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Analysis of 11kV, Obi-Wali, Rumuigbo Distribution Network for Improved Performance using Predictive Reliability Assessment Method

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ABSTRACT: *Reliability assessment is an important factor in designing and planning of distribution systems that should operate in an economic manner with minimal interruption of customer loads. This research critically analysed the 11kV, Obi-Wali, Rumuigbo distribution network in Port Harcourt, Rivers State, Nigeria. Power distribution problems arises from both the customers side and the electric utility side at selected substation and failure rate is high. Therefore, the focus of the analysis is to give improved performance of the distribution system using Predictive Reliability Assessment Method. The reliability indices for the year 2016 to 2019 were used as the case study. The frequency of failure rate and duration of outages on different equipment from 2016-2019 at Obi-Wali feeder were determine. Other parameters considered during analysis include average failure rate, annual outage duration, average outage duration, calculation of customer-hours, Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR) and Availability. Electrical Transient Analyser Program (ETAP) software version 12.6 was used for simulation to determine the reliability improvements. From the results, frequent failure occurs in various sectors of distribution system in Obi-Wali substation. Increase in proactive maintenance of equipment reduces their failure rate and thereby the frequency and duration of interruptions experienced by its customers.*

KEYWORDS: *Distribution system, Reliability assessment, Outage duration, Failure rate, MTBF, MTTR*

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I. INTRODUCTION

Electrical Power system includes generation, transmission and distribution systems. Supply of electricity in an economical and reliable manner can boost the economy of a country because almost all sector of human activities such as industries, education, health, information technology systems etc. need steady power. The cost of interruptions and power outages can have severe economic impact on the utility and its customers. The power utilities require a variety of networked interconnections and telecommunication technologies to monitor and control power system operations especially distribution system operations. [1] [2] [20].

The power distribution system is made up of transformers, poles and wire in a circuits. Distribution substations monitor and adjust circuits within the system. Loss or degradation or failure of equipment can occur over time, which can lead to outage or failure in distribution systems [1]. Customers are directly affected if connected to unreliable distribution system and they could experience poor energy supply even though the generation and transmission systems are highly reliable. This is because the quality of energy distributed to end users is what is used for operations, not what is generated or transmitted [2] [3].

The distribution substations in Obi-Wali, Port Harcourt, have transmission line voltages of 33kV and 11kV respectively. The voltage is then further reduced by distribution transformers to the utilization voltages of 415V three-phase or 220V single-phase supply required by most users. However, the electric power interruption continues to plague the region of Obi-Wali Port Harcourt to the extent that it has become a day to day phenomenon. The unreliable distribution systems in the region give power outage, Low voltage and medium voltage, which has caused damages to equipment used for businesses, production, revenue, and reputation, hence distribution managers must assess, analyse and implement a program that ensure reliability of distribution system. There is an urgent need for assessment of electric power distribution system of the Power Holding Company of Nigeria (PHCN), which include examining the physical factors that may contribute to the poor electric power infrastructure so that solution for improving the system performance is proffered such that quality of service and availability of service is possible for customers [4] [20]

Reliability is commonly defined as the probability that an item will perform a required function without failure understated condition for a stated period of time [5] [6] [7]. Reliability assessment of a distribution system is related to the performance efficiency at the customer load points [2] [8]. Hence, in this research, the problems militating against regular, good quality electric power supply in the Obi-Wali networks are identified with a view to proffering solutions and suggestions where necessary. Predictive Reliability Assessment Method is used to provide determine the existing performance of the distribution system and give solution for improvement. The simulation is carried out on ETAP for year 2016 to 2019 as the reliability indices along with other parameters such power outage rate, Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR) and Availability of equipment. The solution proffered can be implemented for the existing 11kV and 33kV distribution systems in Nigeria.

II. LITERATURE REVIEW

A fault analysis of 11kV distribution system plays a dominant role in the socioeconomic development of the community. The electricity industry in Nigeria has grown progressively more complex from a number of relatively small isolated power stations in the early 1950s to an integrated power system which the National Electric Power Authority (NEPA) now referred to as the Power Holding Company of Nigeria (PHCN), which was later defunct and divided into subsectors [9] [10]. The sub-sectors are made up of 18 companies which include: 11 Distribution Companies (DISCOs), 6 Generation Companies (GENCOs) and 1 Transmission Company of Nigeria (TCN). These companies are saddled with the responsibility of carrying out the functions relating to the generation, transmission, distribution, trading and bulk supply as well as resale of electricity in the country [11]. The electricity generated are transmitted through transmission lines that use three phases namely alternating current (AC), single-phase AC current and high-voltage direct current system. However, transmission of electricity using high voltage (110 KVA or 330 kVA) used in Nigeria, aids in the reduction losses [11].

All electricity industries worldwide experience power-delivery problems. Faults can be very destructive to power system. A great deal of study and development of devices and design of protection schemes have resulted in continual improvement in the prevention of damage to transmission lines, equipment and interruptions in generation following the occurrence of a fault [14]. Some common faults that affect electric distribution system are:

i. Buchholz Fault
ii. Earth Fault
iii. Over-current due to short-circuit in the system
iv. differential fault due to transformer winding
v. unbalanced current in transformer

2.1 Reliability

Reliability is characterized as the likelihood of a product, system or service performing its intended purpose effectively for a stated amount of time or operating without failure in a specified environment [6] [7]. As illustrated in Fig 1, the key components associated with reliability are Probability of success, Durability, Dependability, Quality over time and Availability to perform a function. To clearly understand reliability means to understand the following:

i. Probability: the likelihood of mission success
ii. Intended function: for example, to speed up, light, cut, rotate, or heat
iii. Satisfactory: perform with an acceptable level of compliance as per a specification
iv. Specific period of time: minutes, days, months, or number of cycles
v. Specified conditions: for example, temperature, speed, or pressure

Fig 1. Components of Reliability

2.2 Power Distribution System Reliability

According to [17] and [18], Reliability of power distribution system is the degree of performance of the elements of the bulk electric system that results in electricity being delivered to customers within accepted standards and in the amount desired. It measures the outage duration, the time required tore store supply, the frequency of the outage and the numbers of customers affected as well as the magnitude of adverse effects on the electric supply. In other words, Reliability of power distribution system include continuity of service, meeting customer demands, and the vulnerability of the power system.

