Design and Implementation of an Automated Real-Time Power Distribution Line Monitoring System: A Case Study of Nigerian Power System

Ikenna Calistus Dialoke[1], Nnabueze Edmund Ajimah[2], Franklin Chibueze Njoku[3], Daniel Salka Tanko[4]

[1]Lecturer, [2]Lecturer, [3]Lecturer, [4]Lecturer
[1]Information and Communication Engineering
[1]Air Force Institute of Technology, Kaduna, Nigeria

***Abstract*—In Nigerian power distribution line system, the indiscriminate occurrence of faults along the different distribution lines has become a serious concern that requires urgent attention. Every occurrence of fault usually results to either a total downtime/blackout or voltage and current drop which affect economic and social activities of the country. An efficient fault detection system was developed with the assistance of available high level technology. The construction of the fault detection monitoring system was done using a number of components such as Arduino microcontroller, resistors, connectors, current sensors, voltage sensors, opto-coupler, voltage regulators, capacitors, 12V step-down, bridge rectifier, plastic PVC pipes, switch and fuse. The voltage and current values of the distribution line were classified and categorized using range of values in the program written into the microcontroller so as to display detected fault with the precise location. The fault detection monitoring system provides accurate information which are being constantly transmitted through WiFi interface and displayed in real-time with refresh rate of 3 seconds at the desired control center of the managing company.**

***Index Terms*— power distribution, Fault detection, voltage and current readings, and automated approach**

I. INTRODUCTION

In most regions of the world, electricity has been identified as one of the fundamental needs for human beings as a number of their economic and social activities depend on it. Availability of electricity to homes, offices, industries, social centers or business premises is a resultant of a number of activities ranging from power generation, transmission and distribution to installation and repair/replacement of application equipment and tools such as power plants, poles, feeders, insulators, cables and transformers. After electrical power generation with the use of huge power plants, electricity is then being transmitted through interlinked high voltage transmission lines or electrical grid systems to various desired destination. With cases of ineffective transmission, every problem on electrical power transmission lines causes negative effects on the power transmission/distribution networks. With these challenges, the need for a better power transmission lines network is evolving but will focus on network monitoring system concept [1].

The present power grid in Nigerian is not being maximized due to the poor state of the network as well as insufficient devices used for voltage control within the entire power grid networks. The 330KV transmission lines networks are not only affected by thermal limit but by stability limits (that has to do with longest distance of transmission lines), and voltage drop levels, which result to load reduction critically below their estimated thermal limits. Hence, the urgent requirement for meaningful capital investment into innovations that will help in addressing the power grid challenges [2]. The evolution of information and communication technologies, the inclusion of intelligent systems has been made possible in addressing several challenges in electrical power transmission and distribution system networks. The reliability of the power system operations are mainly affected by electrical power lines issues such as voltage drops, thermal stresses, distribution line cut-off, and other environmental conditions. Effective monitoring of transmission and distribution lines are very important in maintaining reliable services in power system operations [3].

In Nigerian, the power transmission and distribution lines are faced with critical troubleshooting and faults' location reporting challenges have resulted in a number of prolonged power downtime that affect human daily activities, and overbearing fault detection cost on the power companies. The combination of problem finding and location reporting is important in power transmission and distribution networks but lacking in most of the power lines management companies especially in developing countries. Hence, this paper provides technological means that will address the power line faults monitoring and location reporting problems within electrical power network with the use of microcontroller based system.

