

Reliability Analysis of B33 Central Area Power Injection Substation FCT Abuja Distribution Network

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ABSTRACT

The knowledge of the reliability of distribution networks and systems is an important consideration in the system planning and operations for the development and improvements of power distribution systems. To achieve the target of minimum interruptions possible to customers, utilities must strive to improve reliability but at the same time reduce cost. It is a known fact that most of the customer interruptions are caused by the failure in the distribution system. However, valid data are not easy to collect and the reliability performance statistic is not easy to obtain. There is always uncertainty associated with the distribution network reliability. For evaluation and analysis of reliability, it is necessary to have data on the number and range of the examined piece of equipment. It's important to have a database for failure rates, repair time and unavailability for each component in the distribution network. These studies present the analysis of distribution networks and systems by using analytical methods in B33 Central Area Injection Substation of FCT's distribution substations and network systems. These studies will use analytical methods to determine the reliability indices and the effect of distribution substation configuration and network on the reliability indices performance. Then the result obtained will be compared with the actual data from the B33 Central Area Injection Substation to determine the area of improvement required for mutual benefit and also for improvement in future studies.

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INTRODUCTION

The electric power distribution networks are constantly subjected to events that beget interruptions in the supply of energy to the end users. Such events which can be caused by a variety of factors such as bad weather conditions, contact between trees and live wires, equipment failure, unpredictable accidents and many more (Usida et al, 2012). These interruptions decrease the quality indices of the distribution infrastructures, causing poor reliability performances. It has therefore become imperative to develop techniques to improve the process of fault location in distribution networks. This seminar therefore presents a methodology for fault location in electric power distribution systems through the installation of fault indicators. The implementations of such fault indicators devices

in the circuits of the distribution networks have enabled utilities to improve the reliability and quality of power supply (DeSouza et al, 2009). Falaghi et al (2005) stated the benefits achieved by the installation of fault indicators, which translates into increased reliability and quality indices.

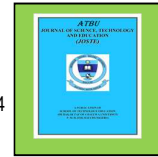
Electrical power systems provide electricity to humongous population around the world. There are three main processes in order to deliver electricity to end users. They are: generation, transmission, and distribution entities. They work as a chain process, where each entity is required to pursue a reliable, secure, and stable service. Therefore, there is an increased interest for developing tools that allow the security evaluation of power systems, and also to ensure high levels of quality, reliability, and availability. These levels are significantly affected by some factors such as:

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environmental/human factors and failures of protections in power systems. However these can be modeled as probabilistic events, which can be calculated taking into account the operating sequences, considering the following operating states: normal, alert, emergency, extreme emergency and restorative (Nasar & Trutt, 2018).

According to the NERC 2008 annual report (NERC, 2009), equipment failures are responsible for about 23% of major disturbances whilst protection mal-operations are involved in about 42% of major disturbances whilst 35% of major disturbances are caused by human/ environmental factors. Thus, the protective system plays an important role in power system operation and in causing cascading events. In recent years, huge investments have been committed to technological advancements in protective systems.

Power distribution network system established mainly to provide adequate electricity supply to customers as economically as possible with reasonable assurance of reliability. Nowadays, 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. The ability of the system to provide adequate supply of electricity energy determine by the term reliability. Reliability analysis of distribution network is not a new topic in electric power industries, a lot of studies and research have been carried out due to the increasing cost of blackouts and fault outages.

Electrical power are vital important to our modern society nowadays in line with the challenges to provide the most efficient and cost effective way of supplying electricity from industrial area up until residential consumers. The availability of a reliable power supply at reasonable cost is crucial for the economic growth and development of a country (Okorie, 2016). Power Utilities Company nowadays try to enhance and develop their own strategies based on experience, trending, research and studies to meet customer demands as economically as possible at reasonable service of reliability. An analysis throughout the world shows that around 90% of all customer reliability

problems are due to the problem in distribution system. Thus, improving distribution reliability is the key to improving customer reliability (Manandhar, 2013). The concept of power-reliability is extremely broad and covers all aspects of the ability of the system to satisfy the customer requirements.

It is very important to assess and evaluate the reliability of power system networks in order to obtain the most accurate and effective way in decision making especially in planning, operation, and maintenance. Historical assessment and predictive methods are normally used to evaluate the reliability of a distribution network. Most utilities focus more on historical assessment rather than predictive methods. Predictive methods are categorized into analytical and simulation methods. Reliability assessment method for distribution system fall into two classes: simulation and analytical (Zhang, *et al*, 2008). Simulation is the most flexible method but require extensive time in computational and also uncertainty in precision. Analytical method can be further divided into network modeling and Markov modeling. The difference between simulation and analytical method is the way in which the system reliability indices are evaluated. By applying analytical method, the reliability indices for distribution systems will be determined such as either by local indices or global indices subject to the availability of the data. Several research has being carried out on the related subject matter to mention but few among others, Xiang, *et al.*, (2020) integration of distributed generation (DG) in distribution network changes the topological structure of distribution network. Meanwhile, the location and size of DG as well as the evolution of the topology structure of distribution network will affect the power supply reliability, which will make the planning process of the distribution network extremely complicated. The main task of distribution systems is to provide acceptable reliability, economic and quality service of electrical power according to the demanded load value Tur, (2020). Hussien *et al.*, (2020) distribution reliability is the availability and quality of power supply for the customer service entrance. The reliability problem is measured by the power interruption problems and it is a big concern in our day to day life. Xu, *et al.*, (2019) this study aims to investigate the topology characteristic

