NATIONAL INNOVATION AND RESEARCH ACADEMIA
International Journal of Computing, Engineering and Information
ISSN: 2713-4677. Volume 6, Issue 1. Pages 21 - 32. October, 2019
Double Blind Peer Reviewed International Research Journal
editornirajournals@gmail.com

Reliability Analysis of Power Distribution System (A Case Study of Yola Electricity Distribution Company, Yerwa Business Unit, Nigeria)

Muhammad Alkali Abbo
[1]Department of Electrical and Electronic Engineering, Ramat Polytechnic Maiduguri, Nigeria | Email: muhammadalkaliabbo@gmail.com

Baba Musa Abbagoni (PhD)
[2]Department of Electrical and Electronic Engineering, University of Maiduguri, Nigeria | Email: Bamusa08@gmail.com

Kalli, B. Mai
[3]Department of Electrical and Electronic Engineering, Ramat Polytechnic Maiduguri, Nigeria | Email: kallibmai@gmail.com

Tijani B. Ngajia
[4]Department of Electrical and Electronic Engineering, Ramat Polytechnic Maiduguri, Nigeria

Abstract: *A power system is set up basically to meet the demands of the customers. However, interruptions greatly contribute to the unreliability of power and thus prevent power system from achieving this. In most cases, it is the sustained interruptions that affect both the utility company and its customers. Electric power interruption in Yerwa Business Unit distribution is becoming a day to day phenomenon. This study attempts to identify causes for power interruptions and customer dissatisfaction and discusses the reliability, operation and maintenance of Yerwa Business Unit distribution system. Distribution reliability indices such as SAIFI have been analyzed. The analyzed and calculated distribution reliability indices have been observed that the customers connected to Jiddari Polo feeder had the highest probability of experiencing power outage. And the month of March 2018 had the highest number of power failure. This clearly indicates that Jiddari Polo Feeder is unreliable. The study discusses the measures to be taken in terms of operational and maintenance tasks to improve the reliability problem of Yerwa Business Unit distribution system.*

Keywords: *Distribution, Interruptions, Maintenance, Operation, and Reliability*

1.0 Introduction

Reliable power systems serve consumer loads without interruptions in supply voltage. Generation facilities must generate adequate power to meet consumer demand. Transmission lines must transfer bulk power over long distances and Distribution systems must distribute electricity to each customer. Reliability assessment of a complete system is a significant ability in overall electric power system operation and planning (Ahmad et al, 2017). The purpose of an electrical power generation system is to distribute energy to a multiplicity of points for diverse applications. The system should be designed and managed to deliver this energy to the utilization points with high reliability and adequate economy. Reliability can be defined as the probability that a device or a system will perform a given task under specified environmental condition for a specific period of time, while availability is that, a system will be able to perform its required function over a specific period of time (Kolowrocki, 1994).

Electricity involves generation, transmission and distribution systems. A sufficient and efficient electric power supply system serves customer loads without interruption. Distribution systems deliver power from bulk power systems to customers. Distribution reliability primarily relates to equipment outages and consumer interruption. The system should be designed and managed to deliver this energy to the utilization points with high reliability and adequate economy (Kiros Tesfay, 2014). Reliability is the probability that a device or a system will perform a given task under specified environmental condition for a specific period of time, while availability is that, a system will be able to perform its required function over a specific period of time. Reliability, availability together with maintainability analysis will determine the ability of equipment to accomplish an intended task. Reliability of an electric power system is the probability that the power system will perform the function of delivering electric energy to customers on a continuous basis and with acceptable service quality.

Power distribution network system established mainly to provide adequate electricity supply to customers as economically as possible with reasonable assurance of reliability. The power distribution networks have grown exponentially in term of size and technology over the past few years. As a result, utility company must strive to ensure that the customer's reliability requirements are met with optimum strategic planning and lowest possible cost. Being one of the most important parts of the power system, substations play a key role in the transmission and distribution of electricity. Substations are fenced yards with switches, transformers and other electrical equipment. Once the voltage has been lowered at the distribution substation, the electricity flows to industrial, Commercial and residential center through the distribution system. Conductors called feeders reach out from the distribution substation to carry electricity to customers. At key locations along the distribution system, voltage is lowered by distribution transformers to the voltage needed by customers or end-users. Electric distribution system power quality is a growing concern. Customers require higher quality service due to more sensitive electrical and electronic equipment. The effectiveness of a power distribution system is measured in terms of efficiency, service continuity or reliability, service quality in terms of voltage profile and stability and power distribution system performance.