2.3 Reliability Assessment Techniques

Reliability is the possibility that without loss, a device can continue to provide service [7]. Power systems reliability assessment has two approaches namely analytical and simulation techniques which includes cost reliability worth on normal and random behaviour of the system [15]. Analytical techniques represent the system by a mathematical model and evaluate the reliability indices from this model using direct numerical solutions. Simulation techniques estimate the reliability indices by simulating the actual process and random behaviour of the system. Those techniques can take into account random events such as outages and repairs of elements represented by general probability distributions, components' behaviour, load, and generation variation. Expected values of reliability indices together with their probability distributions could be evaluated. This information gives a very detailed description, and hence understanding of the system reliability. Nonetheless, the most typical barrier for the simulation approach is the large amounts of computing time [19]. In [12], Sequential Monte Carlo Simulation (SMCS) Framework was used to design models and probability distributions and it was utilized in [13] to evaluated the reliability behaviour of overhead lines using reliability parameters. In [16], a multi-state availability model has been proposed, whereby all possible combinations of component failures are enumerated and associated to a probability.

2.4 Reliability Assessment Parameters

Various parameters are used in this research to determine the reliability assessment of the distribution system of Obi-Wali Substation to give improvement of the system.

The basic reliability assessment indices for load indices 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 include calculating MTBF, Mean Time To Failures (MTTF), MTTR and Availability of equipment [7].

i. MTBF is the mean or average life of a system depending on the number of times (frequency) the system fails. It shows the average time of failure for all the failure times in the population. It is used for repairable items

ii. MTTF is the period of time from the installation of a device or component or system into operation to the time it fails permanently. It is used for non-repairable items that are thrown away when failure occur.

iii. MTTR is the time needed to recover a repairable component of the system's operations. The most popular way to measure MTTR is to simply obtain the cumulative total of all restoration times recorded and divide it by the amount of outages or failures registered.

iv. Availability is the likelihood at any given time that a network (or component) is accessible to users. It is determined as the average time fraction over an interval over which the scheme is up.

Power reliability indices as defined in IEEE Standard 1366 are given by System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Frequency Index (CAIFI), Customer Average Interruption Duration Index (CAIDI), Average Service Availability Index (ASAI) and Average Service Unavailability Index (ASUI).

i. SAIFI is an index that 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.
ii. 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.
iii. SAIDI is 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
iv. CAIDI is the average time needed to restore service to the average customer per sustained interruption
v. 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.
vi. ASUI is the index which has the complementary value compared to ASAI.

Reliability assessment for load and energy is carried out with parameters such as Load or Energy-Oriented Indices, Energy Not Supplied Index (ENS), Average Energy Not Supplied Index (AENS), Average Customer Curtailment Index (ACCI), Average Load Interruption Frequency Index (ALIFI), Average Load Interruption Duration Index (ALIDI), Momentary Average Interruption Frequency Index (MAIFI)

i. Load and energy oriented indices is the average load at each load point bus bar
ii. ENS is the index which represents the total energy not supplied by the system
iii. AENS is the index which represents the average energy not supplied by the system
iv. ACCI, this index represents the total energy not supplied per affected customer by the system.
v. ALIFI is analogous to the SAIFI and describes the interruptions on the basis of connected load (kVA) served during the year by the distribution system.
vi. ALIDI is factor is analogous to the (SAIDI) and describes the number of hours on average that each kVA of connected load was without service
vii. MAIFI is the total number of customer momentary interruptions divided by the total number of customers served. This is a reliability index that considers momentary interruptions that result from each single operation of an interrupting device and it occurs in a specified time not to exceed five minutes

Economics assessment is an instrument that ascertains the likely expenses and allocates qualities to the foreseen advantages of a proposed venture, program or policy. The Economics indices for the distribution system include sector customer damage function (SCDF), composite customer damage function (CCDF), Energy Not Supplied (ENS), Interrupted energy assessment rate (IEAR) index

i. SCDF is a cost function of each customer sector (industrial, commercial and residential customers). SCDF depict the sector interruption cost as a function of interruption duration.
ii. CCDF is an aggregation of the SCDF at specified load points and is weighted proportionally to the load at the load points.
iii. ENS is the Energy Not Supplied is cost for customer sector type and geographical location.
iv. IEAR provides a quantitative worth of the reliability for a particular load point in terms of cost for unit of energy not supplied.

III. MATERIALS AND METHOD

3.1 Description and Analysis of the Distribution system in Obi-Wali Substation

The distribution system of Obi-Wali Port Harcourt is fed from Afam Plant, an interconnected system. The power is stretched and transmitted through a 132 kV transmission line into the substation in various part of the state Port Harcourt Electricity Distribution Company (PHEDC) is a responsible in providing of electric power at this stage. the transmission line voltage is step-down to distribution line primary voltages of 11kV and 33kV respectively. These primary voltages are stepped-down further to 415V and 220V respectively at customer's level. The Obi-Wali 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 centres 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.

In this research study, some assumptions for the distribution system are that the system is design and construct as single radial and parallel systems. The single radial system has 11kV feeder supply direct to customer and 33kV feeder for interconnection between substation, while the parallel system has 33kV transformer (incomer) connected to two bus bar system (reserve and main) to supply 11kV feeder connected to customer. ETAP was used to simulate the system using the assessment indices. As shown from Fig 2, the Obi-Wali substation distribute power to different customers residing in different areas such as Obi-Wali Road S/S II, Haruk Kingdom Hall, Ihunwo street and MCC S/S through power transformers. The power transformers are Chakiricha S/S II (Oil type Transformer 500 KVA – 11/0.433KV), Obi-Wali Road S/S II (11/0.415kv, 500KVA Power Transformer), Iboloji S/S I (500 KVA Power Transformer), Worlu S/S II (132/33KV Mobile Transformer, 40MVA), MCC S/S II (500 KVA Power Transformer), Haruk Rd S/S II (11/0.415kv, 500KVA Power Transformer), and Iboloji S/S II (Transformer 500 KVA – 11/0.433KV). Fig 3 shows the different lumps of the Obi-Wali substation network.