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indices which have a close relationship with reliability of distribution networks via mathematical tools. A wide scale deployment of energy storage systems in power networks for energy balancing applications will lead to network reliability improvements Escalera, *et al.*, (2019). Reliability assessment tools are of crucial importance for planning and modernisation of distribution power systems. In recent years there has been an increased deployment of renewable energy, distributed generation, energy storage, electric vehicle, protection device automation and demand response schemes in the distribution networks Escalera, *et al.*, (2018). Canizes, *et al.*, (2015) this paper proposes a new methodology for the evaluation of reliability in radial distribution networks through the identification of new investments in this kind of networks, in order to reduce the repair time and the failure rate, which leads to a reduction of the forced outage rate and, consequently, to an increase of reliability.

Problem Statement

There are many factors that contribute to the failure of distribution network system. Reliability is very important issue in dealing with planning and operation of the networks. In distribution system planning, reliability aspects are an important part of the decision base. Thus, to be able to assess and evaluate, reliability is needed in the planning process. The data obtained from B33 Central Area Injection Substation of FCT's distribution substations and network systems will be used to determine the reliability performances of the system.

The main problem facing is the power demand is rapidly increased whilst supply growth is constrained by limited sources, environmental problem and other social concerns. According to statistic, about 80% of power interruptions result from power distribution system failure (Zhang, *et al.*, 2008). Historical assessment and predictive methods are normally used to evaluate the reliability of a distribution network. Most utilities focus more on historical assessment rather than predictive methods. Hence, it is vital in design and development of distribution network to study and analyze the reliability. Enhance knowledge in reliability analysis of distribution network will contribute to the measurement of how far the system meet the performance criteria, to help

quantify comparison between various options, and to help in term of economic decision (Emjedi, *et al.*, 2010). Besides that, reliability analysis result will determine the failure rate and mean failure duration for particular equipment or group of equipments, thus with more detail in databases, the information gained may be important for utilities operators, such as the most frequent cause of failures, areas of greatest amount of undelivered energy (Gono, *et al.*, 2007) or the most weakness area of protection system which contribute to interruptions and fault.

In this study, the most challenging and difficult aspect will be on the analytical part where details concentration are required to acquire input data from utilities and calculation to obtained useful reliability indices which will be used for comparison with the historical assessment.

PROPOSED APPROACH

This research is adopting methods involving analysis and evaluation of reliability of the distribution network in B33 Injection Substation network to see how reliability could be improved in the distribution system by incorporating reliability analysis in the systematic planning approach so that optimum reliability is achieved. The reliability indices of the present system shall be evaluated, assessed and compared and sees how risk of failure could be mitigated. The reliability indices for the year 2019 are being considered as base year for the case study.

Reliability indices such as SAIFI, SAIDI and CAIDI/MTBF, MTTR, MTTF and Failure Rate can be calculated using equations given in section 2.2.7. These indices provide a relative measure for a group of load points or for the entire system. Analysis will be carried out at distribution network substation B33 33/11kV system. But the selection of distribution substation depends on the availability of data and information required for calculation and analysis. Result from these approaches will be compare with the actual value of reliability indices obtain from year 2019. In this project, we will apply two analytical methods to determine the reliability indices which are Predictive model and Network modelling. The research is conducting in phase's basis as shown in flowchart in Figure 1:

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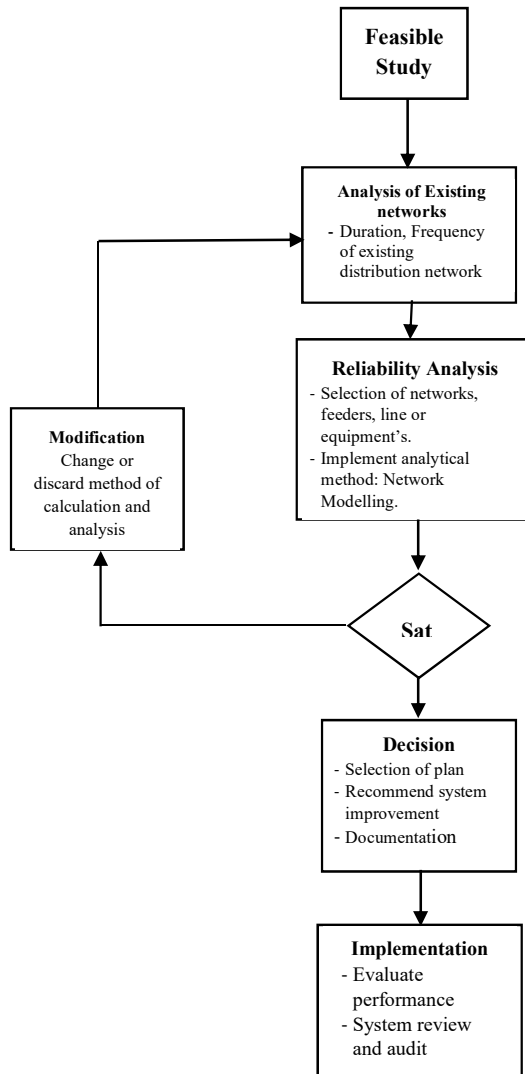


Figure 1: The planning approach for the Reliability Analysis of Distribution Network.