2.0 Literature Review

2.1 Reliability Evaluation

Billinton and Allan. (1990) described that the Markov process is one of the common techniques employed in reliability analysis. The application of Markov Chains in the power system reliability field was illustrated. However, the Markov approach is limited in application because of computer storage requirements and the rounding errors which occur in the solution of large systems. This report presents a reliability analysis method that combines set theory and Graph Trace Analysis (GTA), which provides a rapid reliability evaluation. However, according to Allan, Billinton, and Breipohl (1994), unlike the Markov process, this method utilizes iterators to manage computer memory, which enables it to handle computations for large systems. An accurate reliability evaluation of radial distribution systems must take restoration into account. Most conventional techniques developed for reliability analyses are generally based on minimal cut set approach (MCSA) or failure mode and effect analysis (FMEA). Billinton, and Allan (1994). For a distribution system, which consists of a wide range of components and a great number of load points connected in complex configuration and operating in different modes, it is quite a tedious procedure to determine minimal cut sets for each load point and each contingency. Besides, modeling the overlapping outage times associated with the minimal cut-sets leading to a load point failure is a drawback of this technique. The list of basic failure events using FMEA can also be very lengthy (Billinton and Li,, 1994)

2.2 Reliability Improvement

New techniques have been developed to improve distribution system reliability, such as automatic learning techniques, automatic switches, Microprocessor Relays, and so on. However, the financial aspect of these new techniques is seldom considered. This work investigates new approaches to improving system reliability, which are financially justified, including optimal DG location and DAOP load shifting. (Ahmad et al, 2017). As weather conditions have an important effect on network failure rates, it is necessary to take into account the influence of the weather in the performance of the components located in open-air environments. Previous research has been performed on storm related power outages. Early in the 1980's proposed using a database of customer no-light calls to generate outage patterns. However, the outage patterns were not successful for use in identifying faulted sections (Brown and Hanson, 2001). Uses a two-stage Monte Carlo simulation to evaluate the impact of high wind storms. This work quantifies storm interruptions in a power distribution system. In order to improve outage restoration, suggests a rule-based prediction for determining outage locations from the available call patterns and telemetered data. None of the 'prediction' models provides an outage forecast ahead of time. Takata, (2002) proposed a predictor, which applies a data grouping method and neural networks to estimate the amount of damage due to typhoons. Similar to the work here uses a two-stage process. Instead of typhoons, typical storms in the northeastern section of the United States are analyzed and an observer is used instead of neural networks in the second stage.

3.0 Methodology

The adopted a method of analysis and evaluation of reliability of the distribution system and to suggest how to be improved in the distribution system operations by incorporating reliability analysis for optimization. The reliability indices of the present system will be evaluated and assessed to sees how risk of failure could be mitigated.

3.1 System Average Interruption Frequency Index (SAIFI)

SAIFI indicates how often an average customer is subjected to sustained interruption over a predefine time interval. This index is average number of interruptions per customer served per year. It is determined by dividing the accumulated number of customer interruptions in a year by the number of customers served. A customer interruption is considered to be one interruption to one customer.

$$\text{SAIFI} = \frac{\text{Total Number of Customer Interruption}}{\text{Total Number of Customers Served}} = \frac{\sum \lambda_i N_i}{\sum N_T}$$

Where:

N_i = Total number of customers interrupted,

N_T = Total number of customers served

λ_i = No of interruptions

These indices provide a relative measure for a group of load points or for the entire system, also by considering the customer's population parameter in addition to load, duration and frequency of outage of the system component.

