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Load Reliability Assessment Analysis for Nigerian Agip Oil Company, Port Harcourt, Using Analytical Method

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ABSTRACT
This research significantly examined the analysis of Nigerian Agip Oil and Gas Company, Port Harcourt, 132/33kV injection transmission substation, network for improved performance using analytical method were simulated and analysed for the purpose of investigation. The reliability indices for the year 2018 to 2020 are being considered as base year for the case study. The reliability assessment module was used to calculate and produce output reports of reliability indices and the System Indices. The results shows that from 2018 to 2020 indicates that the failure rate show that Bus 8, and Bus 15 have the highest failure rate values of 0.3441(f/yrs) respectively which means the number of failures for the equipment's should be taken into considered to the barest minimum rate, Outage duration shows that Bus 30 has the highest Outage duration value of 2.80 hrs, average unavailability/outage time shows that Bus 29 has the highest No. of outage time value of 0.9251 hrs, System Average Interruption Frequency Index (SAIFI) shows that Bus 7 has the highest SAIFI values of 0.0146 (Interruptions/system-customer), System Average interruption Duration index (SAIDI) shows that Bus 30 has the highest SAIDI value of 0.0871 hr/system-customer, Customer average Interruption duration index (CAIDI) shows that Bus 30 has the highest CAIDI value of 13.825 hr/interruption, average Load shows that Bus 14 has highest Average Load value of 305.8 kW, Expected Energy Not Supplied (EENS) shows that Bus 29 has the highest EENS value of 170.9585 $MWhr/yr$, Expected Customer Outage Cost (ECOST) shows that Bus 28 has the highest ECOST value of 293.3340 $\$/hr$, total Number of Customer interruptions, shows that Bus 1 has the highest No. of Customer interruptions value of 5.6457 hrs, Interrupted Energy Assessment Rate (IEAR) our results show that Bus 7 has the highest IEAR value of 3.2887, and total Number of Customer interruptions duration, shows that Bus 30 has the highest No. of Customer interruptions duration value of 33.600 mins. The application of Electrical Transient Analyzer Program (ETAP version 12.6) software for simulation is adopted.

KEYWORDS: *load point, system reliability indices, Failure rate of the distribution network, Average outage duration, Annual outage duration, System Indices, System Average Interruption Frequency Index (SAIFI), System Average interruption Duration index (SAIDI), Customer Average Interruption duration index (CAIDI).*

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I. INTRODUCTION

The load point and system reliability indices are normally determined on annual basis. Because of the stochastic nature of a power system, the indices for any particular year are random values and are functions of the component failure rates, repair times and restoration times within the year. A complete representation of these indices involves knowledge of the underlying probability distributions. It is relatively easy to compute the average values as the associated analytical techniques are highly developed for both radial and meshed distribution systems. The connected transformer kVA, peak load, or metered demand (to be clearly specified when reporting) on the circuit or portion of circuit that is interrupted. When reporting, the report should state it is based on an annual peak or on a reporting period peak [15].

The power distribution system is made up of transformers, poles and wire as seen in the circuits. The Distribution substations are monitored and adjustable within the system. The distribution substations in Nigerian Agip Oil Company lower the transmission line voltages to 33 kV and 15 kV or less. The voltage is then further reduced by distribution transformers to the utilization voltages of 380 volts three-phase or 220 volts single-phase supply required by most users.

Substations are fenced yards with switches, transformers and other electrical equipment. Once the voltage has been lowered at the substation, the electricity flows to industrial, commercial, and residential centers through the distribution system. Conductors called feeders reach out from the 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 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 [4].

In the context of Nigerian Agip Oil Company, electric power interruption is becoming a day to day phenomenon. Even there are times that electric power interruption occurs several times a day, not only at the low voltage but also at the medium voltage distribution systems.

The drop of the voltage, especially at the residential loads, is causing early failure of equipment, blackening of light bulbs, and decreased efficiency and performance of high-power appliances. Damage of electronic devices and burning of light bulbs have also occurred due to over voltages.

Reliability of a power distribution system is defined as the ability to deliver uninterrupted service to customer. Distribution system reliability indices can be presented in many ways to reflect the reliability of individual customers, feeders and system oriented indices related to substation. Two approaches to reliability evaluation of distribution systems are normally used; namely, historical assessment and predictive assessment. The distribution system is an important part of the total electrical supply system. This is due to the fact that the distribution system provides the final link between a utility's transmission system and its customers. It has been reported that more than eighty per cent of all customer interruptions occur due to failures in the distribution system [17].

Distribution System Strengthening and Distribution Automation (DA) system are being increasingly implemented under Restructured Accelerated Power Development and Reforms Programme (R-APDRP)/Integrated Power Development Scheme (IPDS) by the electric utilities to reduce the operational problems of distribution networks. System strengthening and the Distribution Automation (DA) system not only provides system wide status and health monitoring but also helps in coordinated controls required to enhance quality and reliability of the supply.

In Nigeria, the Utilities calculate Reliability Index and the same thing submitted to Regulatory commission and Central Electricity Authority. The data base is not available to calculate all the Reliability indices as per IEEE 1366-2012. An attempt has been made in this paper to calculate Reliability indices which includes, System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Frequency Index (CAIFI), Customer Average Interruption Duration Index (CAIDI), Energy Not Supplied (ENS), Average Energy Not Supplied (AENS), etc. [9].

1.2 Statement of the Problem

Load Reliability analysis on electric power supply is crucial for the development of every economy. The incessant increase in the population of people migrating from the rural areas to the urban areas is very alarming causing an unprecedented increase in power demand. Nevertheless, the distribution network has it derivative from the power system facilities, which has led to the following problems listed below:

i. System losses due to mismatches between the power generation and power received.
ii. The problem of epileptic power supply.
iii. Inadequate Network Capacity which prone to frequent failures.
iv. Transient behavior of the systems.
v. To improve/upgrade and expand the distribution power system in Port Harcourt.

1.3 Aim of the Study

The main aim of carrying out this study is to determine the load reliability assessment analysis for Nigerian Agip Oil and Gas Company using analytical technique.