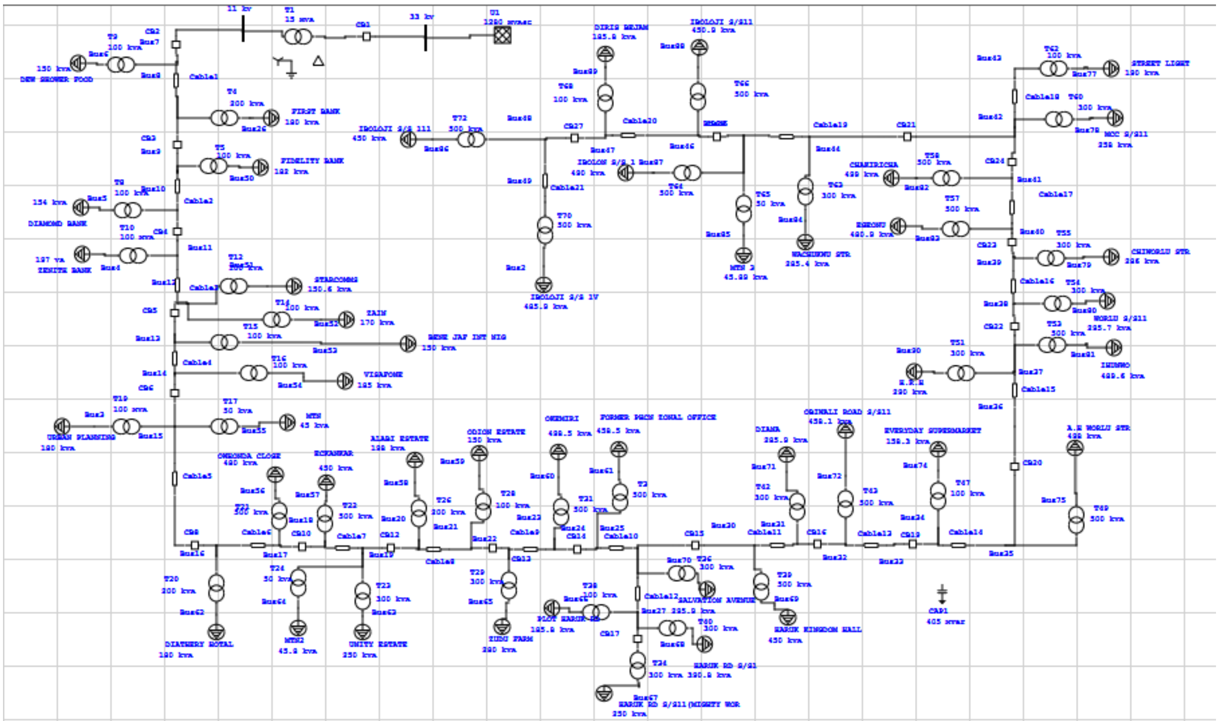

Fig. 2. Single Line Network Diagram of Obi -Wali Substation

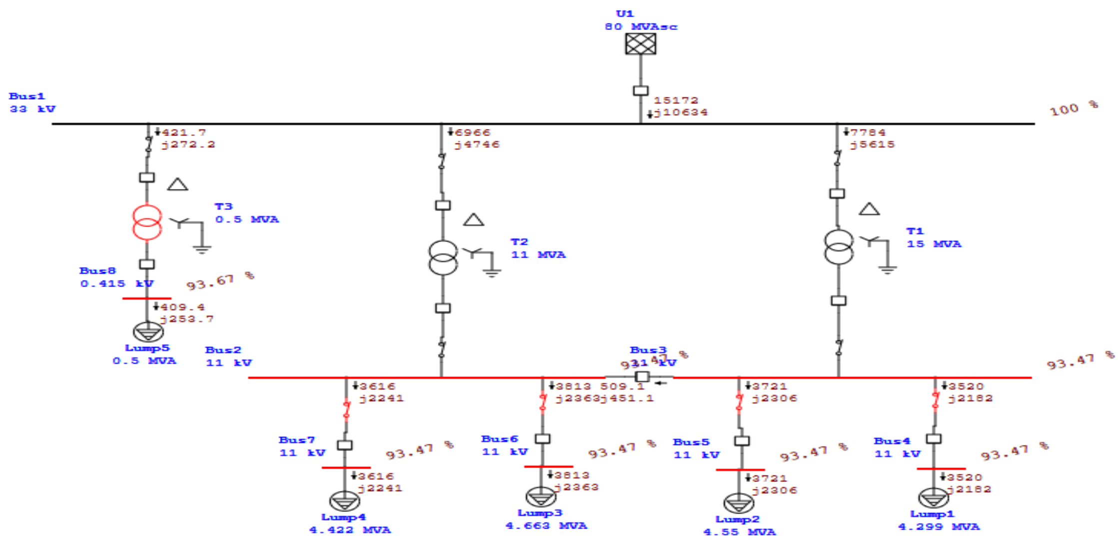

Fig. 3: Line Diagram of Obi-Wali Substation Network Showing the Different Lumps

3.2 *Materials*

Due to the nature of the research, physical instigation and data gathering was done at the Obi-Wali substation to identify power distribution problems that arise from both the customer side and the electric utility side. Some of the materials utilized in this research include the following

i. Distribution data were collected from the Port Harcourt Electricity Distribution Company (PHEDC), from year 2016 to 2019. The data include number of consumers on every circuit on each transformer/substation, number of consumers on each feeder, numbers of feeders (33kV, 11kV), numbers of outages on each feeder, duration of each outage, causes of outages, equipment in the reserve (transformer, feeder pillar, fuse, pole, overhead cables etc.), age of distribution equipment/item.

ii. Observations from the investigation at the Obi-Wali substation show Radial distribution system, Incoming line is 33kV and three 11kV outgoing lines, Conductor size for 11kV is 95mm^2 and 50mm^2 respectively and for for 33kV is 95mm^2. ACSR conductor used for incoming and outgoing feeders, 10MVA rating Step-down distribution transformers – some not fully loaded, Load type is lump load receiving 400V

iii. Electrical Transient Analyser Program (ETAP) Version 12.6 software was used simulate the radial distribution system and for the reliability assessment and improvement.

3.3 *Method*

Predictive Reliability Assessment Method was used for this research. The method 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. The method is a top-down method which involves predicting how reliable the system can be from the tracking failure rate and mapping out improvement. The year 2016 to 2019 were considered for the reliability assessment.

The basic reliability indices are expressed in Equ. (1) to. (8). At each load point *P*, the basic equations for calculating the reliability indices are given by Equ. (9) to (12). Power reliability indices are given by Equ. (13) to (18). Load and Energy reliability indices are given by Equ (19) to (25). Economic reliability indices are given by Equ. (26) to (29).

$$Failure\ Rate, \lambda = \frac{Frequency\ of\ failures}{period\ of\ operation\ (hr)} = \frac{F}{T} \qquad (1)$$

$$Average\ Annual\ Failure\ Rate, \lambda_s = \sum \frac{F}{T}\ (f/yr) \qquad (2)$$

$$Load\ Point\ Repair\ Rate,\ \mu = \frac{T_0}{(\sum T_0 / \sum F)}\ (repair/yr) \qquad (3)$$

$$Annual\ Outage\ \ Duration,\ \ \mu\lambda = \sum \frac{T_0}{T} (hr/yr) \qquad (4)$$

$$Average\ Outage\ Duration,\quad r_y = {}^{\mu y}/_{\lambda y}\,(hr) \tag{5}$$

$$MTBF = \frac{Period\ of\ operation}{Frequency\ of\ failures} = \sum \frac{T}{F}\,(hr) \tag{6}$$

$$MTTR = \frac{Outage\ Time}{Frequency\ of\ failures} = \sum \frac{T_0}{F}\ (hr) \tag{7}$$