3.2 Existing Structure of Yola Electricity Distribution Company (YEDC) Yerwa, Maiduguri, Nigeria Business Unit

The area chosen for this study is Yerwa Business Unit of Yola Electricity Distribution Company. The power distribution system in this area includes five injection substations these are; Baga road, NTA, Gombole, Madinatu, and University of Maiduguri Injection substation. The total capacity of the injection substations and the peak load (demand) that exists in YEDC Yerwa Business Unit are 67.5MVA and 26.9MW and the average power factor of the distribution unit is 0.9. The type of primary distribution network, voltage level and network topology that also exist are overhead network, 11/0.415KV and radial system topology and the standard low voltage level that exist is 415/240V. The distribution injection substations with their voltage levels are shown in Table 3.1

Table 3.1 Yerwa Yedc Business Unit Distribution injection Substation and their Voltage Levels

S/No.	Injection Substation Name	Feeders	Voltage Level (KV)	Capacity (MVA)
1	Baga Road	Industrial	33/11	15
		Mafoni		
		GRA		
		Commercial		
2	NTA	Jiddari polo	33/11	7.5
		Damboa Road		
3	Gombole	Gombole	33/11	15
4	Madinatu	Khaddamari	33/11	7.5
		Old Maiduguri		
5	University	Water Treatment	33/11	15/7.5
		Lagos Street		
		TH		

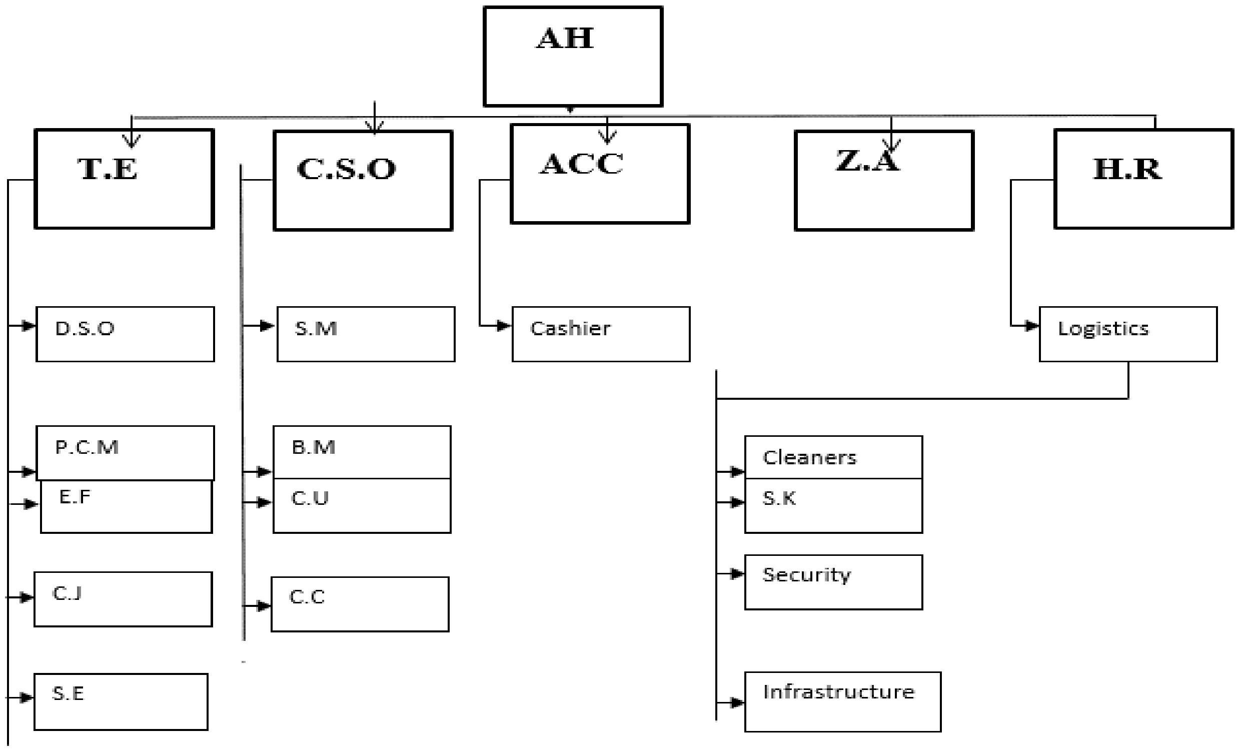

Fig.3.1 Existing Structure of YEDC Yerwa Business Unit
YEDC Yerwa Business Unit Data Collection Center (2013)