1.4 Objectives of the Study

The objectives of this study are stated as follows:

I. The reliability assessment module was used to calculate and produce output reports of reliability indices like load point Indices:
   a. Failure rate of the distribution network
   b. Average outage duration
   c. Annual outage duration.
II. System Indices:

a. System Average Interruption Frequency Index – SAIFI
b. System Average interruption Duration index – SAIDI,
c. Customer Average Interruption duration index – CAIDI

III. The reliability indices for the year 2018 to 2020 are being considered as base year for the case study.

IV. The application of Electrical Transient Analyzer Program (ETAP version 12.6) software for simulation is adopted.

1.5 Scope of the Study

The scope of this research work will focus on determining the load reliability assessment analysis for Nigerian Agip Oil and Gas Company using analytical technique will be considered.

II. LITERATURE REVIES

The economic growth and development of a country depends heavily on the reliability and quality of the electric power supply. Generally, rigorous planning is done for addition of generation and expansion of the transmission networks. However, the distribution systems have generally grown in an unplanned manner resulting in high technical and commercial losses in addition to poor quality of power. Efficient operation and maintenance of distribution system are hampered by non-availability of system topological information, current health information of the distribution components such as distribution transformers and feeders and historical data etc. Other reasons include lack of efficient tools for operational Planning and advanced methodology for quick fault detection, isolation, and service restoration. All these lead to the increased system losses, poor quality and reliability of power supply in addition to the increased peak demand and poor return of revenue [13].

According to [16] standard has formulated broad methods to assess statistically the performance of distribution network and has defined various indices with respect to reliability of the distribution system. In Nigeria, as a part of electricity reforms, electricity regulatory bodies have been formed. Attempts are being made at present by the regulatory bodies to assess the performance of utilities and they are in the process of bringing out uniform methods for statistical analysis of Reliability Indices and their implementation.

The utilities evaluate reliability index regularly on monthly basis and then it is sent to Central Electricity Authority (CEA) and corresponding regulatory commission. In other countries like USA, electric utilities carry out Predictive Reliability assessment and Reliability Assessment. They have huge data base to calculate Reliability Indices and Reliability assessment ([8]; [14]; [2]).

2.2 Importance of Reliability Parameters

The important of reliability parameters is paramount in load analysis and conforms to the Central Electricity Authority (CEA) and respective Regulatory Commission. Below is the Importance of Reliability Parameters:

i. Customer is demanding uninterrupted (24x7) Power Supply.

ii. The Reliability Parameters became one of the benchmark Parameters for evaluating the performance of Utility.

iii. It is mandatory as per National Electricity Policy 2005 (NEP 2005) to submit regular Reliability Index reports to the Central Electricity Authority (CEA) and respective Regulatory Commission [1].

iv. It creates healthy competition to compare reliability parameters with different electrical utilities.

v. The brand image of the utility will improve with the better Reliability parameters.

2.3 Reliability Parameters in Nigerian Context

The Distribution reforms initiated during the year November 2001. Prior to 2001, the sufficient data base of interruptions and duration data in the Electricity Boards of Nigeria is not available to evaluate Reliability performance. The Ministry of Power, Government of Nigeria initiated the reforms programme [3].

Reliability means "the ability of a system to perform the function it is designed for, under the operating conditions encountered during its expected lifetime". It can be calculated, assessed, planned, and designed into equipment or a system [5]. The majority of distribution systems are radial consisting of main feeders and lateral distributors to supply electric power to consumers [6]. The radial nature of distribution system makes it vulnerable to interruptions in power supply to customers due to fault events. This research work is concerned with the study of reliability of distribution systems. The reliability of a power system is affected by the frequency "number of interruptions during an analysis period", duration "the time of the interruption", and extent of the interruption "how many customer loads are interrupted". From the engineering point of view, reliability assessment depends on determining mathematically the frequency and duration of customer interruptions

According to [7] the requirements of the power system reliability can be accomplished through optimal planning and lowest cost. The importance of reliability evaluation of power systems is to achieve the most exact and efficient judgment in the planning, operating and maintenance.

2.4 Distribution System Reliability Evaluation

The distribution system mostly affects the supply reliability because it is the weakest link between the source of supply and the customer load points. This research work focuses on the distribution system with the assumption that there is continuously sufficient power provided through the substations. The focus is on the impact of distribution component failures on individual consumer load points [10].

2.5 Methods of Distribution System Reliability Evaluation

2.5.1 Analytical methods

Analytical methods represent the system by mathematical models and assess the reliability indices from these models using mathematical solutions. The minimal cut-set method is one of the most common analytical methods, can be applied to systems with simple as well as complex configurations, and is a very suitable technique for the reliability assessment of distribution systems [11]. In this study, the minimal cut set method is used for studying and evaluating the reliability of a distribution system in Agip Oil Company, Port Harcourt.

2.5.2 Reliability indices

The Institute of Electrical and Electronic Engineers (IEEE) has standardized a wide range of reliability indices and reliability calculations for power networks. These indices are a measure of the reliability level of the power system by providing information about the rate and duration of customer interruptions in any given network. Any particular element failed in a power system can cause a partial or even entire system interrupting. The availability of these elements is characterized by failure rate and repair or replacement time [12].

III. MATERIALS AND METHODS

3.1 Materials used in the Analysis

I. The distribution data were collected from the Nigerian Agip Oil and Gas Company.

II. Load of this system receives a voltage of 415V and type of load is lump load. Conductor size for 33kV is 50 mm^2 and 95 mm^2 respectively.

III. ACSR conductor is used for incoming and outgoing feeders.

IV. The distribution system is radial distribution system and reliability assessment mode in Electrical Transient Analyzer Program (ETAP version 12.6) software is adopted.

3.2 Method used in the Analysis

Due to the nature of the study the following methods are utilized as follow;

The site was visited and technical data collections from the substation were used to investigate the power distribution problems that arise from both the customer side and the electric utility side, at the substations. The following data were collected from the substation:

I. The reliability assessment module was used to calculate and produce output reports of reliability indices like load point Indices:
   a. Failure rate of the distribution network
   b. Average outage duration
   c. Annual outage duration.

II. System Indices:
   a. System Average Interruption Frequency Index – SAIFI
   b. System Average interruption Duration index – SAIDI, Customer.

III. The reliability indices for the year 2018 to 2020 are being considered as base year for the case study.

IV. The application of Electrical Transient Analyzer Program (ETAP version 12.6) software for simulation is adopted.

3.3 Evaluation and Analysis of the existing Substation

The Distribution Injection Substations covered in this study are fed from the Nigerian Agip Oil and Gas Company, Port Harcourt, 132/33kV injection transmission substation.