The Objective Function

Therefore, the main objective is to find the optimum number and location of sectionalizing switches in order to minimize the customer interruption cost, investment cost of line switches and maintenance cost. Hence, the objective can be expressed as follows.

$$\text{Minimize Cost} = \text{Customer Interruption Cost} + \sum \text{Switch cost} + \sum \text{Maintenance cost} \quad (1)$$

Subject to constraints,

1. Reliability parameters (Duration, Frequency or SAIDI, SAIFI)

2. Approved Budget
3. Switch locations
4. Geography

Where, **Customer Interruption Cost** are simply revenue lost by the utility companies due to power interruption to the connected customers.

Feasible study on reliability analysis

The feasible study on reliability analysis concentrates on the previous methods used for reliability evaluation and assessment. The existing system network will be benchmark

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and compare with the previous study and research so that the methods that need to be applied are suitable with the current systems. In order to achieve this, detailed study and research is required to be conducted by referring to B33 distribution system operation and design/Daily Logbook.

The technique required to analyze a distribution system depends on the type of system being considered and the depth of analysis needed. Firstly, we need to know the basic evaluation technique, then extend to more complex systems inclusive of more refined modelling aspects. This research will be based on two methods which are Network Modelling, including basic evaluation technique for distribution systems and analytical models. More concentration on the basic evaluation technique

as the existing distribution network system is more compatible with this technique.

Network Modelling

Network modelling is the use of series-parallel combinations to reduce the network. It determines the load point indices and aggregates them to get the system-wide indices. A radial system basically consists of a set of series components like breakers, lines, switches, transformers, and at the end, "Customers". In the series structure, both components must be intact for the system to function, "a chain is no stronger than its part" while in the parallel structure, both must fail for the system to stop functioning. In this case, all the components are connected in series as shown in Figure 2 and the equations needed to evaluate the basic indices are as follows;

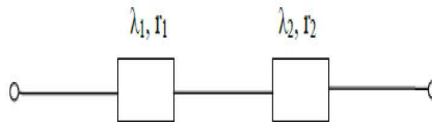


Figure 2: Series Structure

- (a) Average Failure rate of the system:

$$\lambda_s = \lambda_1 + \lambda_2 = \sum_{i=1}^2 \lambda_i \quad (2)$$

- (b) Average outage time of the system:

$$r_s = \frac{\lambda_1 r_1 + \lambda_2 r_2 + \lambda_1 \lambda_2 r_1 r_2}{\lambda_1 + \lambda_2} = \frac{\sum \lambda_i r_i}{\sum \lambda_i} = \frac{U_s}{\lambda_s} \quad (3)$$

if $\lambda_1 \lambda_2 r_1 r_2 \ll \lambda_1 r_1$ or $\lambda_2 r_2$

- (c) Average Annual Outage time of the system:

$$U_s = f_s \cdot r_s = \lambda_s \cdot r_s \quad (4)$$

Where λ_i is the failure rate at node i , r_i is the outage time at node i . In parallel systems, the failure modes of the load point involve overlapping outages, i.e. two or more components must be on outage at the same time in order to interrupt a load point as shown

in Figure 3. It is assumed that the failures are independent and that restoration involves repair or replacement, the equations used to evaluate the indices of the overlapping outage are as shown below.

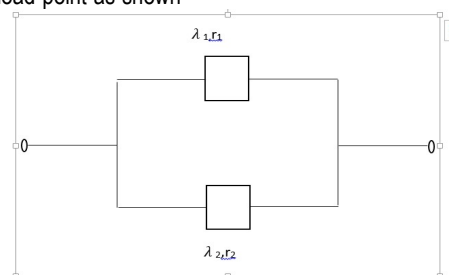


Figure 3: Parallel Structure

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(a) Average Failure rate of the system:

$$\lambda_p = \frac{\lambda_1 \lambda_2 (r_1 + r_2)}{1 + \lambda_1 r_1 + \lambda_2 r_2} = \lambda_2 \lambda_1 \lambda_2 (r_1 + r_2) \quad (5)$$

Where $\lambda_1 r_1$ and $\lambda_2 r_2$ usually $\ll 1$

(b) Average outage time of the system:

$$r_p = \frac{r_1 r_2}{r_1 + r_2} \quad (6)$$

(c) Average Annual Outage time of the System:

$$U_p = \lambda_p r_p \quad (7)$$

These are adequate for simple radial systems and more extended indices have to be used for general distribution systems (mixed radial and meshed systems). In this study, the following alternatives which may improve reliability in the system shall be considered:

- i) Assessment of the existing network
- ii) Change in the network configuration
- iii) Use of additional sectionalizing switches
- iv) Automation and control facilities via control centre monitoring and supervision.

In this project, we will assume that the distribution system are design and construct as single radial and parallel systems:

- i) Single radial system
 - > 11kV feeder supply direct to customer
 - > 33kV feeder for interconnection between substation
- ii) Parallel System
 - > 33kV transformer (incomer) connected to two bus bar system (reserve and main) to supply 11kV feeder connected to customer.