$$Availability,\quad A = \frac{MTBF}{MTBF+MTTR}\,(p.u) \tag{8}$$

$$Average\ Failure\ rate\ at\ Load\ Point\ P,\quad \lambda_p = \frac{\sum F}{T}\,(f/yr) \tag{9}$$

$$Annual\ Outage\ Duration\ at\ P,\quad \lambda_p = \frac{\sum Tdx}{T}\,(hr/yr) \tag{10}$$

$$Average\ Outage\ Duration\ at\ P,\quad r_p = \frac{\mu p}{\lambda_p}\,(hr) \tag{11}$$

$$Annual\ outage\ MTTR = \sum \frac{Tdx}{F} \tag{12}$$

$$SAIFI = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}} = \frac{\sum_i \lambda_i N_i}{\sum_i N_i} \tag{13}$$

$$CAIFI = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers affected}} = \frac{\sum(No)}{\sum(Ni)} \tag{14}$$

$$\text{SAIDI} = \frac{\text{Sum of customer interruptions durations}}{\text{Total number of customers served}} = \frac{\sum_i U_i N_i}{\sum_i N_i} \tag{15}$$

$$CAIDI = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}} = \frac{\sum_i U_i N_i}{\sum_i \lambda_i N_i} = \frac{\text{SAIDI}}{\text{SAIFI}} \tag{16}$$

$$ASAI = \frac{\text{Customer hours of avaliable service}}{\text{Customers hours demanded}} = \frac{\sum_{iNi} \times 8760 - \sum_i UiNi}{\sum_{iNi} \times 8760} \tag{17}$$

$$ASUI = 1 - ASAI = \frac{\text{Customer hours of unavaliuavle service}}{\text{Customers hours demanded}} = \frac{\sum_i \text{U}_i \text{N}_i}{\sum_i \text{N}_i \times 8760} \tag{18}$$

$$Average\ Load, L_a = L_p \times L_f = \frac{\text{total energydemanded in period of interest}}{\text{periodof interest}} = \frac{E_d}{t} \tag{19}$$

$$ENS = \sum_i L_{a(i)} U_i \tag{20}$$

$$AENS = \frac{\text{Total energy not supplied}}{\text{Total number of customers served}} = \frac{\sum_i L_{a(i)} U_i}{\sum_i N_i} \tag{21}$$

$$ACCI = \frac{\text{Total energy not supplied}}{\text{Total number of customers affected}} = \frac{\sum_i L_{a(i)} U_i}{\sum_i N_o} \tag{22}$$

$$ALIFI = \frac{\text{Total load interruptions}}{\text{Total connected load}} = \sum_{i=1}^{m} \frac{L_i}{L} \tag{23}$$

$$ALIDI = \frac{\text{Total KVA– Hours interrupted}}{\text{Total connected KVA}} = \sum_{i=1}^{m} \sum_{j=1}^{ki} \frac{I_{ij} T_{ij}}{L} \tag{24}$$

$$MAIFI = \frac{\text{Total number of customer momentary interruptions}}{\text{Total number of customer served}} = \frac{\sum I\ D_i \times N_i}{N_T} \tag{25}$$

$$CCDF = \sum_{i=1}^{n} C_i + \text{SCDF}i \times \frac{Cost}{KW} \tag{26}$$

$$EENSi = \sum_{i=1}^{Ne} L_i + r_{ij} \times \lambda_{ij} = X p \mu \rho \tag{27}$$

$$ECOSTi = \sum_{i=1}^{Ne} \text{SCDF}_{ij} + r_{ij} \times \lambda_{ij} \quad (28)$$

$$IEARi = \frac{ECOST_i}{EENS_i} \quad (29)$$

Where:

λ = : failure rate; r = outage duration; μ = average annual outage time; F = Frequency of failures; T = Period of operation; T_0 = Outage time; Tdx = Annual outage time (in hours); L = is total connected load (kVA) in subdivision; L_p = peak load demand ; L_f = load factor; U_i = average annual outage time at load point i; L_i = total connected load (kVA) interrupted by ith interruption; E_d = total energy demanded in the period of interest t; m = number of interruptions in a subdivision of the network; k_i = number of restoration steps associated with the ith interruption; I_{ij}= connected load restored during jth restoration step; $T_{i\ j}$ = cumulative interruption duration (hours) for customers/load affected by jth restoration step associated with ith interruption; IDi = number of interrupting device operations; N_i = number of customers experiencing momentary interruptions; N_T = total number of customers served; ECOSTi is Expected customer outage cost at load point i; EENSi is Expected Energy Not Supplied at load point i; C_i is the energy demand of customer type I; Xp = average load of load point,p; μp = annual outage duration at load point p;

IV. RESULTS

This section shows the results after the simulation of the Obi-Wali distribution system using the various reliability assessment indices. Table 1 and Fig 4 shows the relationship between load points with respect to average failure rate for the period of 2016-2019. The number of Customers served (N_i) and the number of Customer Interruptions (N_o) are constant. Fig 5 shows the relationship between load points with respect to Annual outage duration for the period of 2016-2019. Fig 6 shows the relationship between load points in respect to the Average outage duration for the period of 2016-2019. Table 2 shows the relationship between load points with respect to MTTR for the period of 2016-2019. Table 3 shows the relationship between load points with respect to Availability for the period of 2016-2019. Fig 7 to Fig 11 show the cost analysis of EENS and ECOST for Chakiricha S/S II, Diris, Iboloji S/S II, Obi-Wali Road S/S II, and Zudu Farm respectively.

The highest average failure rate from 2016 to 2019 is 0.1021 (f/yrs), which indicates number of component failure is highly expected at those points, therefore the equipment should be kept properly to avoid malfunction. The highest annual outage duration is 0.6563 hrs/yrs, which means that the outages time occurring on a power system could result in some losses of electrical energy being supplied. The highest average outage duration is 6.4343 hrs which means that at the end of the switching time the faulty components are isolated and the supply is restored to the given load point.