Figure 3.1 illustrates the single line network diagram of Nigerian Agip Oil and Gas Company, Port Harcourt

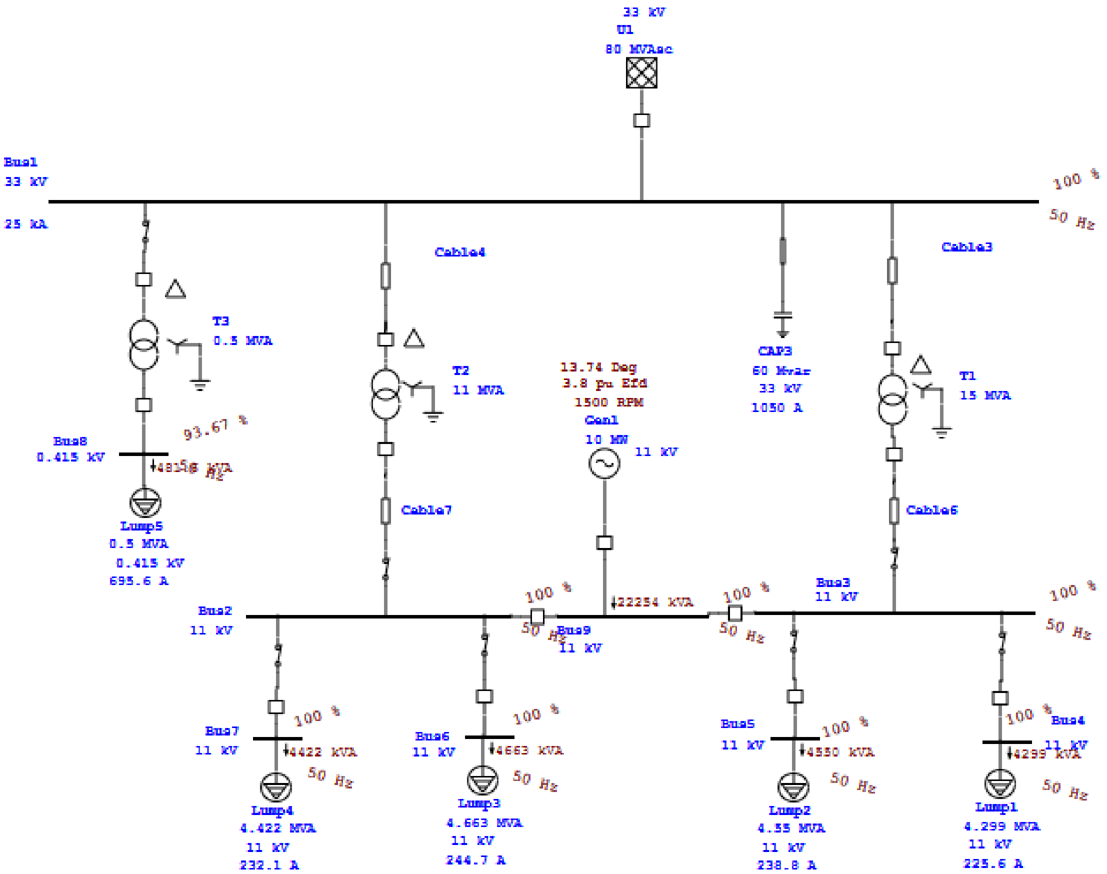

Figure 3.1: Single Line Network Diagram 1 of Nigerian Agip Oil and Gas Company, Port Harcourt

3.4 Basic reliability indices

This is based on the probability theory, which is a very important condition in expressing the indices of system failure event on probability and frequency basis. There are three basic indices: failure rate (λ), outage duration (r) and average annual outage time ($\boldsymbol{\mu}$). These load point indices parameters are used to predict the reliability of a distribution system. They allow the measurement of reliability at each load point to be quantified and allow subsidiary indices such as the customer interruption indices to be determined. The reliability indices basic equations are shown below.

3.4.1 Failure rate

Is the frequency with which an engineered system or component fails, expressed in failures per unit of time. It is expressed mathematically as:

$$\lambda = \frac{Frequency\ of\ faliures}{period\ of\ operation\ (hr)} = \frac{F}{T} \tag{3.1}$$

3.4.2 Average annual failure rate

It is defined as the average number of failures per year and gives the estimated probability that a device or component will fail during a full year of use. It is expressed mathematically as:

$$\lambda_s = \sum \frac{F}{T}\ (f/yr) \tag{3.2}$$

3.4.3 Load point repair rate

It is the rate with which a repair action is performed and is expressed in terms of the number of repair actions performed and successfully completed per hour. It is expressed mathematically as:

$$\mu = \frac{T_0}{(\sum T_0/\sum F)}\ (repair/yr) \tag{3.3}$$

3.4.4 Annual outage duration

It refer to a period of time that a system fails to provide or perform it primary function, t is the proportion of a time-span that a system is unavailable. This is usually a result of the system failing to function because of an unplanned event, or because of routine. It is expressed mathematically as:

$$\mu\lambda = \sum \frac{T_0}{T} (hr/yr) \tag{3.4}$$

3.4.5 Average outage duration

It is defines as an interruption for the average customer given for period time, usually measured over the course of a year. It is expressed mathematically as:

$$r_y = {}^{\mu y}/_{\lambda y}\, (hr) \tag{3.5}$$

3.4.6 Mean time between failures

Is the predicted elapsed time between inherent failures of a mechanical or electronic system, during normal system operation. It is expressed mathematically as:

$$MTBF = \frac{Period\ of\ operation}{Frequency\ of\ failures} = \sum \frac{T}{F} (hr) \tag{3.6}$$

3.4.7 Mean time to repair

Is a basic measured of the maintainability of repairable items. It represents the average time required to repair a failed component or device. It is expressed mathematically as:

$$MTTR = \frac{Outage\ Time}{Frequency\ of\ failures} = \sum \frac{T_0}{F}\ (hr) \tag{3.7}$$

Where;

F = Frequency of failures
T = Period of operation
T_0 = Outage time

The basic equations for calculating the reliability indices at each load point P are given as:

3.4.8 Average failure rate at load point, P

It is defined as the average number of failures per year and gives the estimated probability that a device or component will fail during a full year of use. It is expressed mathematically as:

$$\lambda_p = \frac{\sum F}{T} (f/yr) \tag{3.8}$$

3.4.9 Annual outage duration at load point, P

It refer to a period of time that a system fails to provide or perform it primary function, t is the proportion of a time-span that a system is unavailable. It is expressed mathematically as:

$$\lambda_p = \frac{\sum Tdx}{T} (hr/yr) \tag{3.9}$$

Where;