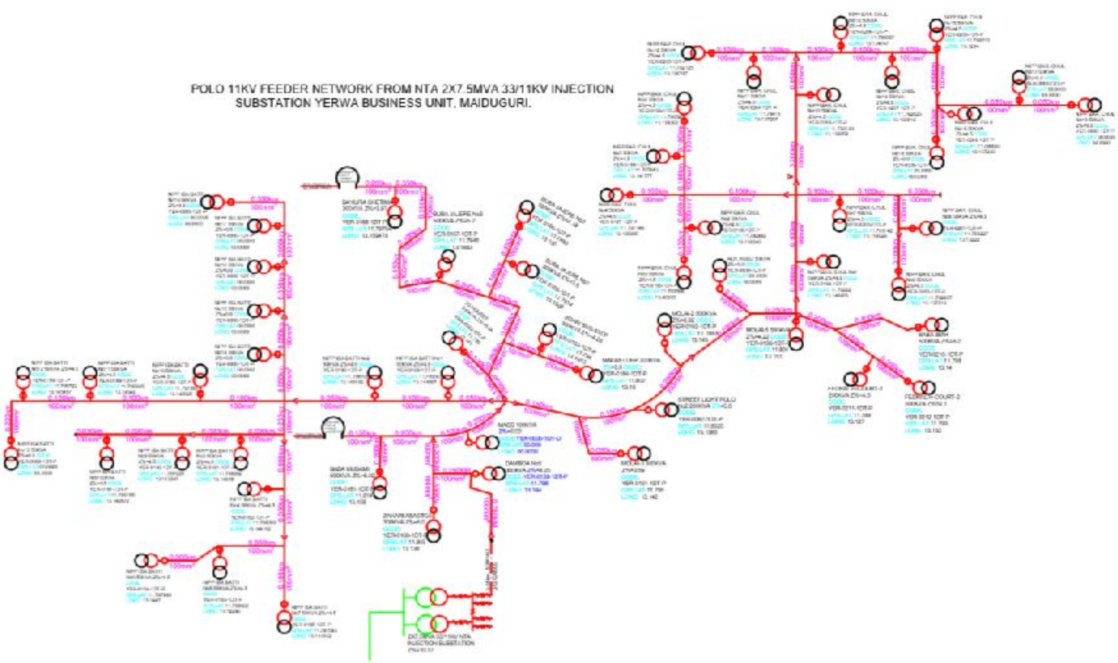

Fig.3.2 Single line diagram of jiddari polo feeder
YEDC Yerwa Business Unit Data Collection Center (2013