II. LITERATURE REVIEW

Electrical power transmission or distribution voltage level differs with respect to country or regions depending on the adopted techniques or energy generation methods. In Nigeria, voltages of 132kV and 330kV are transmitted, while the voltages of 33kV, 11kV and 0.415kV, are being distributed [4]. Faulty points' identification has been long desired by electrical engineers to address some troubleshooting challenges and risks involved in power system. Timely fault identification provides early notification for prompt maintenance or disconnection of relevant lines so as to ensure equipment protection. Current and voltage readings at different power lines are usually utilized in various techniques of fault detection [5]. The undesirable occurrences of faults along

power transmission or distribution system have contributed in making electrical power networks unreliable. Hence, faulty points detection in power systems are of utmost important for efficient power system network [6].
A novel smart power line system implementation design shall be expected no distant time which will provide remote monitoring and controls for ensuring more dependable power lines management systems. The smart power line system will ensure transmission or distribution data collection as well as data transmission to a control center [1]. The design quality of different electrical power transmission or distribution systems is a determinant factor for providing desired level of efficiency in various power distribution systems [7]. The electric power transmission or distribution processes are usually disrupted by different kinds of faults at different locations resulting from unwanted incidents along the power lines. To address these problems, a GSM based fault detection system can be employed to precisely locate the faulty points along the power lines. This will help to provide minimum response time for the maintenance team to ensure effective power distribution system [8].

III. METHODOLOGY

This smart power transmission lines monitoring system was achieved through the different steps presented in Figure 1 shown below.

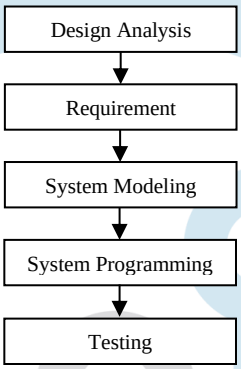

Fig 1: System design procedures

Design Analysis

This project was fully automated to give immediate detection and response to current or voltage changes along the power transmission lines. The automated system shall be attached to different electric poles; maybe at interval of ten poles or as desired by either the person or company implementing the project. It was designed and modeled to perform effective operations considering the effect of several environmental conditions. This automated system contained different components such as current sensor, voltage sensor, resistors, voltage regulator and rectifier which were integrated onto an ESP8266 microcontroller with Wi-Fi interface. This system was programmed using a power reading algorithm to constantly get the readings of those sensors which are constantly being sent wirelessly to be displayed at the control center.

System Modeling

The schematic model of the smart electric power monitoring and reporting system is as presented in Figure 2. Proteus 8 professional as a good IDE for developing circuit diagrams was used to achieve the hardware circuit diagram. The main circuit diagram is as presented in Figures 3. The smart voltage and current monitoring system was modeled to ensure proper interconnection of various needed components in order to achieve the desired goal of the project.