Tdx = Annual outage time (in hours)

3.4.10 Average outage duration at load point, P

It is defines as an interruption for the average customer given for period time, usually measured over the course of a year. It is expressed mathematically as:

$$r_p = \frac{\mu p}{\lambda_p} (hr) \tag{3.10}$$

$$MTTR = \sum \frac{Tdx}{F} \tag{3.11}$$

3.4.11 Availability

It is the degree to which a system, subsystem or equipment is in a specified operable and committable state at the start of a mission, when the mission is called for at an unknown, i.e. a random time.

$$A = \frac{MTBF}{MTBF+MTTR} (p.u) \tag{3.12}$$

3.5 Power System Reliability Indices

The degree of reliability may be measured by the frequency, duration, and magnitude of adverse effects on the electric supply. There are many indices used in measuring reliability. The three most referred indices are SAIFI, SAIDI, and CAIDI, as defined in IEEE Standard 1366. There are explained as follows:

3.5.1 System Average Interruption Frequency Index (SAIFI)

System Average Interruption Frequency Index (SAIFI), the index represent the average frequency of sustained interruptions per customer over a predefined area which is expressed as the total number of customer interruptions divided by the total number of customers served.

For instance, a feeder SAIFI indicates the average number of interruptions a customer serviced by the particular feeder would experience in a year. Similarly SAIFI reported for a substation or a distribution system encloses the total customers in the service area. The system average interruption frequency index is given in (3.13).

$$\text{SAIFI} = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}} = \frac{\sum_i \lambda_i N_i}{\sum_i N_i} \qquad (3.13)$$

Where:

λi is the failure rate at load point i and,

Ni is the number of customers at load point i.

3.5.2 Customer Average Interruption Frequency Index (CAIFI)

Customer Average Interruption Frequency Index (CAIFI) is the index that gives the average frequency of sustained interruptions for those customers experiencing sustained interruptions. The customer is counted once in spite of the number of times interrupted and is calculate as expressed in (3.14).

$$\text{CAIFI} = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers affected}} = \frac{\Sigma(No)}{\Sigma(Ni)} \qquad (3.14)$$

Where:

No is the number of interruptions

Ni is the total number of customers interrupted.

3.5.3 System Average Interruption Duration Index (SAIDI)

System Average Interruption Duration Index (SAIDI) It is generally referred to as customer minutes of interruption or customer hours, and is designed to provide information as to the average time the customers are interrupted and this is expresses as the sum of the restoration time for each interruption event times the number of interrupted customers for each interruption event divided by the total number of customers.

$$\text{SAIDI} = \frac{\text{Sum of customer interruptions durations}}{\text{Total number of customers served}} = \frac{\sum_i U_i N_i}{\sum_i N_i} \qquad (3.15)$$

Where:

Ui is the annual outage time at load point$i$ and

Ni is the number of customers at load point i.

3.5.4 Customer Average Interruption Duration Index (CAIDI)

Customer Average Interruption Duration Index (CAIDI) is the average time needed to restore service to the average customer per sustained interruption and is it expressed as the sum of customer interruption durations divided by the total number of customer interruptions.

$$\text{CAIDI} = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}} = \frac{\sum_i U_i N_i}{\sum_i \lambda_i N_i} = \frac{\text{SAIDI}}{\text{SAIFI}} \qquad (3.16)$$

Where:

λi is the failure rate at load point i

Ui is the annual outage time at load point i and

Ni is the number of customer at load point i.

3.5.5 Average Service Availability Index (ASAI)

Average Service Availability Index (ASAI) is the index which represents the fraction of time (expressed in percentage) that a customer has power provided during one year or the defined reporting period. It is calculated using (3.17) as shown below.

$$\text{ASAI} = \frac{\text{Customer hours of avaliable service}}{\text{Customers hours demanded}} = \frac{\sum_{i_{Ni}} \times 8760 - \sum_i UiNi}{\sum_{i_{Ni}} \times 8760} \qquad (3.17)$$

Where:

Ui is the annual outage time at load point$i$and

Ni is the number of customer at load point$i$.

3.5.6 Average Service Unavailability Index (ASUI):

Average Service Unavailability Index (ASUI) is the index which has the complementary value compared to the average service availability index (ASAI). This is shown below in (3.18).

$$ASUI = 1 - ASAI = \frac{\text{Customer hours of unavaliuavle service}}{\text{Customers hours demanded}} = \frac{\sum_i U_i N_i}{\sum_i N_i \times 8760} \qquad (3.18)$$

Where:

Ui is the annual outage time at load point i and
Ni is the number of customer at load point i.

IV. RESULTS AND DISCUSSION

4.1 Description of the Work

This session analyses the outcome of results and examine how Nigerian Agip Oil and Gas Company, Port Harcourt, 132/33kV injection transmission substation, network for improved performance using analytical method were simulated and analysed for the purpose of investigation. The power distribution problems arise from both the customer side and the electric utility side at selected substations were investigated. Similarly, accessibility and evaluation of the existing reliability indices of distribution network system of area in Obiwali grid network was also examined. Moreover, the reliability indices System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) using predictive (analytical) methods were also analyzed.

4.2 Representation of Tables

The section represents different tables that were used for simulation, and their results were discussed effectively. Relationship between Load Point, Average Load, Failure Rate, Outage Duration, and Number of Customers served, Total No. of Customer Interruptions and Total No. of Customer Interruptions Duration for 2018-2020 were illustrated below.