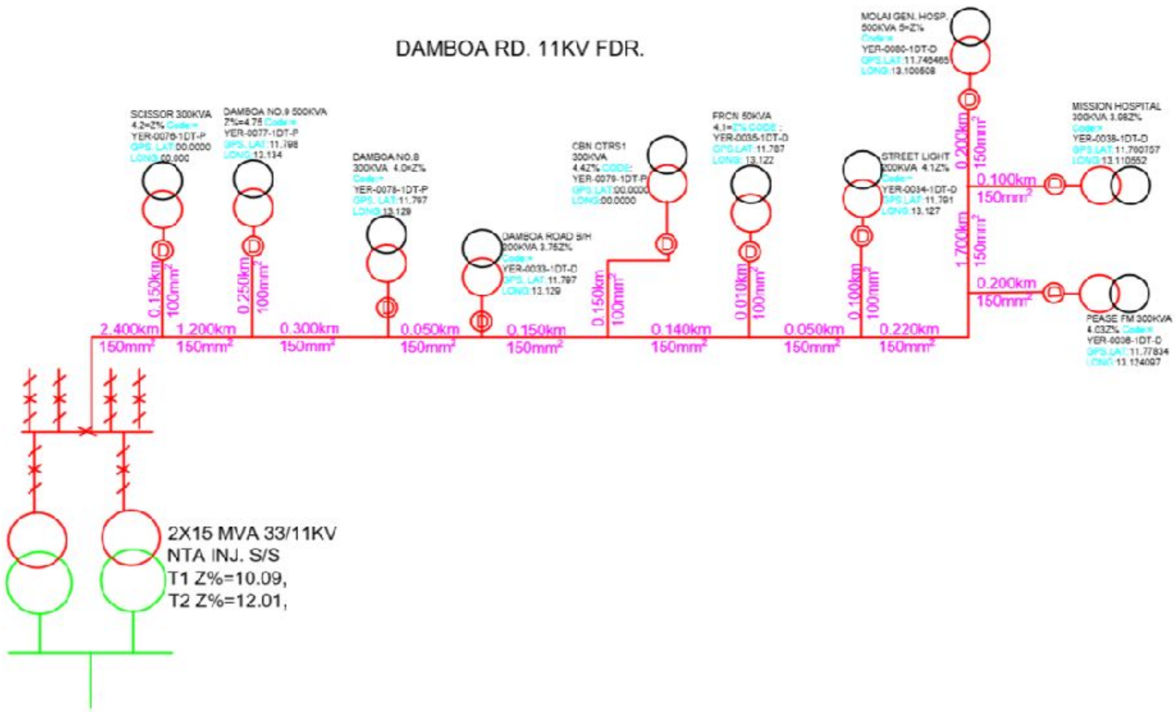

Fig.3.3 Single Line Diagram of Damboa Road Feeder
YEDC Yerwa Business Unit Data Collection Center (2013)

4.0 Result and Discussion

4.1 Introduction

The data collected from the selected injection substation was used to estimate the reliability indices of the substation, the source of data and format of collection of the data used in reliability analyses were analysed and discussed as follows:

4.2 Data Collected from NTA Injection Substation

The data of a period of six months was collected from NTA injection substation .The collected data is a recorded data that includes a duration of service, type of fault, frequency and duration of interruption of the faults occurred on each of the two 11kV outgoing feeders. The selected months are November 2017, December 2017, January 2018, February 2018, March 2018 and April 2018. The data used for the Analysis was obtained from the 11kv feeders operational log book of the NTA injection substation 33/11kV substation. The data are extracted and entered into the excel spread sheet application package format. Using the excel application tools the data are then sorted first by "feeder" then by "outage type" and then by "duration of outage".

4.3 Frequency and Duration of power Interruption

The power interruption is evaluated based on the frequency and duration of electric power interruption. Frequency indicates the rate of occurrence or the number repetition of the power interruptions in distribution feeders. Whereas duration indicates the length of time the power interruptions continues or exist in the power distribution systems.

Table 4.1 Frequency of Interruption for Jiddari Polo Feeder

Month	Frequency of Interruption
November 2017	202
December 2017	152
January 2018	181
February 2018	231
March 2018	238
April 2018	228

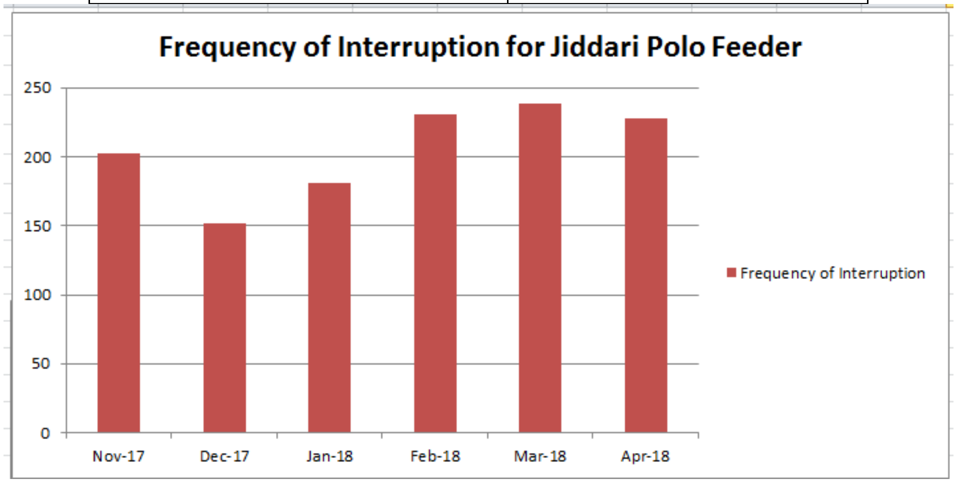

Figure 4.1 Frequency of Interruption for Jiddari Polo Feeder

An average of 205.33 frequency of interruption per month occurs in the Jiddari polo feeder.