Three basic reliability parameters requires for analysis:

$$\text{Average failure rate: } \lambda_s = \sum_i \lambda_i \quad (8)$$

$$\text{Average annual outage time: } U_s = \sum_i \lambda_i r_i \quad (9)$$

$$\text{Average outage time: } r_s = \frac{U_s}{\lambda_s} = \frac{\sum_i \lambda_i r_i}{\sum_i \lambda_i} \quad (10)$$

Analytical modelling

Analytical models are mathematical models that have a closed form solution, i.e. the solution to the equations used to describe changes in a system can be expressed as a mathematical analytic function. An analytical model estimates or classifies data values by essentially drawing a line through data points. When applied to new data or records, a model can predict outcomes based on historical patterns. Block diagrams are widely used in engineering and science and exist in many different forms. For the purposes of system reliability analysis, they can be used to describe the interrelation between the components and to define the system.

In system reliability analysis, we construct a "system" model from these component models. In other words, we are concerned with the construction of a model (life distribution) that represents the times-to-failure of the entire system based on the life distributions of the subsystems, assemblies and/or components ("black boxes") from which it is composed.

Automation in Distribution Feeder Reconfiguration

In the radial distribution system, the fault current always flows from source to fault location. Therefore, in the properly coordinated automatic distribution system, the fault will be cleared by the nearest protecting devices. After the fault has been isolated, the system will reconfigure in order to restore power to its customers. The reconfiguration is done with the help of automatic and manual switches. The study mainly focuses on a two stage reconfiguration where a limited number of customers are restored quickly using automatic switches and the remaining customers are restored later using manual switching.

System reconfiguration usually takes place in two phases, upstream and downstream restoration. In the upstream restoration after the circuit breaker clears the fault, the fault is located and the nearest upstream switch is opened. This will restore power to all upstream customers.

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In the downstream restoration, after the upstream reclosing switch is opened, the downstream sectionalizing switch close to the fault location is opened. This will allow the

normally open switch to close, restoring service to downstream customers. The overall two stage reconfiguration process is elaborated in the next section with a diagram.

Explanation of a two stage automatic feeder reconfiguration

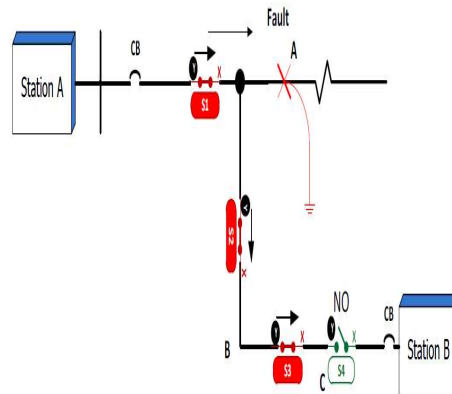


Figure 4: Upstream and Downstream Protection in Power System

In Figure 4, assume normally closed switches S1 and S2 are manual while S3 is automatic. It is normal practice of the power company to make normally open (NO) switches automatic. When the fault occurs at point A, the circuit breaker at the substation will trip and interrupts all customers in feeder A, B and C. However, since switch S3 is automatic, it will open itself in a few seconds and will let normally open (NO) automatic switch S4 close restoring customers in segment C in a few seconds. After the fault has been located, the dispatch crew will open switch S1 and S2 through remote operation using SCADA in order to isolate the fault. This will restore power to upstream customers of switch S1 in feeder A. In downstream restoration, after the dispatcher opens switch S2, then switch S3 will close and power is restored to all customers in feeder B and C. The restoration time of loads A and B is longer than automatic switching and will depend on how long it takes for the dispatcher to locate and isolate the fault. Therefore, with an increase in the number of automatic switches, the reliability of the distribution system will increase significantly. However, it is important to have an idea about what reliability actually means and ways to evaluate it in order to take proper corrective measures.

Failure Mode and Effect Analysis

Failure Mode and Effect Analysis (FMEA) is an analytical inductive technique that accounts for the possible failure mode of the system and their impact on reliability of the distribution system. For each component the failure mode and resulting impact on the system is recorded in the worksheet. This method is often used in the system reliability study. A successful FMEA helps to identify each failure mode, probability of occurrence of each failure mode, and necessary actions required to mitigate such failure modes.

The steps followed in FMEA are listed as follows:

1. Identify all failure modes.
2. Figure out their probability of occurrence λ .
3. Select a contingency and its impact on all loads.
4. Weigh the impact of contingency by multiplying with λ .
5. Follow the previous steps to the rest of all contingencies.
6. Sum the contribution of all individual contingencies.

RESULTS AND DISCUSSION

Expected results of reliability studies of B 33 Distribution System is presented in this

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section and discussed extensively from point of view. The results of reliability assessment of distribution systems supplying electricity of various consumers in B 33 Injection Substation distribution network of Abuja Federal Capital Territory are presented and discussed in this section. The various reliability indices computed for the distribution systems in all the feeders of B 33 substation network of Abuja Federal Capital Territory are based on the methodology described in section two. The major causes of power supply problems in B 33 network of Abuja have been identified and also summarized in this section. Finally, the results are discussed extensively from the stand point of adverse effect on the revenue loss by the distribution

company and more importantly the economic losses and psychological impacts on the consumers.

Major causes of power supply disruptions in B 33 network of Abuja

There are a number of problems associated with transmission, distribution and consumption of electricity in a rural area. A study into the problems of power supply shows that disturbance on the commercial mains power supply can be categorized into the following:

Weather problems, Human problems and planned outages as presented in Figure 5.