Table 1: Relationship between Load Points with Average Failure Rate (λ_i) for 2016-2019

Load Point	2016	2017	2018	2019	No. of Customers served (N_i)	No. of Customer Interruptions (No)
VISAFONE	0.0995	0.0970	0.0997	0.0985	816	495
MTN	0.0992	0.0910	0.0982	0.0920	707	383
IBOLOJI S/S III	0.0856	0.0861	0.0856	0.0868	850	437
OWHONDA CLOSE	0.0979	0.0970	0.0979	0.0965	950	424
PLOT HARUK RD	0.0959	0.0953	0.0959	0.0945	896	478
H.R.H	0.0858	0.0865	0.0858	0.0865	156	75
CHAKIRICHA	0.0962	0.0958	0.1021	0.0993	886	472
EGEONU	0.0842	0.0839	0.0981	0.0972	956	428
IHUNWO	0.1001	0.0993	0.0995	0.0816	860	408
WORLU S/S II	0.0984	0.0981	0.0970	0.0855	840	475
CHIWORLU STR	0.0970	0.0976	0.0858	0.0863	801	485
MCC S/S II	0.0977	0.0972	0.1021	0.0979	968	429
STREET LIGHT	0.0993	0.0998	0.0650	0.1006	804	484
HARUK RD S/S I	0.0958	0.0954	0.0998	0.0954	816	483
SALVATION AVENUE	0.0977	0.0970	0.0977	0.0970	225	173
ECKANKAR	0.0799	0.0810	0.0810	0.0810	120	84
ALABI ESTATE	0.0856	0.0867	0.0856	0.0867	216	140
ODION ESTATE	0.0739	0.0744	0.0858	0.0744	207	154
OKEMIRI	0.0993	0.0995	0.0982	0.0995	850	425
FORMER PHCN ZONAL OFFICE	0.0619	0.0635	0.1011	0.0954	874	440
DIANA	0.0858	0.0856	0.0858	0.0970	160	135
OBIWALI ROAD S/S II	0.1021	0.1018	0.0962	0.0810	804	480
EVERYDAY SUPER MARKET	0.0650	0.0656	0.0842	0.0867	45	15

A.H. WORLU STR	0.0998	0.0993	0.1001	0.0744	852	425
HARUK KINGDOM HALL	0.0977	0.0980	0.0984	0.0995	231	182
HARUK RD S/S II	0.0981	0.0976	0.0650	0.0954	886	428
ZUDU FARM	0.0995	0.0993	0.0998	0.0970	150	115
UNITY ESTATE	0.0970	0.0972	0.0977	0.0810	168	135
MTN 2	0.0810	0.0816	0.0995	0.0656	130	83
DIATHERY HOTEL	0.0856	0.0855	0.0992	0.0993	160	140
DIRIS BEJAM	0.0858	0.0863	0.0856	0.0976	156	119
IBOLOJI S/S II	0.0982	0.0979	0.0979	0.0972	872	458
IBOLOJI S/S I	0.1011	0.1006	0.0959	0.0998	852	422