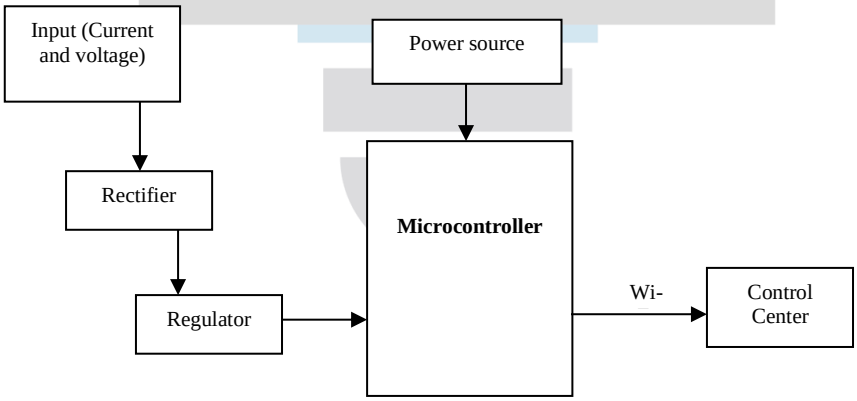

Fig 2: Schematic model of the power line monitoring system

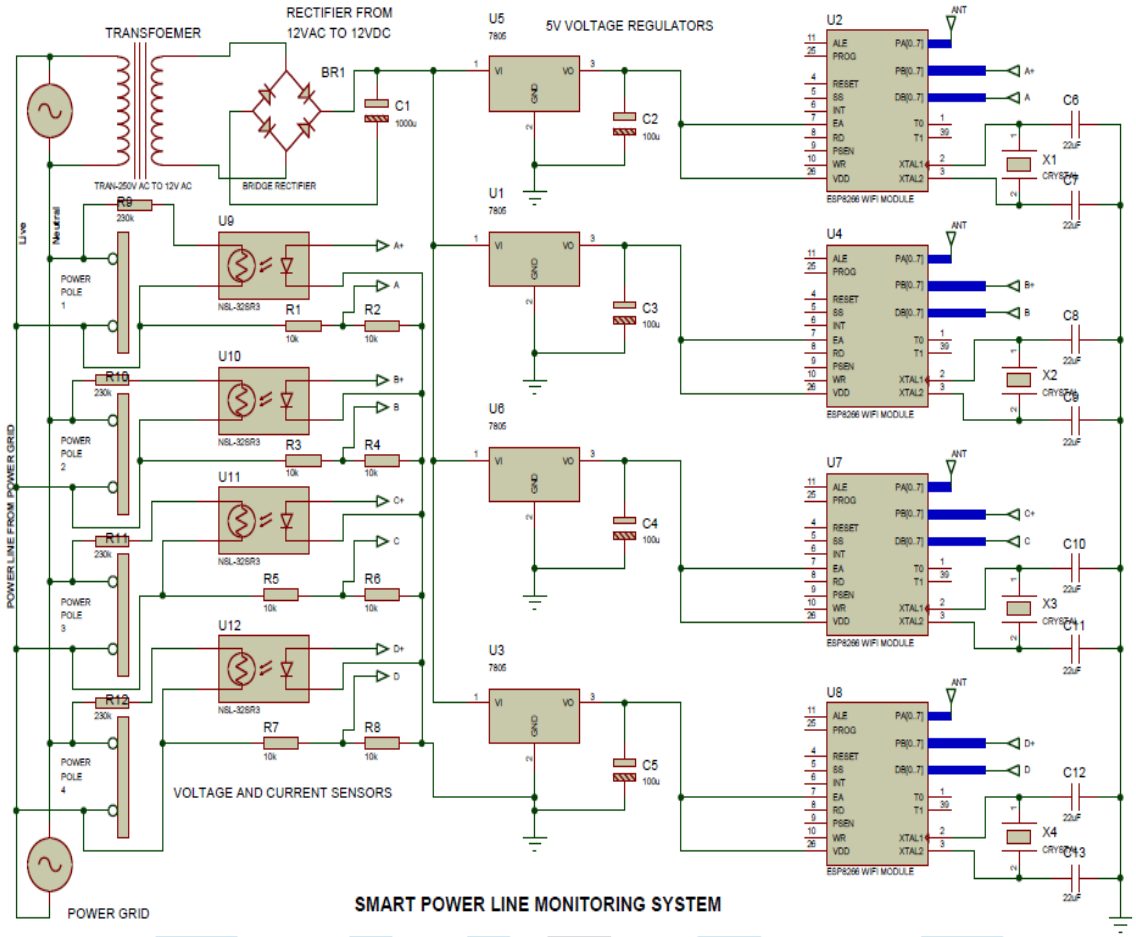

Fig 3: Main circuit diagram of the Smart power line monitoring system

Programming of the Smart Monitoring System

The smart power line monitoring system was programmed to ensure adequate interconnections and communications of various units of the system considering voltage range of 200 to 240 volts as acceptable. The entire programs were written and stored in the microcontroller which has the capacity to accept data, process data and send out information. The IDE used was the Arduino development environment which is flexible to install. The functional activities of the power line monitoring system are as presented in Figure 4.

