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Research Article

Probabilistic assessment of transmission station in Nigeria

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ABSTRACT

To know the kind of maintenance that should be carried out and when to carry out the maintenance in a power system, it is very important to investigate the reliability and availability of various sections of the power system. Therefore, in this paper, the probabilistic worth of Ikorodu transmission station (ITS) has been discussed. Available data for the study were collected from ITS; thereafter, the electrical transient analyzer program 12.6 was used to model the oneline diagram of the network of interest in the edit mode. The network was eventually simulated in the run mode and interpreted graphically using the Microsoft Excel 2007 software. Results show that the lowest and highest values of energy not supplied (ENS) were recorded in Fakale and Industrial 33kV feeders, respectively. Further results show the ENS for ITS is very high which may lead to loss of revenue also, it was revealed from the study that the average service availability index deviates from acceptable international standards. There is a need therefore, for the authority concerned to improve on the maintenance technique used in the station in order to for sustainability to be recorded in the station.

Keywords: Electrical Analyzer Transient Program, modeling, Nigeria, reliability, simulation

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INTRODUCTION

Before a rapid development can be recorded in any nation(s), there must be a reliable power supply to cater for the load; there should also be the presence of redundant unit(s) that should be called in action in cases of emergency. It is already an established fact that the western world is leading in science technology innovation today because they have taken full advantage of the opportunities that emanate from a reliable power supply not only that they are but also building strong redundant unit(s) as well as operating a strong maintenance scheme. However, the reverse seems to be the case in developing countries especially in Africa characterized by energy poverty thus slowing down the pace of technology within this region. This has greatly affected the citing of industries in these regions and makes their products more expensive as compared to developed countries.[1] Despite the complete privatization of the Nigerian power sector in 2013, Nigerian electricity generation and supply still represents around 4000 MW or less for a population of approximately 170 million people.[2] Inspite of the government's claims of huge investment in the sector, lack of network access and constant power outage has been a common experience by the Nigerian populace. At present, just 10% of rural households and 40% of the country's entire the population have access to electricity.[3] Therefore, it is paramount for electrical energy supply to be available 24 h a day for national economic growth. Hence, it is of utmost important for electric power utilities throughout the world to ensure they meet customer demands at a reasonable level of service reliability.

REVIEW OF RELATED LITERATURES

Reliability is the probability that a system, item, component, equipment, etc., will continue functioning without failure under a given environmental condition within a period of time. It is worth noting that there is a convergence where all definitions of reliability synchronize irrespective of the area of engineering study or otherwise. Hence, the definition of reliability according to Allan and Eriksson, Moubray, Okaro

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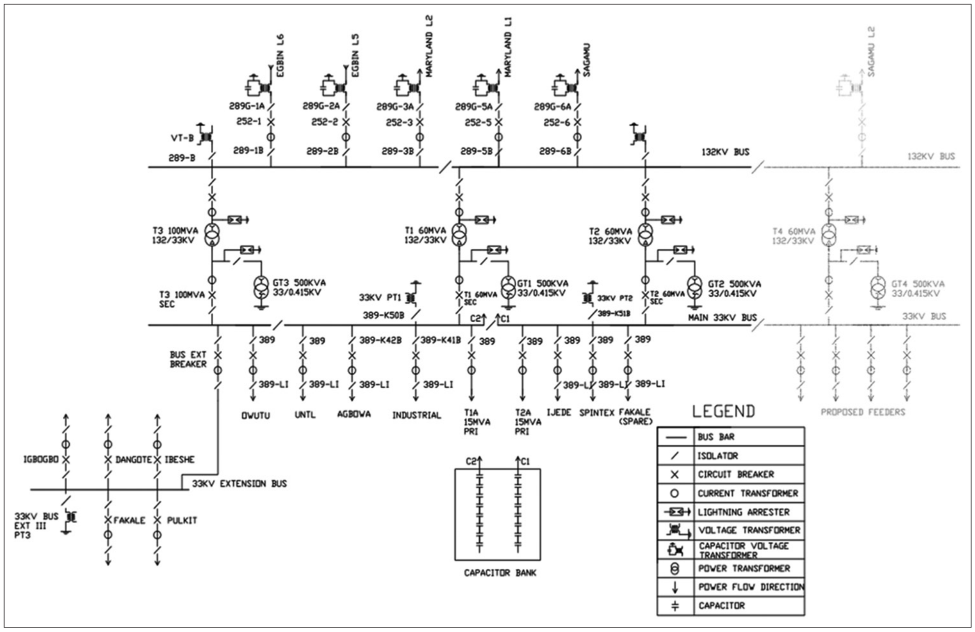