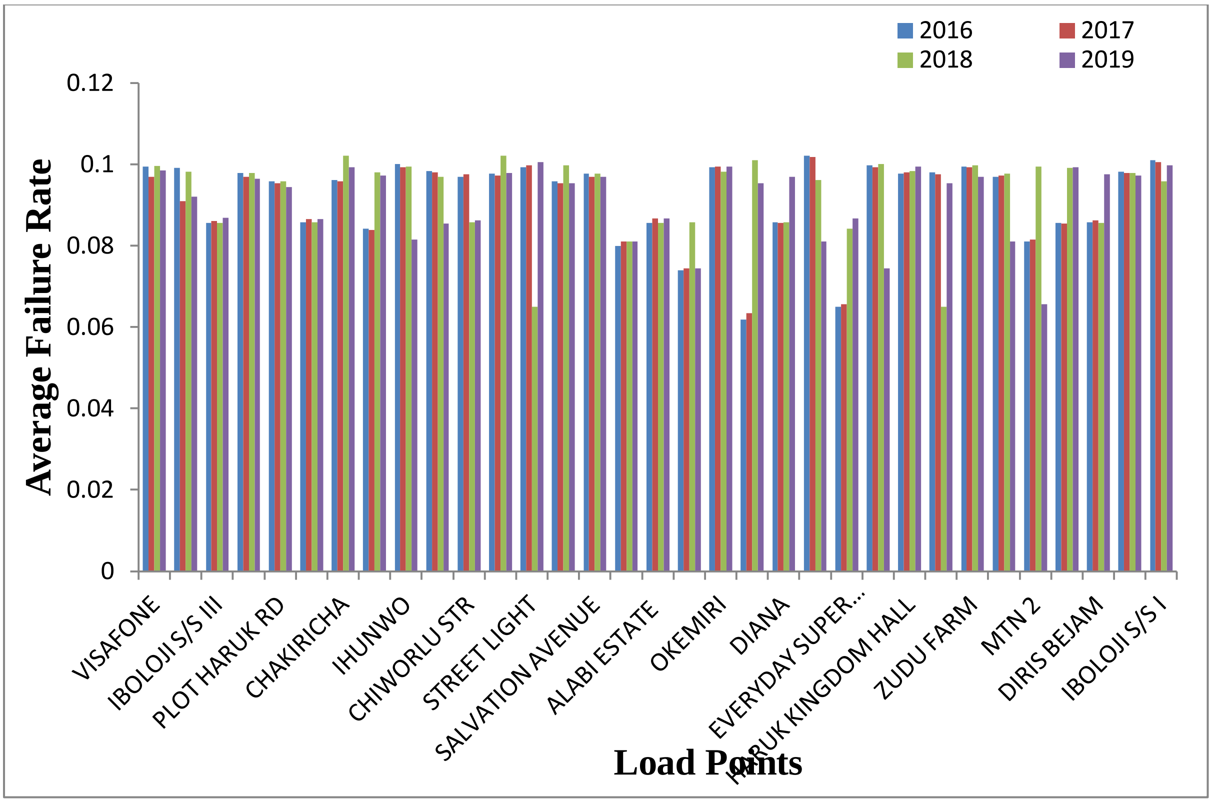

Fig. 4: Load Points with respect to Average Failure Rate (λ_i) for 2016-2019

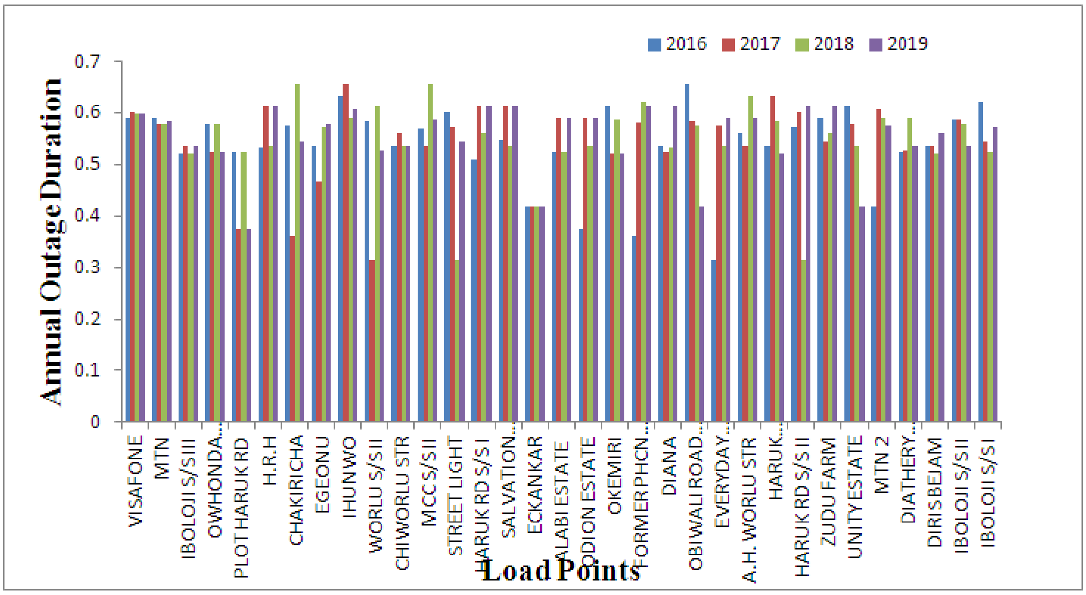

Fig. 5: Load Points with respect to Annual Outage Duration (μ_i) for 2016-2019

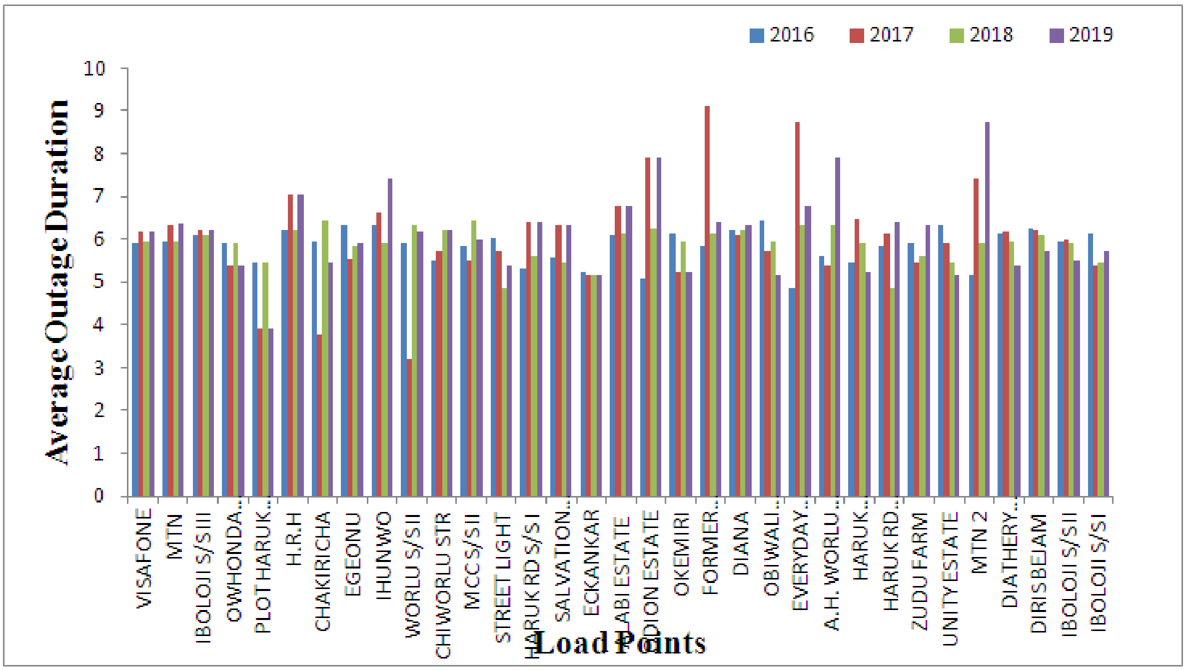

Fig. 6: Load Points with respect to Average Outage Duration (r_i) for 2016-2019

Table 5: Load Points with respect to MTTR for 2016-2019

Load Point	2016	2017	2018	2019
VISAFONE	5.910	6.176	5.915	6.180
MTN	5.942	6.337	5.942	6.446
IBOLOJI S/S III	6.093	6.198	6.093	6.204
OWHONDA CLOSE	5.915	5.394	5.915	5.394
PLOT HARUK RD	5.458	3.934	5.458	3.934
H.R.H	6.210	7.058	6.216	7.058
CHAKIRICHA	5.961	3.770	6.424	5.459
EGEONU	6.341	5.544	5.825	5.927
IHUNWO	6.328	6.609	5.923	7.426
WORLU S/S II	5.928	3.217	6.311	6.163
CHIWORLU STR	5.505	5.742	6.216	6.210
MCC S/S II	5.823	5.498	6.424	5.984
STREET LIGHT	6.041	5.725	4.854	5.385
HARUK RD S/S I	5.311	6.417	5.611	6.417
SALVATION AVENUE	5.589	6.311	5.473	6.311
ECKANKAR	5.220	4.305	5.154	4.305
ALABI ESTATE	6.113	6.781	6.120	6.781
ODION ESTATE	5.069	7.920	6.231	7.920
OKEMIRI	6.149	5.240	5.959	5.240
FORMER PHCN ZONAL OFFICE	5.832	7.111	6.151	6.417
DIANA	6.216	6.113	6.210	6.311
OBIWALI ROAD S/S II	6.424	5.717	5.961	4.305
EVERYDAY SUPER MARKET	4.854	8.784	6.341	6.781
A.H. WORLU STR	5.611	5.379	6.328	7.920
HARUK KINGDOM HALL	5.473	6.461	5.928	5.240
HARUK RD S/S II	5.825	6.140	4.854	6.417
ZUDU FARM	5.923	5.459	5.611	6.311
UNITY ESTATE	6.311	5.927	5.473	4.305
MTN 2	5.154	7.426	5.910	8.784
DIATHERY HOTEL	6.120	6.1633	5.942	5.379
DIRIS BEJAM	6.231	6.210	6.093	5.742
IBOLOJI S/S II	5.959	5.984	5.915	5.498
IBOLOJI S/S I	6.151	5.385	5.458	5.725

Table 6: Load Points with respect to Availability Rate for 2016-2019

Load Point	2016	2017	2018	2019
VISAFONE	0.6296	0.6252	0.6286	0.6357
MTN	0.6292	0.6339	0.6292	0.6453
IBOLOJI S/S III	0.6573	0.6518	0.6573	0.6425
OWHONDA CLOSE	0.6332	0.6564	0.6332	0.6564