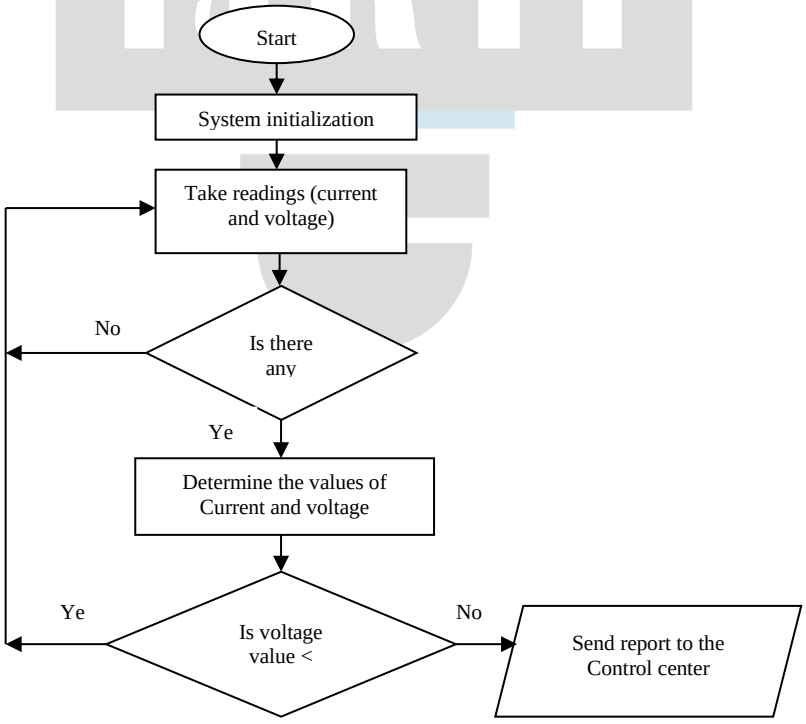

Fig 4: Flowchart description of the smart monitoring system

IV. RESULTS

In this section, the various construction and implementation results are being presented in parts as shown Figures 5 and 6. Figure 5 presents the pictorial image of the system.

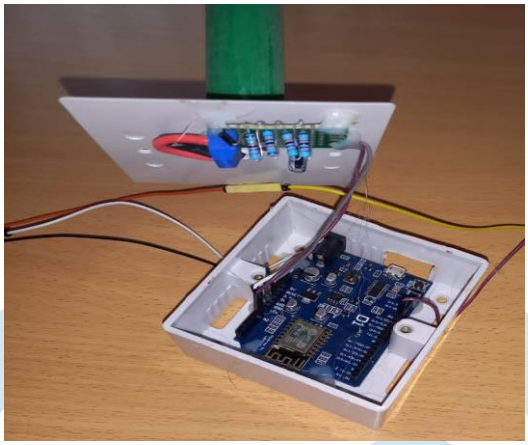

Fig 5: Components testing using multimeter

Figure 6 presents the pictorial image of the complete system implementation from which various readings were collected to determine the functionality of the prototype power line distribution faults monitoring system. The power distribution lines were powered through a power socket. The faults monitoring system was activated and used to carry out the predefined activities.

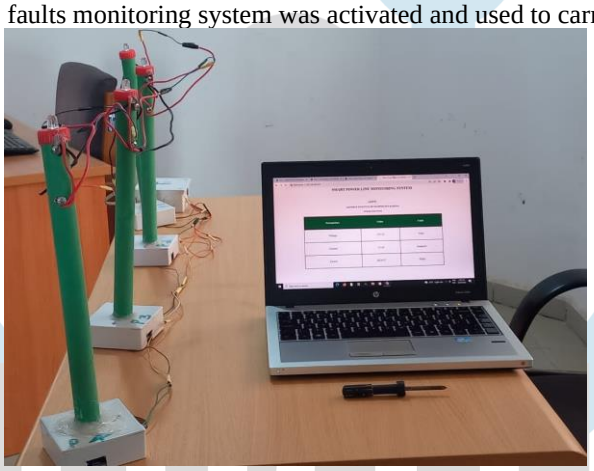

Fig 6: Control centre of the power line monitoring system

After the program has been tested to ensure proper integration and interconnectivity, the power line monitoring was adequately set up to take desired readings; voltage, current and power. These various readings were being transmitted and displayed on the computer or smart phone.