Figure 1: One-line diagram of Ikorodu transmission station

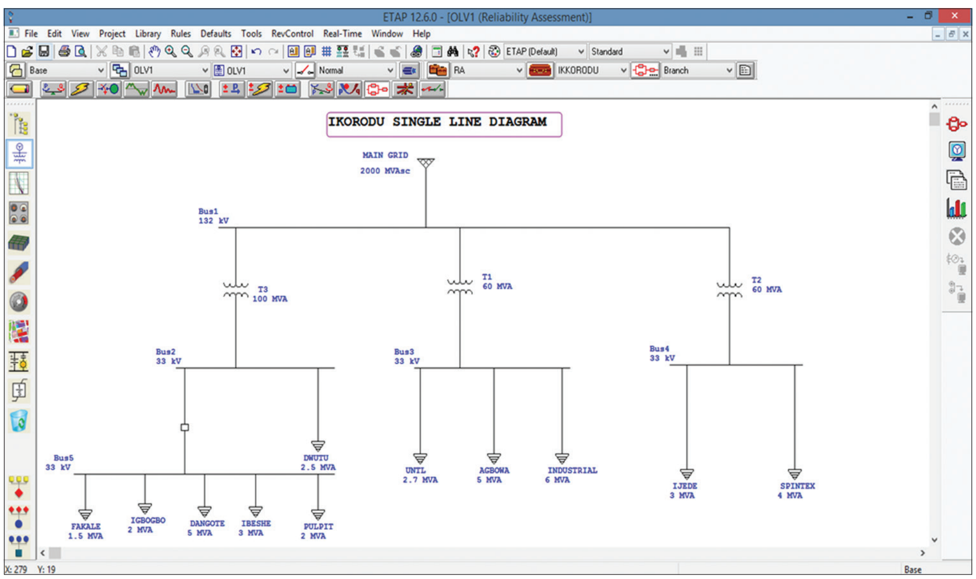

Figure 2: One-line diagram of Ikorodu transmission station on the Electrical Transient Analyzer Program environment

and Tao, Ryan *et al*., Edward and Richard[4-8] and lots more can be summarized as the chances of a zero tolerance to an unsatisfactory event.

The reliability analysis of 33kV feeders in Edo State Nigeria using the LPI was carried out by Airoboman *et al*.[9] and the obtained results show that none of the feeders were operated within acceptable international standards.

The modeling and assessment of the reliability of the Nigerian grid were carried out[10] using the analytical method; the authors suggested policy enforcement as a means of improving the reliability of the grid. The forecasting of the behavioral trend of the reliability of electricity distribution system in Rivers State Nigeria using the NEPLAN software was carried out by Uhunmwagho and Okedu,[11] the work which determined various values for the various customer based indices (CBI) show that the obtained results were not within acceptable standards of average service availability index (ASAI). The authors further suggested that the use of NEPLAN software can aid in predicting failure in the system. A poor reliability was noticed by Jibril and Ekundayo[12] in a reliability assessment study carried out in Kaduna State, Nigeria. One of the major reasons for the poor reliability was linked to the ever-increasing