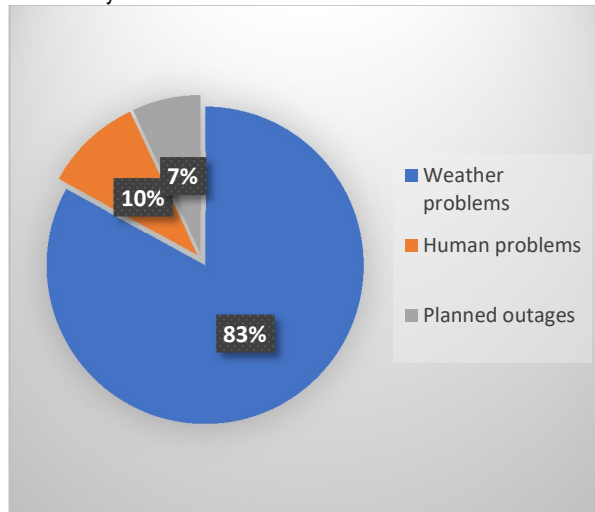


Figure 5: Causes of Power Supply Disruptions in B 33 Network

System Failure and Reliability Analysis

Based on field data collected, the system failure and reliability analysis were carried out. Table 1 presents comprehensive statistics of B 33 Injection substation, Abuja distribution network faults for the study period. Note that thirteen fault types were identified and average outage frequency per year, percentage

contributed by each fault, duration in hour per and duration in hour per fault per year were all computed as shown in table 1. The various reliability indices computed for the distributions systems supplying power to consumers in the nine feeders of B 33 injection substation central area of Abuja Federal Capital territory are summarized in Table 2.

Table 1: Statistics of B 33 Injection substation Central Area of Abuja Distribution faults for the period under study

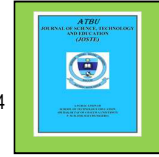
S/No.	Nature of Faults	Average outage frequency/year	Percentage of fault Type contribution	Duration Hours/year	Duration in Hours per Fault/year
1	2- phase O/C	3	4.76	8.37	3.19
2	Phase Inbalance	1	1.59	10.56	10.56
3	Disconnections	4	6.35	23.94	6.39

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S/No.	Nature of Faults	Average outage frequency/year	Percentage of fault Type contribution	Duration Hours/year	Duration in Hours per Fault/year
4	O/C and E/Fault	13	20.63	31.03	2.39
5	Over current	4	6.35	13.08	3.27
6	Load shedding	7	11.11	22.86	3.27
7	3-phase O/C & E/Fault	10	15.87	26.1	2.61
8	Forced outage/Maintenance	2	3.17	14.05	7.03
9	J&P	3	4.76	10.04	3.35
10	Cross-arm	2	3.18	10.64	5.32
11	Tree falling on line	1	1.59	6.33	6.33
12	Oil leakage	1	1.59	9.85	10.25
13	2-phase o/c & E/Fault	12	19.05	43.11	3.59
	TOTAL	63	100	229.94	67.55

Table 2: Reliability Indices of B33 Injection Substation Distribution Network for the specific study period.

S/N	Parameters	FEEDER I	FEEDER II	FEEDER 3B	FEEDER 4B	FEEDER 6A	FEEDER 6B	FEEDER 8A	FEEDER 8B	FEEDER NNPC 2
1	Total number of failure/outage	78	95	184	95	96	209	64	138	29
2	Total outage Duration	73.58	190.30	494.44	157.99	306.20	391.28	222.28	203.94	186.24
3	Average duration of outage hrs/yr (MTTR)	73.58	190.30	494.44	157.99	306.2	391.28	222.28	203.94	186.24
4	Failure rate	8.90×10^{-3}	10.85×10^{-3}	21.01×10^{-3}	10.85×10^{-3}	10.96×10^{-3}	23.86×10^{-3}	7.31×10^{-3}	15.75×10^{-3}	3.31×10^{-3}
5	Mean Time To Failure (MTTF)	112.31	92.21	47.61	92.21	91.25	41.92	136.87	63.48	302.02
6	Mean Time Between Failure (MTBF)	185.89	282.51	542.05	250.20	397.45	433.20	359.15	267.42	488.26
7	Repair rate	13.59×10^{-3}	5.26×10^{-3}	2.02×10^{-3}	6.33×10^{-3}	3.27×10^{-3}	2.56×10^{-3}	4.49×10^{-3}	4.90×10^{-3}	5.37×10^{-3}

DEFINITIONS:

$$\text{Failure rate } (\lambda) = \frac{\text{Average No. of failure}}{8760}$$

$$\text{Mean Time To Failure (MTTF)} = \frac{1}{\lambda}$$

$$\text{Mean Time Between Failure (MTBF)} = \text{MTTF} + \text{MTTR}$$

$$\text{Repair rate } (\mu) = \frac{1}{\text{MTTR}}$$

PRESENTATION OF RESULTS

The computed annual outages and their durations between January and December 2019 according to fault types are given in Table 3. Furthermore, the monthly distribution of outages and their duration over the period under study as well as their averages and summary of outage per feeder in B 33 distribution network, Central Area of Abuja Metropolis are presented in Table 4. For the sake of clarity, Table 2 is the reliability indices which emerged from Table 3,

and utilization of others equations, comprehensive summary of basic reliability indices for the nine feeder of B 33 injection substation of Abuja distribution company (ADC).