PLOT HARUK RD	0.6564	0.7272	0.6564	0.7272
H.R.H	0.6523	0.6208	0.6520	0.6208
CHAKIRICHA	0.6354	0.7344	0.6037	0.6484
EGEONU	0.6518	0.6825	0.6361	0.6343
IHUNWO	0.6122	0.6037	0.6290	0.6226
WORLU S/S II	0.5928	0.7599	0.6201	0.6551
CHIWORLU STR	0.6518	0.6408	0.6520	0.6510
MCC S/S II	0.6374	0.6515	0.6037	0.6305
STREET LIGHT	0.6249	0.6361	0.7599	0.6484
HARUK RD S/S I	0.6625	0.6201	0.6408	0.6201
SALVATION AVENUE	0.6467	0.6201	0.6515	0.6201
ECKANKAR	0.7056	0.7053	0.7053	0.7053
ALABI ESTATE	0.6564	0.6295	0.6561	0.6295
ODION ESTATE	0.7272	0.6291	0.6514	0.6291
OKEMIRI	0.6208	0.6571	0.6309	0.6571
FORMER PHCN ZONAL OFFICE	0.7344	0.6331	0.6164	0.6201
DIANA	0.6520	0.6564	0.6523	0.6201
OBIWALI ROAD S/S II	0.6037	0.6320	0.6354	0.7053
EVERYDAY SUPER MARKET	0.7599	0.6342	0.6518	0.6295
A.H. WORLU STR	0.6408	0.6517	0.6122	0.6291
HARUK KINGDOM HALL	0.6515	0.6121	0.5928	0.6571
HARUK RD S/S II	0.6361	0.6252	0.7599	0.6201
ZUDU FARM	0.6290	0.6484	0.6408	0.6201
UNITY ESTATE	0.6201	0.6343	0.6515	0.7053
MTN 2	0.7053	0.6226	0.6296	0.6342
DIATHERY HOTEL	0.6561	0.6551	0.6292	0.6517
DIRIS BEJAM	0.6514	0.6510	0.6573	0.6408
IBOLOJI S/S II	0.6309	0.6305	0.6332	0.6515
IBOLOJI S/S I	0.6164	0.6484	0.6564	0.6361