Table 4.2 Frequency of Interruption for Damboa Road Feeder

Month	Frequency of Interruption
November 2017	213
December 2017	165
January 2018	163
February 2018	306
March 2018	247
April 2018	244

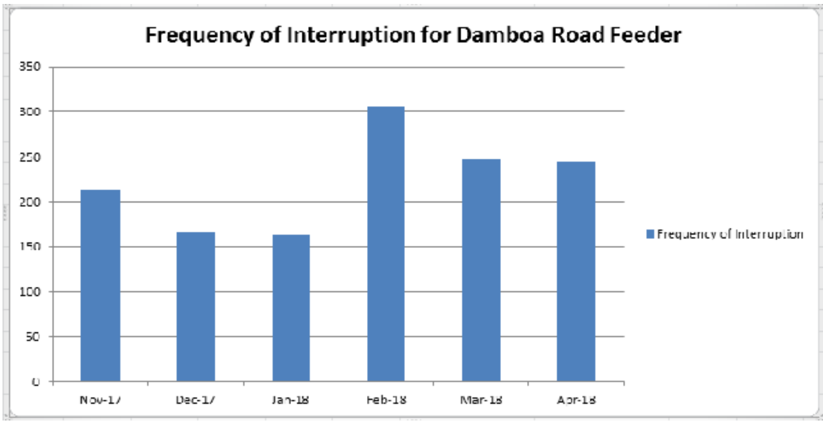

Figure 4.2 Frequency of Interruption for Damboa Road Feeder

An average of 223 frequency of interruption per month occurs in the Damboa Road feeder.

Table 4.3 Duration of Interruption for Jiddari Polo Feeder

Month	Duration of Interruption (Hours)
November 2017	204
December 2017	157
January 2018	194
February 2018	227
March 2018	300
April 2018	412

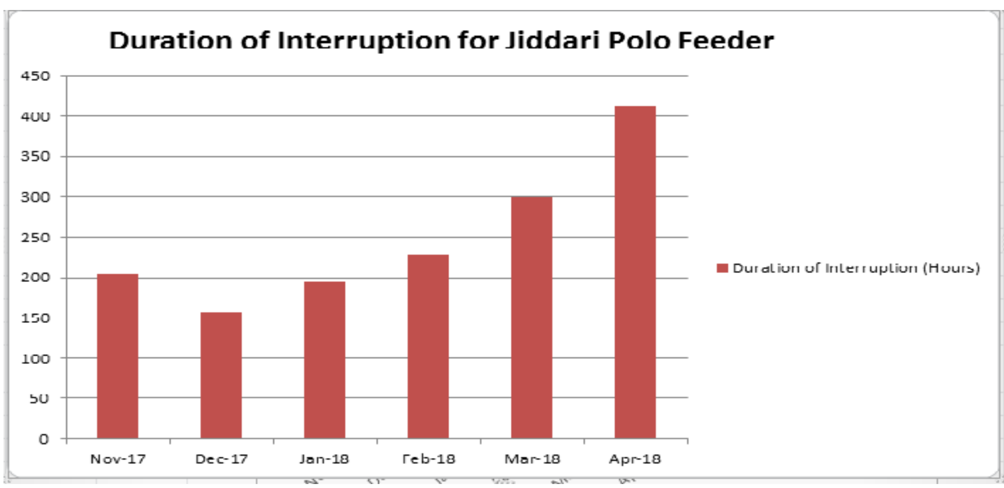

Figure 4.3 Duration of Interruption for Jiddari Polo Feeder

An average of 249 hours duration of interruption per month occurs in the Jiddari polo feeder.

Table 4.4 Duration of Interruption for Damboa Road Feeder

Month	Duration of Interruption (Hours)
November 2017	217
December 2017	138
January 2018	170
February 2018	232
March 2018	280
April 2018	421