Table 4.1: Relationship between Load Point, Average Load, Failure Rate, Outage Duration, No. of Customers served, Total No. of Customer Interruptions and Total No. of Customer Interruptions Duration for 2018

Load Point	Average Load (kW)	Failure Rate (λ_i)	Outage Duration (γ_i)	No. of Customers served (N_i)	Total No. of Customer Interruptions (No)	Total No. of Customer Interruptions Duration
1	183.6	0.3311	0.72	10	3.3110	7.200
2	176.5	0.3231	0.75	12	3.8772	9.000
3	177.5	0.3401	0.78	15	5.1015	11.700
4	183.6	0.3311	0.83	12	3.9732	9.960
5	215.7	0.3312	0.74	14	4.6368	10.360
6	187.7	0.3401	0.68	15	5.1015	10.200
7	168.2	0.3021	0.67	12	3.6252	8.040
8	173.8	0.2981	0.74	15	4.4715	11.100
9	176.5	0.3311	0.77	13	4.3043	10.010
10	168.2	0.3312	0.80	10	3.3120	8.000
11	183.6	0.3401	0.83	12	4.0812	9.960
12	210.2	0.3021	0.75	10	2.0210	7.500
13	219.5	0.3311	0.68	11	3.6421	7.480
14	250.6	0.3231	0.67	11	3.5541	7.370
15	155.7	0.3401	0.72	12	4.0812	8.640
16	204.7	0.3311	0.75	11	3.6421	8.250
17	183.6	0.3312	0.83	10	3.3120	8.300
18	174.6	0.3401	0.74	11	3.7411	8.140
19	173.5	0.2021	0.68	12	2.4252	8.160
20	185.6	0.1985	0.67	12	2.3820	8.040
21	183.8	0.3311	0.74	15	4.9665	11.100
22	172.6	0.3312	0.77	12	3.9744	9.240
23	175.4	0.3401	0.80	10	3.4010	8.000
24	180.5	0.3311	1.75	14	4.6354	24.500
25	183.7	0.3231	1.84	13	4.2003	23.920
26	178.6	0.3401	1.76	10	3.4010	17.600
27	172.5	0.3311	1.62	9	2.9799	14.580
28	180.6	0.3312	2.68	11	3.6432	29.480
29	184.8	0.3401	2.72	10	3.4010	27.200
30	176.5	0.2021	2.80	12	2.4252	33.600
31	173.5	0.2981	2.71	11	3.2791	29.810
32	183.6	0.3311	2.62	12	3.9732	31.440

33	180.5	0.3312	2.65	9	2.9808	23.850
				386		

Table 4.1 show the relationship between Load Point, Average Load, Failure Rate, Outage Duration, No. of Customers served, Total No. of Customer Interruptions and Total No. of Customer Interruptions Duration for 2018.

Table 4.2: Relationship between Load Point, Average Load, Failure Rate, Outage Duration, No. of Customers served, Total No. of Customer Interruptions and Total No. of Customer Interruptions Duration for 2019

Load Point	Average Load (kW)	Failure Rate (λ_i)	Outage Duration (γ_i)	No. of Customers served (N_i)	Total No. of Customer Interruptions (No)	Total No. of Customer Interruptions Duration
1	185.2	0.3321	0.74	17	5.6457	12.580
2	175.8	0.3401	0.77	12	4.0812	9.240
3	174.5	0.3431	0.76	15	5.1465	11.400
4	180.7	0.3311	0.84	12	3.9732	10.080
5	205.8	0.3312	0.72	12	3.9744	8.640
6	217.3	0.3401	0.65	15	5.1015	9.750
7	179.4	0.2092	0.68	20	4.1840	13.600
8	166.6	0.3341	0.72	15	5.0115	10.800
9	174.7	0.3309	0.78	12	3.9708	9.360
10	165.3	0.3312	0.81	10	3.3120	8.100
11	184.8	0.3389	0.79	15	5.0835	11.850
12	212.6	0.3042	0.71	14	4.2588	9.940
13	211.5	0.3291	0.65	11	3.6201	7.150
14	305.8	0.3231	0.64	15	4.8465	9.600
15	156.2	0.3341	0.70	15	5.0115	10.500
16	154.7	0.3241	0.71	9	2.9169	6.390
17	189.6	0.3312	0.80	10	3.3120	8.000
18	176.9	0.3382	0.72	11	3.7202	7.920
19	175.7	0.2016	0.66	13	2.6208	8.580
20	188.6	0.1955	0.65	9	1.7595	5.850
21	189.2	0.3285	0.72	12	3.9420	8.640
22	172.8	0.3304	0.84	11	3.6344	9.240
23	175.6	0.3384	0.78	10	3.3840	7.800
24	182.5	0.3307	1.74	9	2.9763	15.660
25	188.2	0.3224	1.80	8	2.5792	14.400
26	180.6	0.3382	1.75	10	3.3820	17.500
27	176.9	0.3308	1.60	8	2.6464	12.800
28	184.6	0.3309	1.98	9	2.9781	17.820
29	190.8	0.3301	2.05	10	3.3010	20.500
30	186.2	0.3025	2.21	12	3.6300	26.520
31	180.5	0.2963	2.21	11	3.2593	24.310
32	185.6	0.3301	2.42	9	2.9709	21.780
33	185.8	0.3212	2.37	9	2.8908	21.330
				390		

Table 4.2 show the relationship between Load Point, Average Load, Failure Rate, Outage Duration, No. of Customers served, Total No. of Customer Interruptions and Total No. of Customer Interruptions Duration for 2019.

Table 4.3: Relationship between Load Point, Average Load, Failure Rate, Outage Duration, No. of Customers served, Total No. of Customer Interruptions and Total No. of Customer Interruptions Duration for 2020

Load Point	Average Load (kW)	Failure Rate (λ_i)	Outage Duration (γ_i)	No. of Customers served (N_i)	Total No. of Customer Interruptions (No)	Total No. of Customer Interruptions Duration
1	182.5	0.3312	0.78	15	4.968	11.70
2	175.8	0.3401	0.72	12	4.081	8.64
3	177.5	0.2021	0.76	15	3.032	11.40
4	183.6	0.3311	0.85	12	3.973	10.20
5	215.7	0.3312	0.70	15	4.968	10.50
6	210.8	0.3401	0.72	15	5.102	10.80
7	170.5	0.3401	0.65	17	5.782	11.05
8	165.7	0.2021	0.70	14	2.829	9.80
9	186.6	0.1985	0.80	13	2.581	10.40

