block diagram is shown in Figure III-1

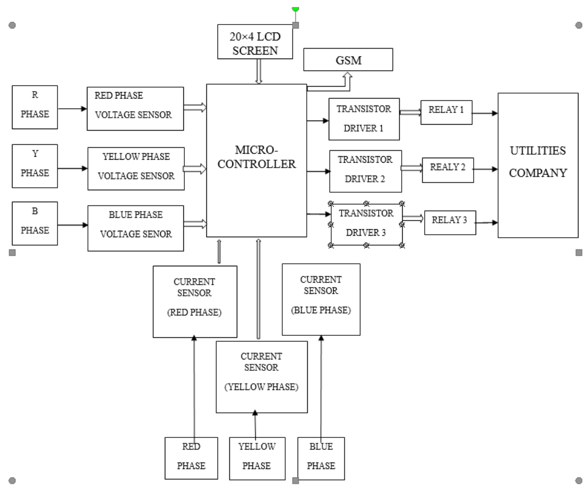


Figure III-1 block diagram of the complete system

The design and construction of the prototype Arduino-based fault detection system for the Agu-Awka 132 kV transmission line were structured to detect phase faults and communicate occurrences via GSM feedback. The methodology consists of system design, hardware construction, software development, and performance testing. The control system centers on an Arduino Uno microcontroller which receives voltage and current data from sensors interfaced with the three-phase line (R, Y, and B). These sensors continuously monitor line voltages and currents. When an abnormality beyond the preset threshold is detected, the microcontroller activates a relay to isolate the faulty line and triggers a GSM module to send an SMS alert to the operator. The system flow chart is shown in Figure III-2

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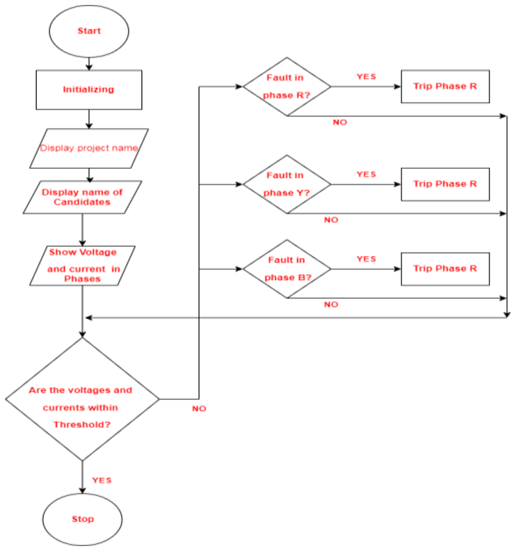


Figure III-2 the flow chart of the program sequence

3.1 Circuit Description and Analysis

The system architecture in proteus as shown in Figure III-3 includes a regulated power supply unit, Arduino Uno controller, GSM module (SIM900A), voltage and current sensing circuits, a 16×2 LCD for data display, and relay circuits for phase isolation. The Arduino was programmed using the Arduino IDE in C/C++ language to acquire and process sensor data, detect faults, and execute communication commands. The operation begins with system initialization, voltage display, and continuous monitoring of phase conditions. If any phase voltage falls below or rises above a set threshold, the corresponding relay disconnects the line and the GSM sends an alert such as 'Phase R Fault' to the operator. When normal voltage levels are restored, the system automatically reconnects the the phase and start the monitoring again. A 12 V DC power source derived from a step-down transformer and rectifier was used to supply the circuit. The system was tested using a scaled-down three-phase simulation representing the Agu-Awka 132 kV transmission line. Induced faults on individual phases triggered accurate relay response and GSM feedback within approximately two seconds, demonstrating reliable detection and communication capability