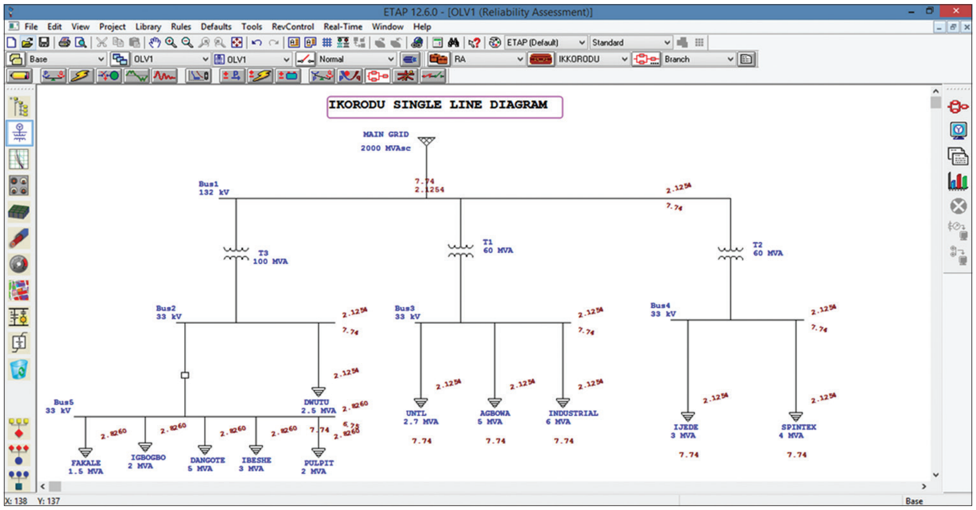

Figure 3: One-line diagram showing the simulated results on Electrical Transient Analyzer Program