10	170.3	0.3311	0.75	10	3.311	7.50
11	180.8	0.3231	0.85	13	4.200	11.05
12	212.5	0.3401	0.72	14	4.761	10.08
13	210.7	0.3351	0.70	10	3.351	7.00
14	250.6	0.2021	0.72	11	2.223	7.92
15	165.8	0.2105	0.85	10	2.105	8.50
16	278.7	0.3311	0.70	12	3.973	8.40
17	185.8	0.3312	0.81	10	3.312	8.10
18	183.6	0.2021	0.77	11	2.223	8.47
19	175.7	0.2105	0.65	12	2.526	7.80
20	190.2	0.3311	0.70	12	3.973	8.40
21	180.6	0.3311	0.78	10	3.311	7.80
22	174.7	0.3312	0.80	12	3.974	9.60
23	174.8	0.3401	0.85	11	3.741	9.35
24	182.2	0.3341	1.81	12	4.009	21.72
25	185.3	0.3311	1.80	11	3.642	19.80
26	180.1	0.3312	1.60	10	3.312	16.00
27	170.2	0.3311	1.58	11	3.642	17.38
28	182.2	0.3231	2.42	10	3.231	24.20
29	180.4	0.3311	1.65	11	3.642	18.15
30	174.9	0.3231	1.75	12	3.877	21.00
31	180.5	0.3401	1.64	11	3.741	18.04
32	180.8	0.3311	1.60	13	4.304	17.6
33	179.5	0.3312	2.52	10	3.312	25.2
				395		

Table 4.3 show the relationship between Load Point, Average Load, Failure Rate, Outage Duration, No. of Customers served, Total No. of Customer Interruptions and Total No. of Customer Interruptions Duration for 2020.

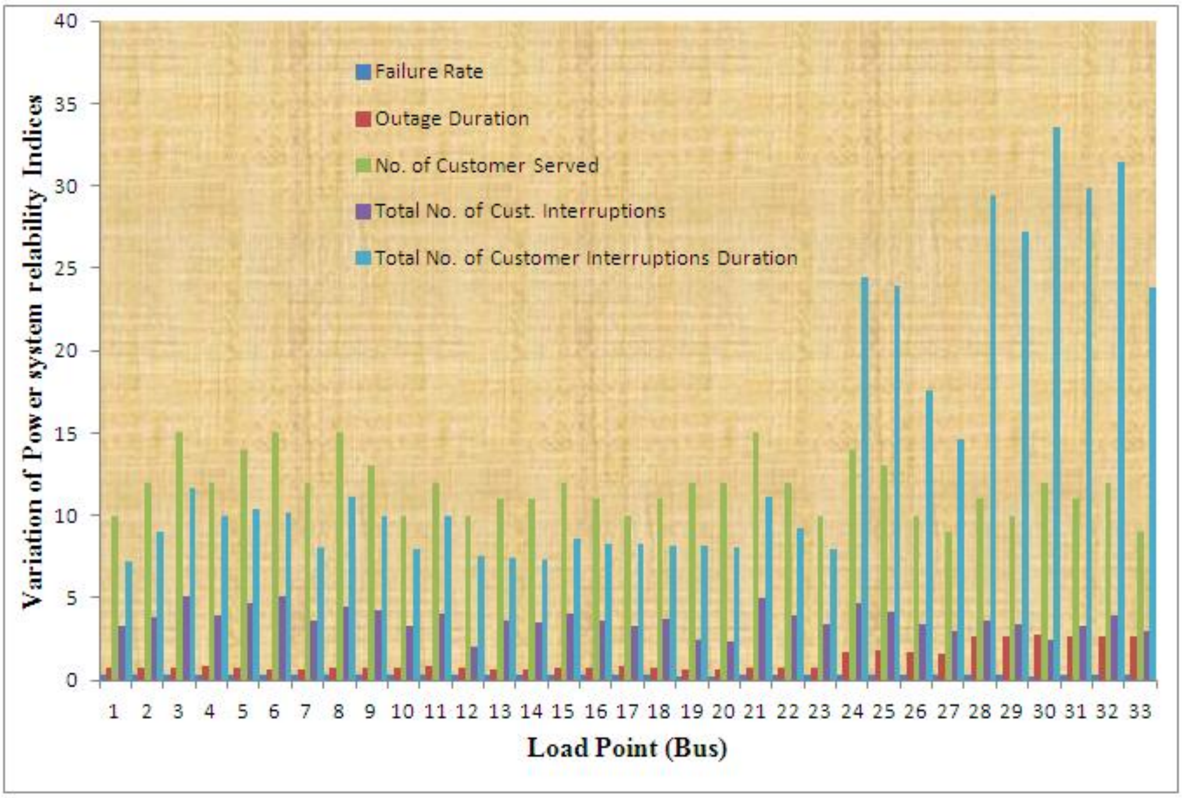

Figure 4.1: Variation of power system reliability indices showing the failure rate, Annual Outage Time, No. of customer served and No. of customer Interruptions for 2018

The above figure represents the Power System Reliability Indices showing the failure rate, Annual Outage Time, No. of customer served and No. of customer Interruptions for 2018. From our result on Average Load shows that Bus 14 has highest Average Load value of 250.6 kW, followed by Bus 13 with 219.5 kW while Bus 15 has the lowest Average Load value of 155.7 kW. For the failure rate, our results show that Bus 3, Bus 6, Bus 11, Bus 15, Bus 18, Bus 23, Bus 26, and Bus 29 have the highest failure rate values of 0.3401, followed by Bus 4, Bus 10, Bus 17, Bus 22, Bus 28 and Bus 33 with 0.3312 while Bus 20 has the lowest failure rate value of 0.1985. For the Outage duration, our results show that Bus 30 has the highest Outage duration value of 2.80, followed by Bus 29 with 2.72 while Bus 27 has the lowest Outage duration value of 0.62. For the Number of Customer Served, our results show that there are 386 total number of Customer Served but Bus 3, Bus 6, Bus 8 and Bus 21 have the highest No. of Customer Served value of 15, followed by Bus 5 and Bus 24 with 14 while Bus 27 and Bus 33 has the lowest No. of Customer Served value of 9.

For the total Number of Customer interruptions, our results show that Bus 6 has the highest No. of Customer interruptions value of 5.1015 hrs, followed by Bus 21 with 4.9665 hrs while Bus 20 has the lowest No. of Customer interruptions value of 2.3820 hrs.

For the total Number of Customer interruptions duration, our results show that Bus 30 has the highest No. of Customer interruptions duration value of 33.600 mins, followed by Bus 32 with 31.440 mins while Bus 1 has the lowest No. of Customer interruptions value of 7.200 mins.