Figure 6 shows the monthly outage rate for the period understudy and Figure 7 shows the outages duration feeders. The bar chart showing the contribution of each fault type over the study period is shown in Figures 8 and 9 while Figure 10 show the annual average fault outages and durations. The outage and duration

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are presented in figure 10, it can be deduced that Feeder 6B has the highest outages with the frequency of 209, while Feeder 3B has the highest outage duration of 494.44hrs for the study period which contributed to (approximately 21days accumulative outage for

the said study period. The least feeder was that of Feeder NNPC 2 with the outage frequency of 29, while Feeder I has the lower outage duration of 73.58hrs corresponding to only 3 days blackouts the same study period.

Table 3: Outage and Duration of Fault types for the B 33Injection Substation Distribution network

S/NO.	Nature of Faults	JAN		FEB.		MAR		APRIL		MAY		JUNE		JULY	
		Freq	Duration	Freq	Duration	Freq	Duration	Freq	Duration	Freq	Duration	Freq	Duration	Freq	Duration
1	2-phase O/C	2	5.59	1	6.15	3	7.18	2	5.13	1	5.41	4	9.45	3	
2	Phase Inbalance	1	24.14	0	0	0	0	2	19.52	1	18.41	1	20.2	0	
3	Disconnections	3	29.11	2	28.15	4	30.41	1	0	5	25.45	3	0	2	
4	O/C and E/Fault	11	33.14	13	29.44	10	31.12	8	27.43	9	26.11	20	42.1	11	
5	Over current	1	3.11	1	0	3	10.42	2	7.16	4	13.43	2	7.53	7	
6	Load shedding	8	24.18	7	22.41	9	30.31	4	13.49	5	17.42	7	24.2	10	
7	3-phase O/C & E/Fault	5	24.32	3	21.18	7	14.35	9	18.53	15	30.19	8	17.1	21	
8	Forced outage/Maintenance	3	25.16	2	15.47	1	10.15	2	15.31	3	19.32	2	9.42	2	
9	J&P	3	12.28	4	18.12	2	5.49	1	5.25	2	8.52	3	12.4	1	
10	Cross-arm	2	14.34	1	10.54	0	0	2	8.45	4	21.37	1	9.11	2	
11	Tree falling on line	1	5.45	0	0	0	0	2	6.24	4	11.57	2	7.11	0	
12	Oil leakage	1	10.25	0	0	0	0	2	22.13	0	0	2	9.5	3	
13	2-phase o/c & E/Fault	3	18.45	5	47.34	9	30.52	20	94.14	14	74.31	10	29.6	13	
TOTAL		44	229.52	39	198.8	48	169.95	57	242.8	67	271.5	65	198	75	

AUGUST		SEPT		OCT.		NOV.		DEC.		Average outage & duration per year		
Duration	Freq	Duration	Freq	Duration	Freq	Duration	Freq	Duration	Freq	Duration	Duration	
8.47	6	15.18	4	19.33	2	6.18	2	7.12	1	5.28	2.58	8.37
0	3	19.51	2	19.44	0	0	1	5.56	0	0	0.92	10.56
15.41	4	17.52	5	27.1	3	31.18	5	28.57	6	54.34	3.58	23.94
30.15	25	24.59	22	43.12	15	22.54	7	35.37	9	27.23	13.33	31.03
21.36	10	21.52	9	31.33	4	28.41	1	5.23	4	7.45	4	13.08
32.18	12	35.23	9	29.51	6	19.43	3	10.54	4	15.41	7	22.86
41.54	19	39.58	20	41.22	7	15.43	5	23.34	2	26.41	10.08	26.1
12.51	3	20.18	4	21.11	3	5.39	2	6.45	1	8.15	2.33	14.05
5.41	7	16.33	4	9.59	5	8.38	4	11.23	2	7.46	3.17	10.04
9.58	3	24.32	0	0	1	4.41	3	16.52	2	9.11	1.75	10.64
0	3	24.15	2	14.23	1	7.18	0	0	0	0	1.25	6.33
45	1	10.48	0	0	2	18.38	0	0	1	2.49	1	9.85
71.32	17	59.42	15	24.25	21	50.19	9	12.43	4	5.37	11.67	43.11
292.93	113	328.01	96	280.23	70	217.1	42	162.36	36	168.7	62.67	230

S/N	Months	Feeder I		Feeder II		Feeder 3B		Feeder 4B		Feeder 6A	
		frequency	Duration	frequency	Duration	frequency	Duration	frequency	Duration	Frequency	Duration
1	January	1	0.24	2	11.16	20	82.03	3	5.11	3	16.05
2	February	4	1.36	1	1.54	7	60.19	5	9.08	5	29.11
3	March	2	0.48	4	12.1	10	58.15	8	16.38	2	11.37
4	April	2	0.48	9	54.15	11	31.25	3	10.13	8	34.05
5	May	5	2.37	13	10.13	14	25.18	11	12.41	7	20.12
6	June	10	6.54	11	24.4	20	80.11	9	6.18	10	15.42
7	July	9	7.15	10	30.57	41	94.22	16	24.28	13	25.59
8	August	15	27.1	18	12.5	19	30.46	19	30.33	11	48.18
9	September	13	18.45	16	15.18	10	11.54	3	21.45	8	50.19
10	October	8	7.4	2	4.58	12	15.18	3	7.49	8	30.14
11	November	7	1.47	4	6.51	9	1.58	1	5.5	6	19.46
12	December	2	0.54	5	7.45	11	4.55	2	9.44	4	11.52
13	Total year										

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Table 4: Summary of Power Supply Outages in B 33 Central Area Distribution network for the period under study