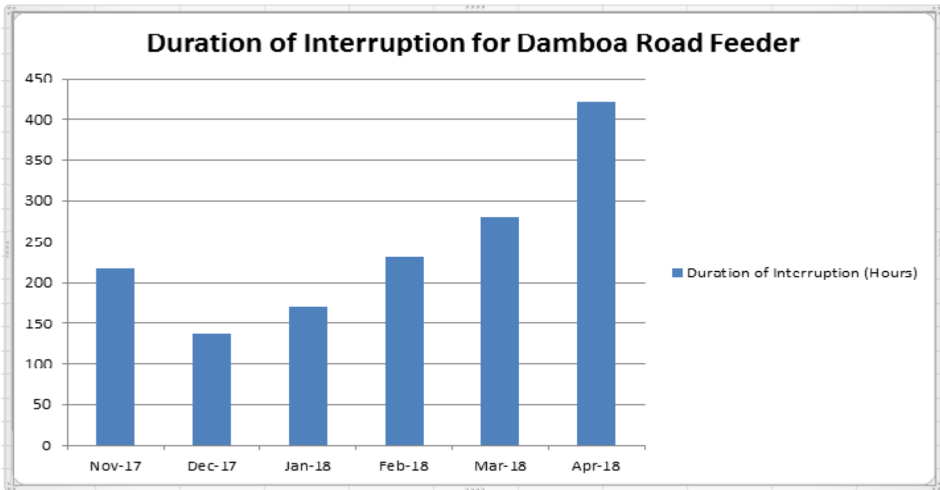

Figure 4.4 Duration of Interruption for Damboa Road feeder

An average of 243 hours duration of interruption per month occurs in the Damboa Road feeder.

4.4 Major Causes of Interruption in the Existing Distribution System

Interruption to service is the isolation of an electrical load from the system supplying that load, resulting from an abnormality in that system. The abnormality in the system can either be a malfunction of a system component, a fault or a system operation due to maintenance or repair. Interruptions, independent from the cause, are generally undesired, as they leave energy unserved and customers without service. Most of the time, interruptions occur because the system is reacting to a fault. A fault or short-circuit is defined as an abnormal connection of relatively low impedance, whether made accidentally or intentionally, between two points of different potential. Over-loading, earth fault and short circuits are the major cause of interruptions in YEDC distribution system. These major faults are classified in to two main categories: temporary and permanent faults. Temporary faults account for the majority of faults in distribution systems. Temporary faults can occur for many reasons, but may include tree or animal contact and weather as the main contributors. Temporary faults can be easily solved, with little or no intervention from the system itself. Many are self-clearing, such as a branch or animal contact which burn and fall off, conductors slapping together in severe wind or insulation flashover due to contamination. Lightning is also a temporary fault. Lightning arrester failure, on the other hand, can become a permanent fault. Other temporary faults are simply cleared once a trip from the substation is issued. Instantaneous reclosing de-energizes the line for a short duration of time, which allows the arc or contact path to disappear, which in turn eliminates the fault path. Once the circuit is re-energized, the system resumes normal operation. Permanent faults, on the other hand, are those that cannot be solved with reclosing action and will not self-clear. Equipment malfunction, cable failure, or persistent tree contact can all produce permanent faults. It is important to point out, that some tree contact can cause permanent faults, such as a tree falling on a line. There are many principal causes of electrical failure; such as dust and dirt accumulation, moisture, lose connections, and friction of moving parts, aging of conductors, clearance from trees and limbs and structures, equipment over loading, frequency and so on. An effective maintenance program should aim to minimize these effects by keeping equipment clean and dry, keeping connections tight.

4.5 Calculation of Distribution System Reliability indices

System average interruption frequency index (SAIFI): Reliability indices are normally calculated on either monthly or yearly basis; however, it can also be calculated daily, or for any other time period. In this paper, reliability indices are calculated by considering monthly basis. SAIFI indicates how often an average customer is subjected to sustained interruption over a period of time interval. This index is average number of interruptions per customer served. It is determined by dividing the accumulated number of customer interruptions in a period of time by the number of customers served. SAIFI is calculated by the following formula and are tabulated in tables 4.5 and are graphed in figure 4.6 respectively.

$$SAIFI = \frac{\text{Total number of customers interrupted}}{\text{Total number of customer served}} = \frac{\sum \lambda_i N_i}{\sum N_T}$$

Where:

N_i= Total number of customers interrupted,

N_T = Total number of customers served

λ_i = No of interruptions

Table 4.5 below shows the total number of customers interrupted per month on each feeder