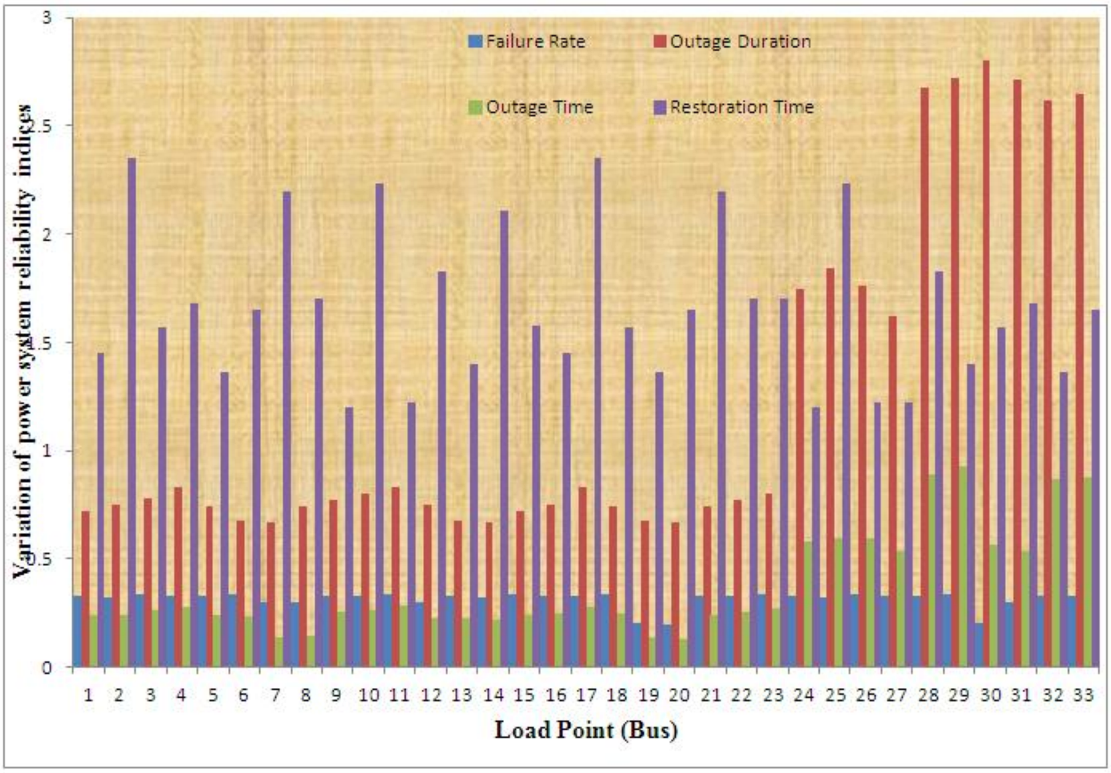

Figure 4.2: Variation of power system reliability indices showing the failure rate, Outage Unavailability/Time, outage duration and Restoration time for 2018.

Figure 4.2 represents the failure rate, Outage Unavailability/Time, outage duration and Restoration time for 2018.

From our result the failure rate, our results show that Bus 3, Bus 6, Bus 11, Bus 15, Bus 18, Bus 23, Bus 26, and Bus 29 have the highest failure rate value of 0.3401, followed by Bus 4, Bus 10, Bus 17, Bus 22, Bus 28 and Bus 33 with 0.3312 while Bus 20 has the lowest failure rate value of 0.1985.

For the Outage duration, our results show that Bus 30 has the highest Outage duration value of 2.80 followed by Bus 29 with 2.72 while Bus 27 has the lowest Outage duration value of 0.62.

For the Average unavailability/outage time, our results show that Bus 29 has the highest No. of outage time value of 0.9251 hrs followed by Bus 28 with 0.8876 mins while Bus 20 has the lowest outage time value 0.1329 mins.

For the restoration time, our results show that Bus 2 and Bus 17 have the highest restoration time values of 2.35 mins, followed by Bus 10 and Bus 25 with 2.23 mins while Bus 9 has the lowest restoration time value of 1.20 mins.

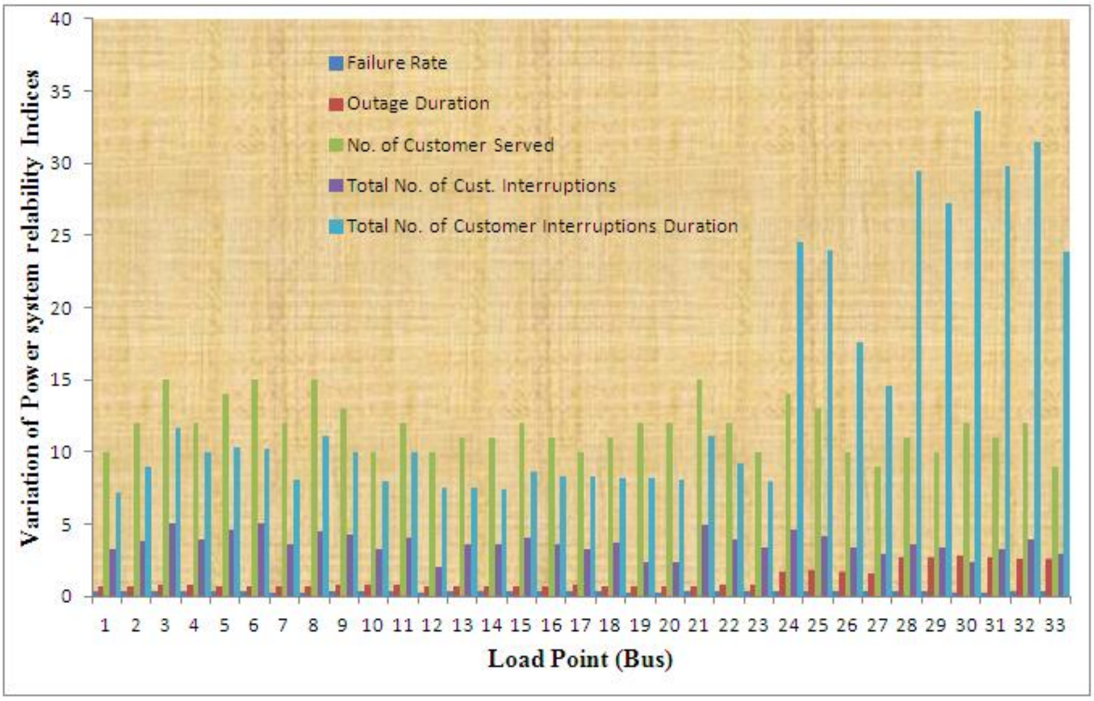

Figure 4.1: Variation of power system reliability indices showing the failure rate, Annual Outage Time, No. of customer served and No. of customer Interruptions for 2018

The above figure represents the Power System Reliability Indices showing the failure rate, Annual Outage Time,
No. of customer served and No. of customer Interruptions for 2018.
From our result on Average Load shows that Bus 14 has highest Average Load value of 250.6 kW, followed by Bus 13 with 219.5 kW while Bus 15 has the lowest Average Load value of 155.7 kW.