Two different results were collected to determine whether the power line monitoring system could provide accurate readings at different conditions. The readings presented in Figure 7 was obtained at normal operational condition of the power line distribution system, while Figure 8 presents the readings collected when the amount of voltage and current flowing through the power lines were switched off or adjusted. These readings were obtained using two constructed monitoring systems with different IP addresses as can be seen in the various figures.

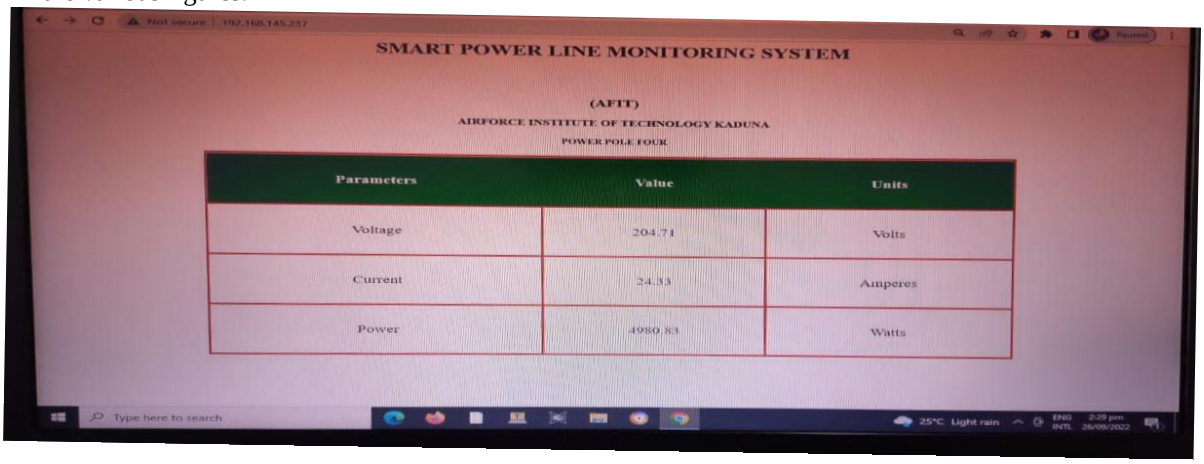

Fig 7: Set of readings collected at normal condition

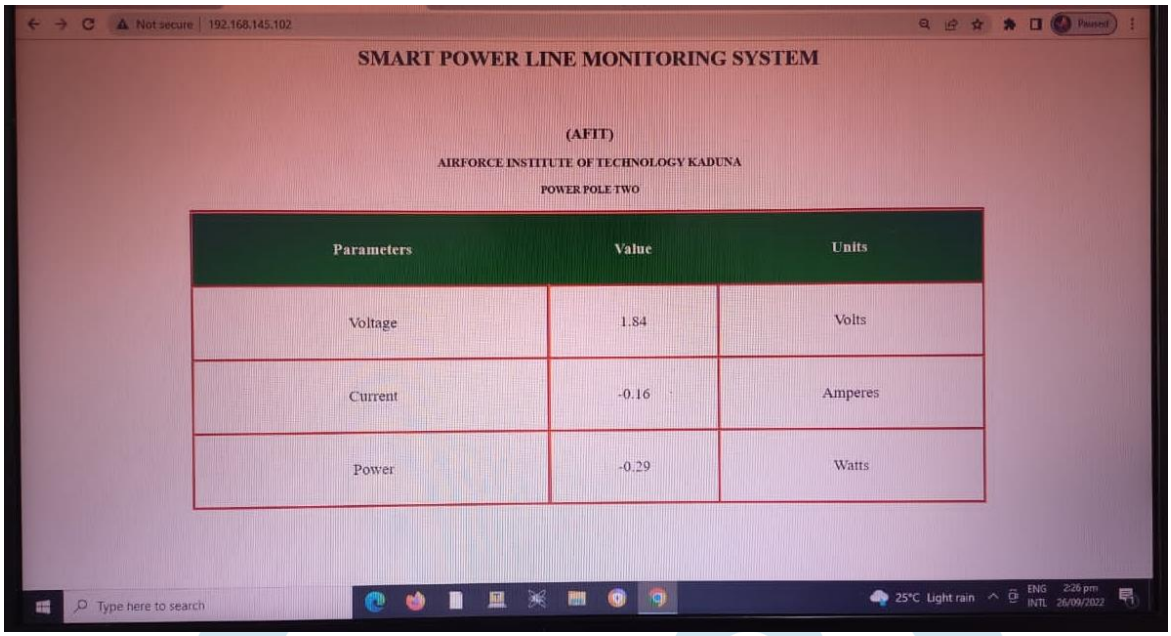

Fig 8: Set of readings collected at abnormal condition

Considering the various set readings obtained, it was clearly observed that the readings were different at every instant of time, which shows that the amount of voltage or current present on any power distribution line is not constant. Having fixed a voltage range of '200 to 240' volts as normal voltage, the power line monitoring system reported no faults.

Result Analysis

Whenever power is connected to the device, all the components will be automatically initialized. This initialization process is done in the setup function of the program. Workflow of the project is done in the loop function of the program. First of all, microcontroller will be waiting for the input from the fault detection monitoring system that constantly measures both current and voltage of the power distribution lines. Faults are considered to be generated when there is either voltage or current drop with reference to the range of values provided in the program. Whenever the fault is generated, the fault data will be sent as inputs to the monitoring system. The voltage and current values of the line unit were classified and categorized using range of values by the microcontroller to display detected fault with the precise pole location. The fault detection monitoring system has function of providing accurate information which are being constantly transmitted through WiFi interface and displayed at the desired control center of the managing company. Monitoring was made to be at real-time with refresh rate of 3 seconds. Table 1 shows performance measures based on the common measuring techniques with the existing manual or traditional method. Every measuring parameter is significant in the computation. This smart power monitoring system has higher accuracy in detecting faults and pole locations in a networked power distribution lines.