Feeder 6B		Feeder 8A		Feeder 8B		Feeder NNPC II		TOTAL	
Frequen- cy	Durati- on	Frequen- cy	Durati- on	Frequen- cy	Durati- on	Frequen- cy	Durati- on	Frequen- cy	Durati- on
11	33.04	2	15.47	2	3.03	1	13.2		
9	28.44	3	24.59	4	8.19	3	28.42		
18	49.32	5	38.45	9	30.42	2	19.5		
20	15.24	1	23.53	11	3.4	1	11.45		
11	33.19	4	2.59	15	34.05	1	0.52		
24	42.5	7	17.44	10	22.3	6	22.32		
19	18.52	10	31.25	20	29.48	4	29.15		
30	56.3	9	28.45	21	15.19	4	12.57		
10	53.19	6	31.12	9	18.44	2	18		
11	30.48	6	11.52	4	4.54	1	12.51		
10	19.59	10	9.38	4	6.29	2	13		
13	8.4	8	11.12	2	8.45	2	5.49		

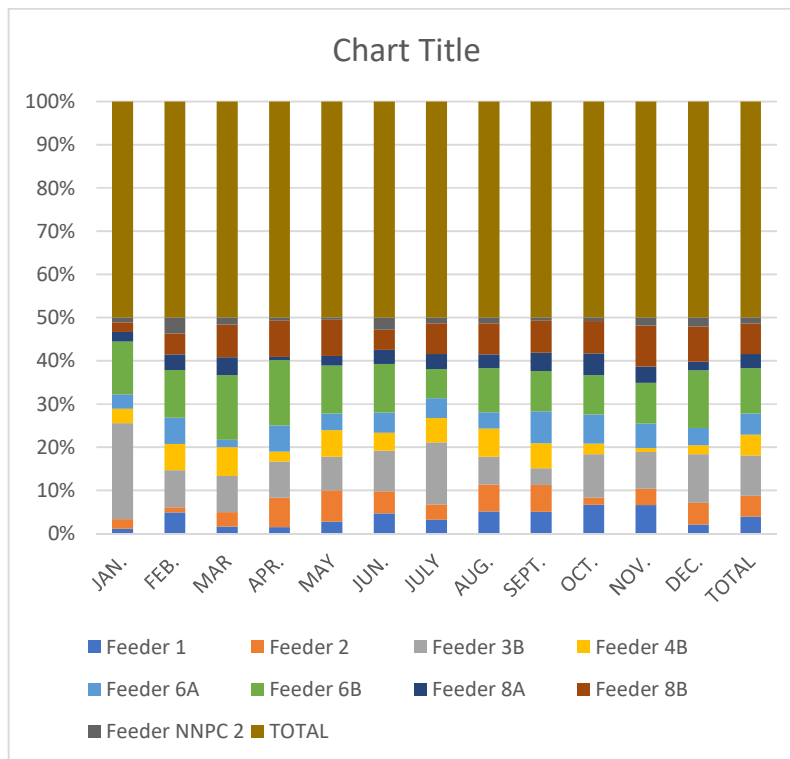


Figure 6: B 33 Feeder Monthly outage

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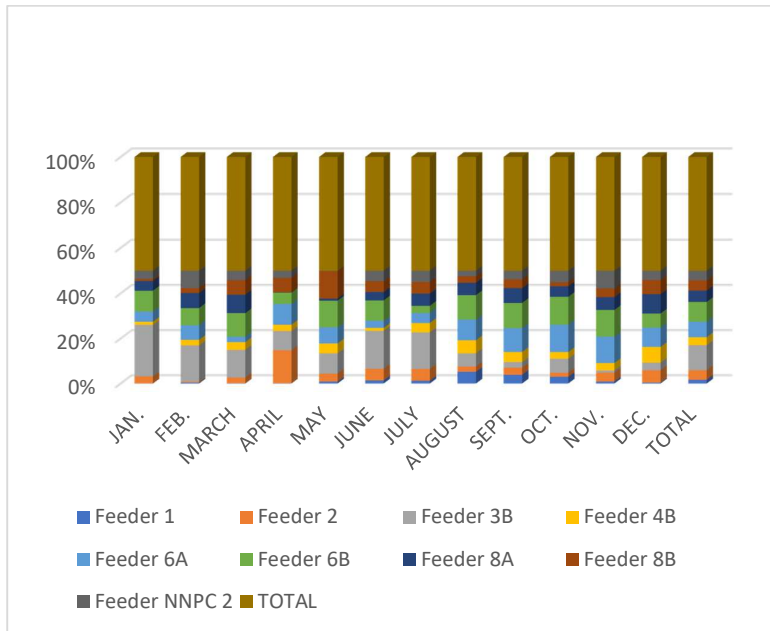