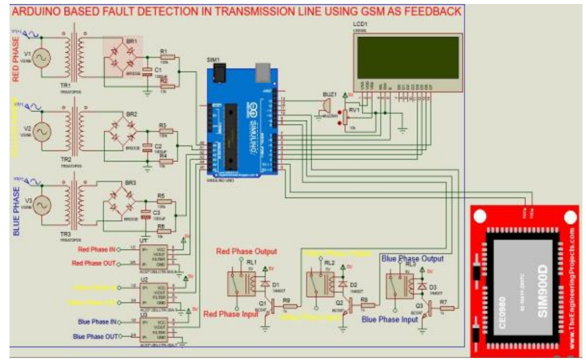


Figure III-3 circuit diagram of the system

3.2 System Laboratory Design and Construction

The proposed laboratory prototype of the fault detection system is represented by the construction of the Arduino based fault detection that simulates the operational behavior of the Agu–Awka 132kV transmission line at a reduced voltage scale. , Three single-phase step-down transformers rated 220 V/12 V were connected to represent the red (R), yellow (Y), and blue (B) phases of the 132 kV line. Each transformer reduced the line voltage to 12 V AC, which was subsequently rectified to DC using a full-bridge rectifier composed of 1N4007 diodes. A 1000 µF, 25 V electrolytic capacitor was connected across the rectifier output to filter ripples and produce a stable 12 V DC supply.

The Arduino Uno microcontroller (ATmega328P) may be operated safely when the input voltages are 5 V. Consequently, a voltage divider network consisting of 100 kΩ and 10 kΩ resistors was connected in parallel with the capacitor to reduce the voltage from 12 V DC to approximately 1.1 V DC or 5V regulator can be used. After that, these three scaled-down values are fed into the Arduino analog input pins namely A0-A2, which correspond to all three phases that are being transmitted. We connected Hall-effect sensors, of ACS712 type, to pins A3–A5 to monitor line current of each phase. The sensors work on 5 V and give a corresponding analog voltage according to the measured current. This current feedback, combined with voltage sensing, allowed the system to detect short-circuits, over-voltages, and under-voltages corresponding to real fault conditions on the Agu–Awka corridor.

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If the voltage or current goes above or below the programmed logic, it displays "FAULT DETECTED" on the LCD with the faulty phase. At the same time, Arduino will switch on the relay circuit, removing the faulty phase and buzzer alarm. A 1n4007 flyback diode is connected in parallel with each 5 V, 10 A relay to prevent reverse EMF from damaging the transistor and control circuit.

The biasing of an NPN Transistor (BC547) switch connected a collector of the relay coil to the ground through a 1 Ω resistor. When activated by the Arduino logic signal, the transistor activates the relay and its contacts go from NC – Normally Closed – to NO – Normally Open, thus disconnecting the faulted phase. For voltage fault indication, a 20×4 LCD display was connected to the digital pins of Arduino (2 to 5 & 6 Enable). The GSM module (SIM900A) was connected using the digital pins of 0 and 1 to allow wireless communication to the control room in the TCN Onitsha sub-region for fault notice. An alarm buzzer powered by 12-24volts dc will be connected to digital pin 13 using a BC547 transistor.

We assembled the circuit on the perforated board using IC Sockets. The purpose of using IC Sockets was to prevent the Arduino Board from being burnt while soldering. Furthermore, using IC Sockets makes it easy to upload the code again if the previous one fails to work. All connections were tested for continuity before power-up. The entire laboratory set up is shown in Figure III-4 successfully mimicked the operation of the Agu–Awka 132 kV transmission line under reduced voltage and current conditions, therefore confirming the reliability of the design for educational and pre-deployment

Figure III-4 laboratory circuit design

3.3 Transmission Tower Prototype Design

In the lab, two miniature prototypes of a transmission tower were devised and created to give a physical support to the simulated transmission line. The Agu – Awka single-circuit towers representing a 132kV TCN network belong to Transmission Company of Nigeria (TCN). The construction utilized 1.5 mm bare copper wires, soldering lead, super glue, and paper reinforcements. Required tools included a soldering iron, pliers, sandpaper, a meter rule, protective gloves, and a facial mask.

The fabrication process commenced with a design sketch defining the geometry and the dimensions of the tower. The insulation was removed from the copper conductors, and each wire was straightened out by stretching to remove elasticity. The base frame of each tower was 8 cm × 8 cm and thus the joints were soldered to support rigid square bases as shown in Error! Reference source not found.. The shape of the tower body was fixed in pyramidal fulcrum structure with slant member of 18 cm joining at a top base of 4 cm × 4 cm. This was to form the top most section of the structure as shown in Error! Reference source not found.