Month	Total number of customers interrupted	
	Jiddari feeder	Damboa Road feeder
November 2017	850	900
December 2017	650	570
January 2018	800	700
February 2018	940	966
March 2018	1250	1106
April 2018	170	1007

Table 4.5 Total number of customers interrupted per month on each feeder

Table 4.6 SAIFI Value of each feeder for the months of November 2017 to April 2018

Months	Jiddari feeder	Damboa Road

		feeder
November 2017	0.30	0.29
December 2017	0.23	0.18
January 2018	0.28	0.23
February 2018	0.33	0.31
March 2018	0.44	0.36
April 2018	0.06	0.33

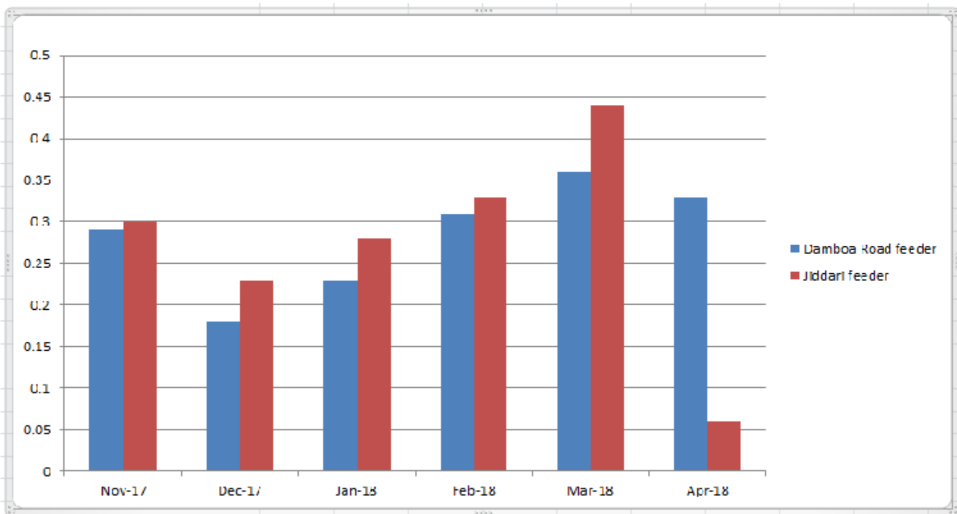

Figure 4.5 SAIFI Value for the Months of November 2017 to April 2018

It has been observed that the customer connected to Jiddari feeder had the highest probability of experiencing a power outage. In addition, the month of March 2018 was the month with the highest power outage.

5. Conclusion

This project has illustrated serious problems of Yerwa Business Unit distribution system and recommended possible ways of solutions for the problems identified. These have been done through detailed gathered and analyzed data obtained from the distribution substations. This project work has discussed reliability of power distribution system, causes of power interruption, possible solutions and maintenance of Yerwa Business Unit distribution system and following conclusions were drawn:

1. Most of the failures in the distribution system are due to short circuits, earth fault, over load, operation and system over load (i.e. when generated power is below the total demand other than blackout.
2. Over-loading, earth fault and short circuits are the major cause of interruptions in YEDC distribution system.
3. Equipment malfunction, cable failure, or persistent tree contact can all produce permanent faults.
4. The analyzed and calculated distribution reliability indices have been observed that the customers connected to Jiddari Polo feeder had the highest probability of experiencing power outage. In addition, the month of March 2018 had the highest number of power failure. This clearly indicates that Jiddari Polo Feeder is unreliable

References

Ahmad, S., Sardar, S., ul Asar, A., & Karam, F. W. (2017). *Reliability Analysis of Distribution System using* ETAP. IJCSIS, 1, 197.

Billinton, R., Li, W., (1994). *Reliability Assessment of Electric Power Systems Using Monte* Carlo Methods. New York: Plenum.

Billinton, R., and Allan, R.N., (1990) .*Reliability Evaluation of Engineering Systems: Concepts and Techniques*. 2nd.New York: Plenum,

Kolowrocki, K.(1994) "Limit reliability functions of some seriesparallel and parallel series systems," *Journal of Applied Mathematics and Computation,* 62: 129-151

Takata, H. (2002) "A prediction method of electric power damage by typhoons in Kagoshima via GMDH and NN", Proceedings of the 41st SICE Annual Conference, 4: 2424- 2429.