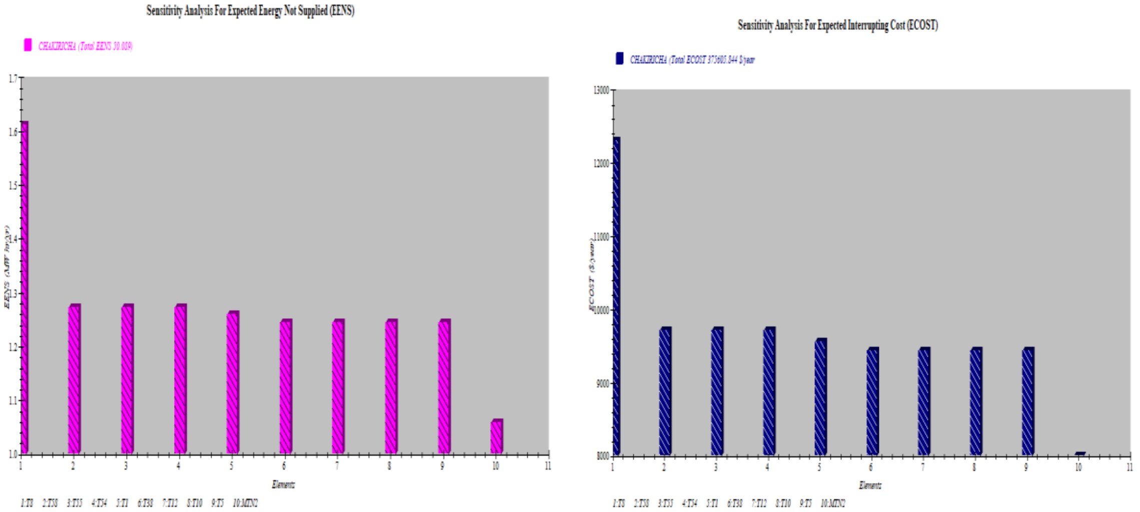

Fig. 7: Cost Analysis of EENS and ECOST for Chakiricha S/S II

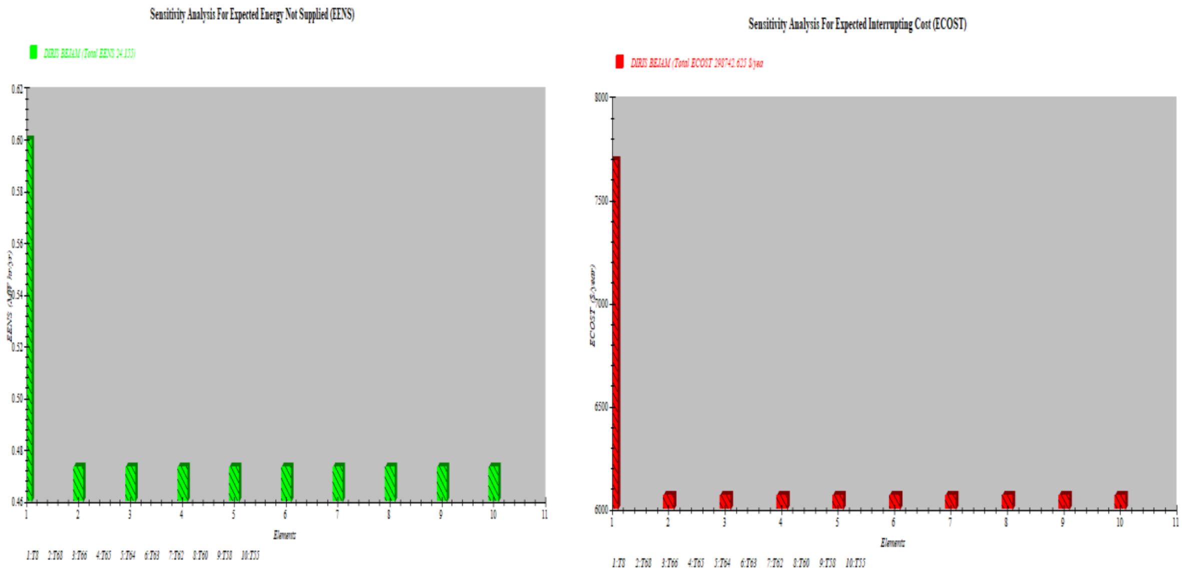

Fig. 8: Cost Analysis of EENS and ECOST for Diris

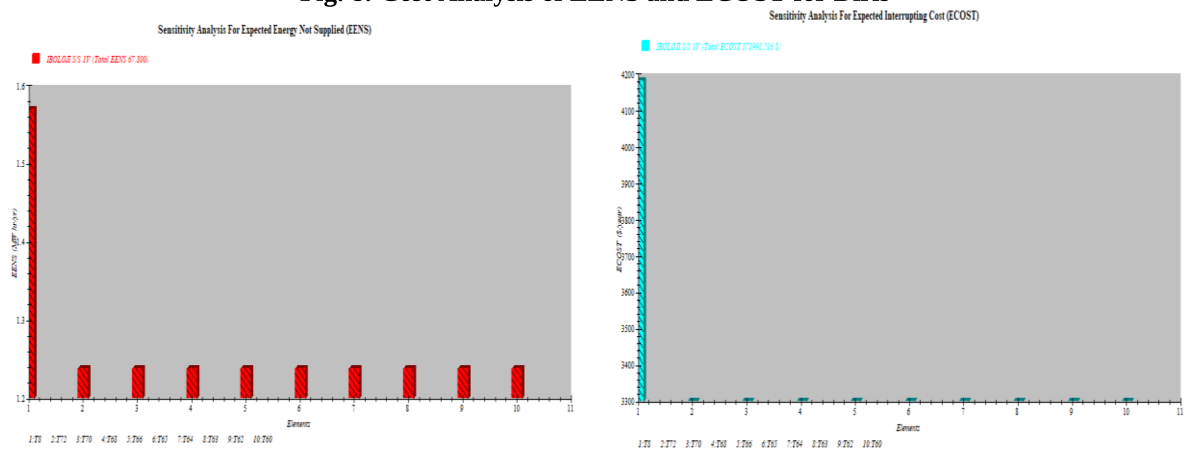

Fig. 9: Cost Analysis of EENS and ECOST for Iboloji S/S II

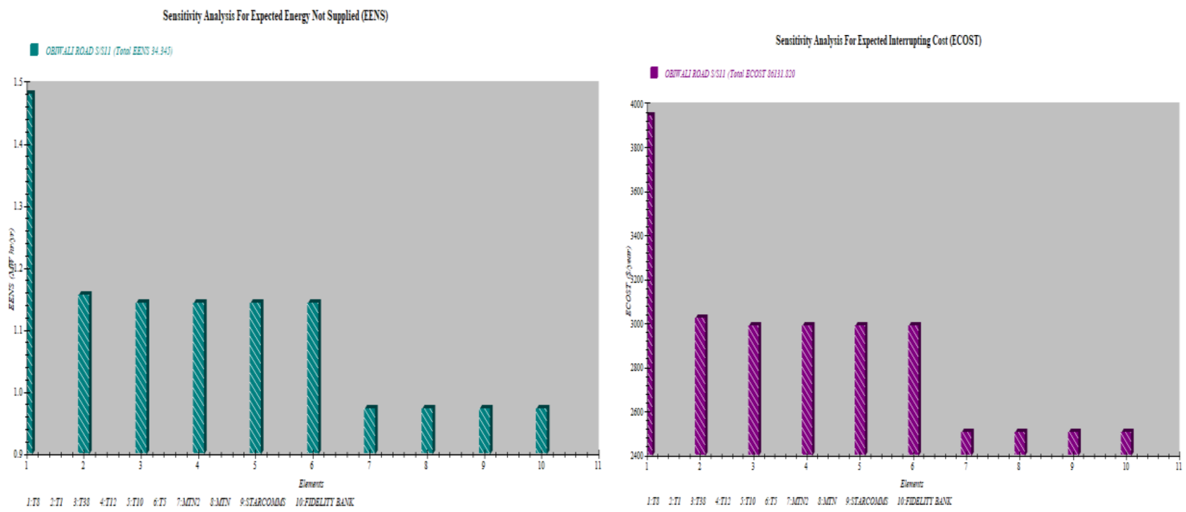

Fig. 10: Cost Analysis of EENS and ECOST for Obi-Wali S/S II

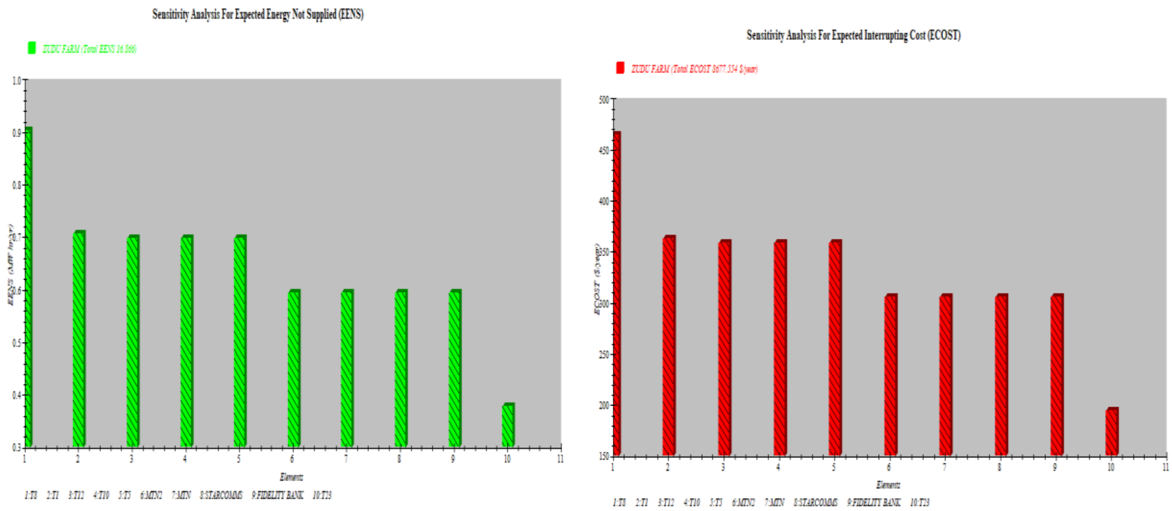

Fig. 11: Cost Analysis of EENS and ECOST for Zudu Farm

V. CONCLUSION

This research critically examined the analysis of 11kV Obi-Wali Rumuigbo distribution network in Port Harcourt, Nigeria, for improved performance using analytical method. The existing distribution networks 33kV and 11kV system were analysed using reliability indices from the year 2016 to 2019. From our results obtained, it was concluded that the following area were considered; investigation of the power distribution problems that arises from both the customers side and the electric utility side at selected substations, to assess and evaluate the existing reliability parameters of average failure rate (λ), annual outage duration (r) and average outage duration (U), calculation of customer-hours, Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR) and Availability results shown the distribution network systems of Obi-Wali grid networks. However, the frequency of failure rate and duration of outages on different equipment from 2016-2019 at Obi-Wali feeder was determine such as supply of line (11KV), Busbar, Transformer, Circuit breaker, switchgear, fuse, surge arrester and earth fault were calculated for the purpose of analysis. From the analysis, it is recommended that load management should be considered as a method used in improving the performance of equipment to allow the system should be allowed to operates within its prescribed limits in order to helps reduce losses and improve the efficiency of equipment.

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