Table 1: Performance comparison results obtained

S/No.	Measuring Metrics	Manual method	Smart System Method
1	Fault Detection	Imprecise	Precise
2	Location Identification	Imprecise	Precise
3	Computation Time	High	Low
4	Accuracy	Low	High
5	Risk Level	Very High	Low
6	Fault detection Cost	High	Low

V. CONCLUSION

Nigerian electricity distribution lines have been passing through difficult challenges since the beginning of electricity distribution in the country. These challenges facing the power sector in the country were as results of poor infrastructures and methods of monitoring power distribution. This research examined the major developments that have taken place in power system as well as the challenges that have characterized poor electricity distribution across Nigeria. Thereafter, several kinds of fault finding and reporting methods were reviewed and considered so as to provide efficient and reliable means of handling electricity distribution problems. The causes of overhead power transmission and techniques for identifying them were discussed using existing methods. In this research work, an efficient fault detection technique was developed with the assistance of available high level technology. The knowledge-based method of identification of faulty poles and distance calculation through microcontrollers were discussed. The accuracy and reliability of the fault detection monitoring system proved to be very high when compared to traditional methods. The construction of fault detection monitoring system was done using a number of components such as Arduino microcontroller, resistors, connectors, current sensors, voltage sensors, opto-coupler, voltage regulators, capacitors, 12V step-down, bridge rectifier, plastic PVC pipes, switch and fuse. Hence, this research has designed a Microcontroller based power distribution line fault detection system that detects and sends information and classification of fault to the electricity management company via wireless technology.

Also, it sends real time values of current and voltage to the control center of the electricity management company. This research was implemented using four constructed fault detection monitoring systems with different assigned IP addresses. The different IP addresses were used to enable faults location identification.

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