V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This research significantly examined the analysis of Nigerian Agip Oil and Gas Company, Port Harcourt, 132/33kV injection transmission substation, network for improved performance using analytical method were simulated and analysed for the purpose of investigation. The reliability indices for the year 2018 to 2020 are being considered as base year for the case study.

The reliability assessment module was used to calculate and produce output reports of reliability indices like load point Indices: Failure rate of the distribution network, average outage duration, annual outage duration and the System Indices: System Average Interruption Frequency Index – SAIFI, system Average interruption Duration index – SAIDI, Customer, average Interruption duration index – CAIDI and Expected Energy Not Supplied (EENS) Index, Expected Customer Outage Cost (ECOST) Index, Interrupted Energy Assessment Rate (IEAR) Index were calculated. The application of Electrical Transient Analyzer Program (ETAP version 12.6) software for simulation is adopted.

5.2 Recommendations

Based on the work done in this dissertation, the following recommendations are made:

i. The company should continue to keep accurate record of interruptions, the causes and durations as these will really help to carry out concise research work.
ii. There should be conscious effort to ensure that duration of outages is reduced to the lowest minimum as possible as this will help improve the reliability of the substation.
iii. Proper and regular inspection of utility facilities like poles will also improve reliability of the substation.

5.3 Contribution to Knowledge

This research work has contributed to knowledge as follows:

i. The failure rate from 2018-2020 shows that 2019 has the highest failure rate where Bus 8 and Bus 15 have the highest failure rate value of 0.3441 (f/yrs). This signifies that System reconfiguration should be considered in order to reduce the number of over stressed distribution network.

ii. The Expected Energy Not Supplied (EENS) Index from 2018-2020 shows that 2018 has the highest Expected Energy Not Supplied (EENS) Index where Bus 29 has the highest EENS Index of 10.959. This implies that the Company should put more funds to infrastructural development of electric power distribution so that defective components can be replaced as soon as possible.

iii. The total number of customer interruptions duration from 2018-2020 shows that 2018 has the highest number of customer interruptions duration where Bus 30 has the highest value of 33.60 mins. This implies that the value is attributable to poor supply from source of power, periods of load shedding, periods of fault as a result of the poor state of the lines and other outages whether planned or unplanned.

REFERENCES

[1]. Adegboye, B. A. & Dawal, E. (2012). Outage Analysis and System Integrity of an 11kV Distribution System. Advanced Material Research. 3(67), 151-158.

[2]. Akhikpemelo, A. (2011). 'Reliability assessment of electrical distribution in Port Harcourt Area', Master's Thesis, University of Port Harcourt.

[3]. Anthony, R. (2014). "Reliability Analysis of Distribution Network". Master of Science Thesis, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia.

[4]. Behailu., A. (2014). "Designing of an Improved Distribution Substation to Mitigate the Power Reliability at Bishoftu City", Master's Thesis, Federal Democratic Republic of Ethiopia Ministry of Defense Defense University, College of Engineering Office of Postgraduate Programs and Research.

[5]. Ezeolisah, C. (2015). TCN Transmission News. In-House Journal Of Transmission Company of Nigeria, 4(7), 1-76.

[6]. Faulin, J., Juan, A. A., Martorell, S. & Ramirez-Marquez, J. (2010). "Simulation Methods for Reliability and Availability of Complex Systems". London: Springer-Verlag London Limited. 3(6), 80-89.

[7]. Gao, L., Zhou, Y., Li, C. and L. Huo, (2014). "Reliability Assessment of Distribution Systems with Distributed Generation Based on Bayesian Networks". Engineering Review. 34(1), 55-62.

[8]. Hag-Kwen, K. (2009). 'Reliability Modeling and Evaluation in Aging Power Systems', Masters Dissertation, A&M University.

[9]. Harikrishna, K., Ashok, V., Chandraskhar, P., Raghnatha, T., & Deshpande, R. (2013). 'Predictive Reliability in the Power Distribution System', the Journal of CPRL. 9(3), 335-342.

[10]. Izuegbunam, F. I., Uba, I. S., Akwukwaegbu, I.O. & D.O. Dike, (2014). "Reliability Evaluation of Onitsha Power Distribution Network via Analytical Technique and the Impact of PV System". IOSR Journal of Electrical and Electronics Engineering, 9(3), 15-22.

[11]. Jibril, Y. & Ekundayo, K.R. (2015). "Reliability Assessment of 33kV Kaduna Electricity Distribution Feeders, Northern Region, Nigeria". World Congress on Engineering and Computer Science , San Francisco, USA. 5(4), 1-5.

[12]. Lantharthong, T., & Phanthuna, N. (2012). Techniques for Reliability Evaluation in Distribution System Planning. *World Academy of Sceince, Engineering and Technology*, 65(12) 431-434.

[13]. Obaro, B. A. (2010). 'Reliability Evaluation of Distribution Systems - Using Failure Modes, Effect & Analysis', Master's Thesis, University of Port Harcourt.

[14]. Ogujor, E.A., & Kuale, P.A. (2007). 'Using Reliability Indices-Markov Model in Electric Power Distribution System', International Journal of Electrical and Power Engineering 1(4), 416-420.

[15]. Solomon., D.(2014). "Study on Reliability Improvement of Adama City Power Supply Using Smart Grid Technology" Addis Ababa University Addis Ababa Institute of Technology School of Electrical And Computer Engineering.

[16]. Tsao, T.F., & Cheng, H.B. (2014). "Value-Based Distribution Systems Reliability Assessment Considering Different Topologies," IEEE, Proceedings of the 2014 International Conference on Machine Learning and Cybernetics, Lanzhou, 5(8), 13-16.

[17]. Venu, B., Bhargava, C., & Sumanth, K. (2014). 'Reliability Assessment of Radial Distribution System by Using Analytical Methods', International Journal of Engineering Studies, 4(4), 85-196.

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