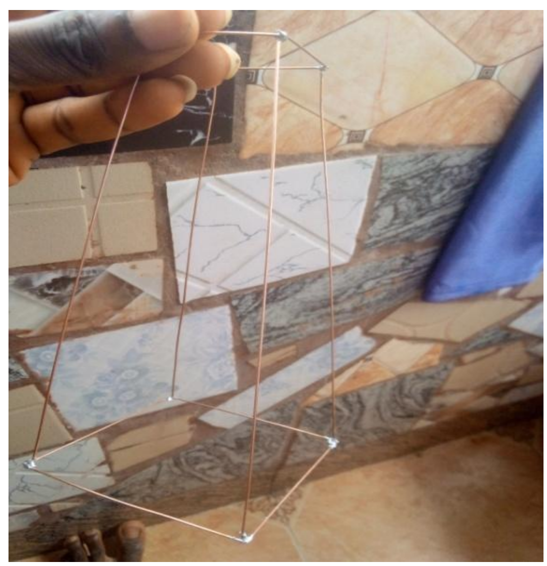

Figure 3 5 The tower body

Figure 3 6 Complete tower body

## IV. RESULTS AND DISCUSSION

4.1 Testing of the Prototype System

After putting together, the complete prototype the system was subjected to several lab tests to check the functioning performance and reaction to several fault conditions. The power that is provided was connected with a simulated incoming tower representing Agu–Awka 132 kV line and switched ON. When we powered the LCD display, it displayed the name of the project and the names of the designers. After that it showed voltage and current of the red, yellow and blue phases. The parameters were continuously monitored in real-time to find out the actual line conditions and phase voltages as shown in Figure IV-1. Various cases of abnormalities were tried to check this system for fault detection. We disconnected the yellow phase first to create a low voltage fault. As a result, voltage level dropped below preset 180 V limit value by the Arduino program. The voltage drop was immediately indicated on the LCD display, and the pilot light for the yellow phase went off. The indicator LED for the relay corresponding to the faulty phase would go off. This indicates that the relay will trip. Thus, the faulty section is isolated. At the same time, the buzzer was activated to warn the operators of the occurrence of a fault as shown in Figure IV-2 and Figure IV-3

Figure IV-1 Diagram of the project in working mode


Figure IV-2 Diagram showing the switched off LED of the yellow Phase and the Voltage values in the system

Also, the load at the grid was replaced with high-load which draws larger current compared to the rated current of the prototype, because of the current sensor the microcontroller caused the phase which the load is connected to trip until the load is changed to the maximum capacity of the prototype. After the reconnection of the yellow phase, there was an automatic reset of the system so that normal operation was resumed, the buzzer got switched off, and the pilot light was re-energized. The process described above was re-done for the blue phase as another fault scenario as shown in Figure IV-4. In each case, the system realized and identified the faulted phase and tripped the particular relay along with visual and audible indications. The tests show that the prototype system can detect and isolate phase faults as it would do on an actual 132 kV transmission line under safe low voltage conditions.

Figure IV-3 The tripped off yellow phase bulb

Figure IV-4 Diagram showing the switched of pilot light and relay indicator LED of the blue phase

4.2 GSM Feedback Functionality of this System

In the design and construction of this system, the incorporation of the GSM module (SIM900A) played a crucial role in providing remote feedback. The GSM module connects the Arduino controller with the remote operator to communicate with them remotely. If any fault occurs, the control signal is sent from an Arduino to GSM module which sends SMS to a pre-registered mobile number. Usually, the message contains fault type, phase affected, time at which the fault occurred. With this, the Transmission Company of Nigerian (TCN) Onitsha sub-region can notify maintenance personnel and cause a correction, even when staff members are not at the monitoring spot. The GSM Module was checked by injecting a fault on the each phase and studying its response. Every time, the module sent an error message within seconds, which verifies communication is OK. The SMS was brief, but it reflected the fault condition detected. This indicates that GSM feedback could be reliable for alarming the Agu–Awka 132 kV transmission corridor.

## V. CONCLUSION

The 132 KV Agu-Awka transmission lines is a major component in the distribution of power in the Awka and its environs, and fault detection on it is very necessary. The project created a prototype device that will use GSM feedback to help detect faults on Agu-Awka 132 KV transmission line using Arduino. The system was excellent in detecting phase faults. It showed on LCD which phase is affected. It produced an alarm and sent SMS through the GSM module. The results from the tests confirmed that a fault can be quickly identified and automatically isolated. This proved that the design can improve monitoring and communication of a fault in a transmission network. Since the prototype is inexpensive and scalable, it can be adapted at a real substation. Future work will focus on improving the system with IoT integration and high-voltage compatible sensors for field deployment.

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