Figure 7: B 33 Feeder Monthly Duration

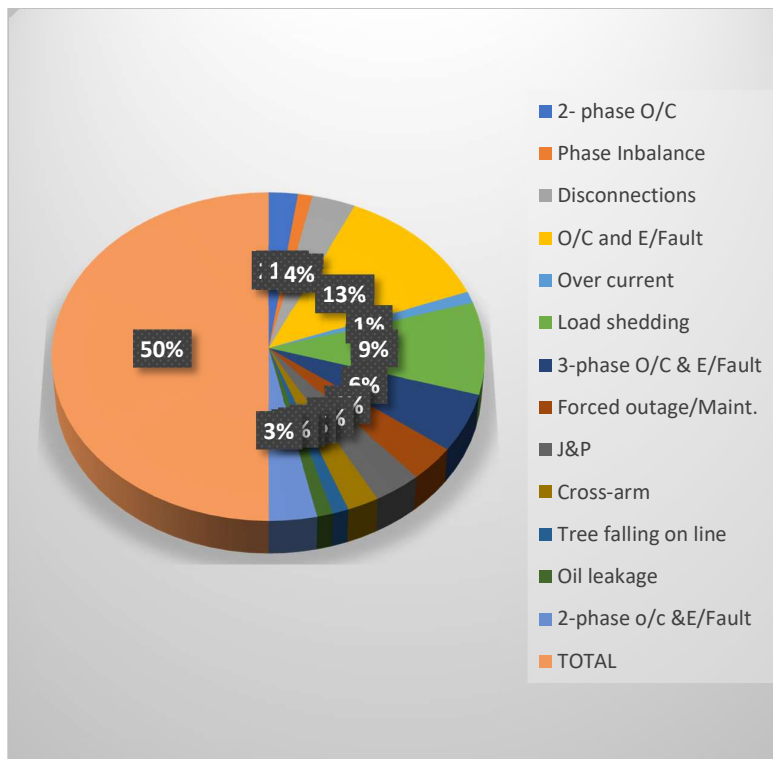


Figure 8: Fault types versus Outage

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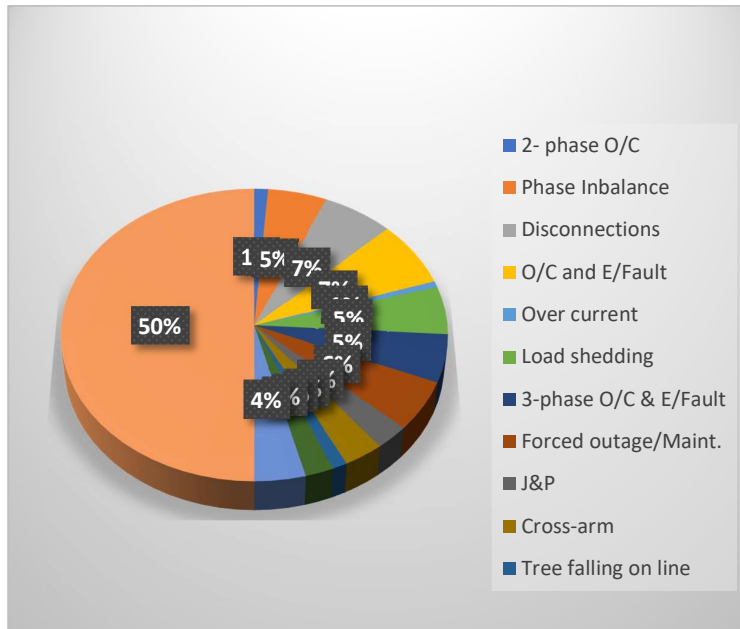


Figure 9: Fault types versus Duration

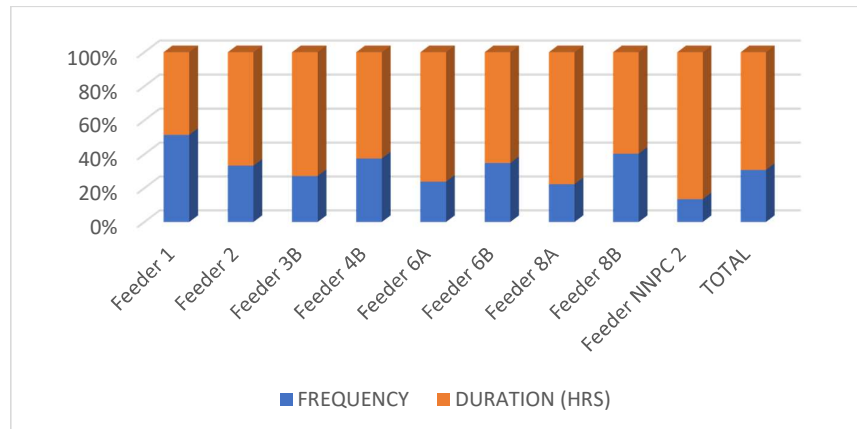


Figure 10: Frequency and Duration for the period understudy

CONCLUSION

The main objective of the study is the reliability assessment of the automated distribution system and to propose the optimum number and location of automatic switches that will improve reliability of the distribution system. A very simple analytical method will be adopted and implemented for the system analysis. This research aims to help the manager and reliability engineers of the utility company to understand the characteristic behavior of their network and to perform economic analysis of

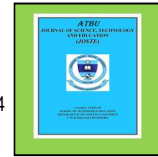
the automation system. The reliability of the system improves as the automation increases for all kinds of load until a certain number of automatic switches are installed. Reliability of the distribution system greatly depends upon the placement of automatic switches. From the finding, it can be deduced that Feeder 6B has the highest outages with the frequency of 209, while Feeder 3B has the highest outage duration of 494.44hrs for the study period which contributed to (approximately 21days accumulative outage for the said study period.

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The least feeder was that of Feeder NNPC 2 with the outage frequency of 29, while Feeder 1 has the lower outage duration of 73.58hrs corresponding to only 3 days blackouts the same study period.

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