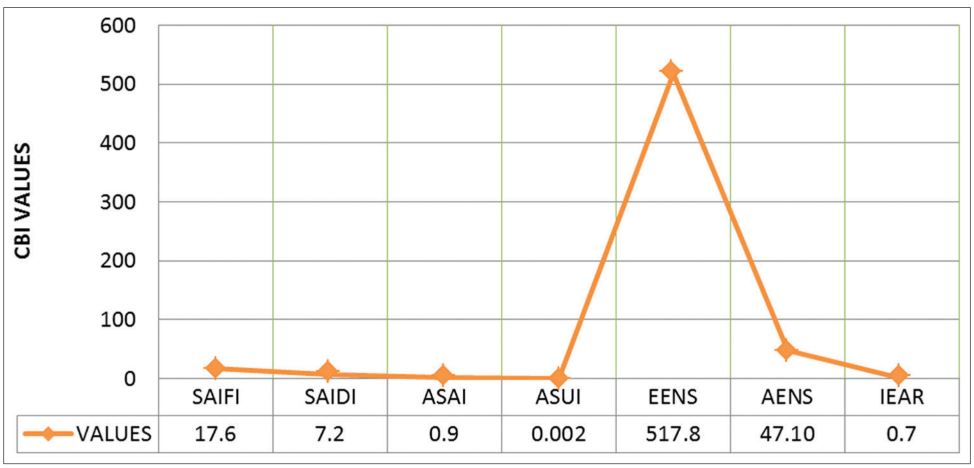

Figure 4: Graph of customer based indices

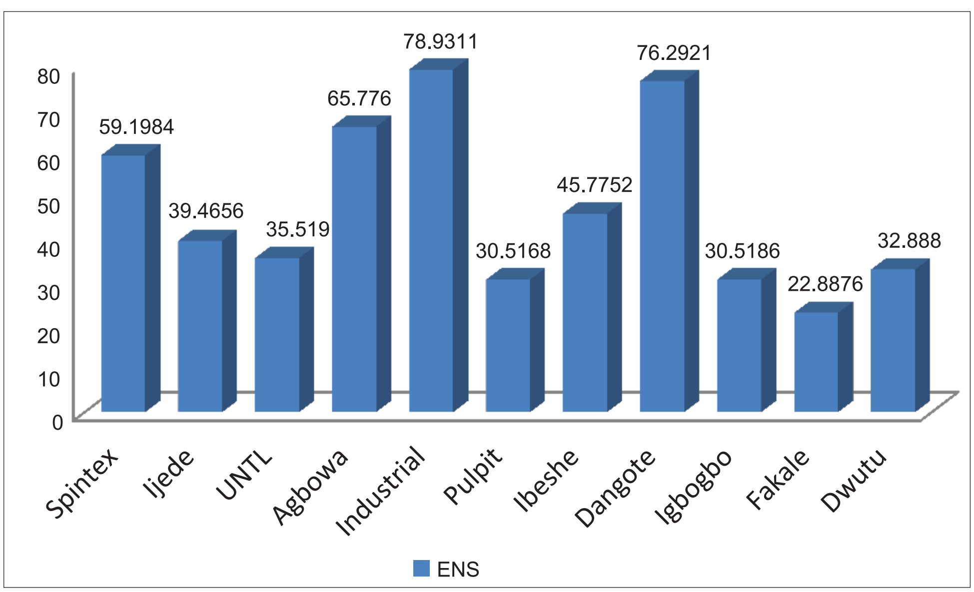

Figure 5: Graph of ens in its

number forced outage. A study to investigate the reliability of distribution transformer was carried out by Sulaiman and Ali,[13] the authors identified overloading of transformer as one of the causes of a frequent power outage, and this eventually leads to poor reliability of the system. In a study carried out by Odior *et al*.,[14] the author was quick to identify policy paralyzes as a bane in the Nigerian power sector. Further work carried out by Ngaja *et al*.[15] in the North-Eastern part of Nigeria using simple reliability analysis shows that the reliability of the network is seasonally dependent as shown in equation 1.

$$Reliability of\ Nigeria\ Power\ Sector \propto \frac{Rainy\ Season}{Dry\ Season} \quad (1)$$

The work further identifies poor maintenance technique, activities of vandals as well as obsolete equipment as other causes of poor system performance. It is with a view to improve the maintenance of the system that[16-18] suggested that a more recent maintenance technique should be introduced into the system for properly management of asset while[19] did work on the framework and application of the maintenance technique. From the review above, it is evident that the power system network in Nigeria is characterized with: Lack of sustainable policy and this has made the authority concerned to operate the system out of acceptable standards, the network is further characterized with overloading, poor maintenance, etc. Various studies have been carried out on reliability study, but no assessment has been done yet on Ikorodu transmission station (ITS). The electrical transient analyzer program (ETAP) 12.6 is used to determine the reliability of the network. ETAP is a sophisticated tool that is user-friendly and interactive. The ETAP environment can be used in the simulation of problems that are non-linear in nature. When the network becomes large, ETAP is a tool that can be trusted to yield a good result other than using the analytical method. In reliability studies, especially when the available data are not exhaustive enough, the ETAP can be used. When calculating the CBI in a given reliability study, equations 2–13 can be used in the ETAP environment. This paper, therefore, is aimed to carry out reliability analysis on ITS in Lagos State Nigeria to determine the reliability indices of the network.

Table 1: Input data of load

Feeder name	BUS I.D	Load (kW)	λ_A	MTTR
Spintex	4	3600	0.3664	6.99
Ijede	4	2400	0.1045	2.77
UNTL	3	2160	0.0269	8.88
Agbowa	3	4000	0.2556	2.44
Industrial	3	4800	0.5091	3.43
Pulpit	5	1600	0.800	2.11
Ibeshe	5	2400	0.0190	2.04
Dangote	5	4000	0.4006	4.37
Igbogbo	5	1600	0.1750	2.22
Fakale	5	1200	0.0205	2.70
Dwutu	2	2000	0.1679	3.22

METHODOLOGY

The following reliability indices were utilized in the analysis of the system network.

Average Failure Rate at Load Point *i*, λ_i (f/yr)

This is expressed as:

$$\lambda_i = \sum_{j \in N_e} \lambda_{e,j} \quad (2)$$

Where;

$\lambda_{e,j}$ is the average failure rate of element *j*

N_e is the total number of the elements whose faults will interrupt load point *i*.

Table 2: Output report from load point

Feder name	BUS I.D	AIR (f/yr)	AvOD (hr)	AOD (hr/yr)	ENS MWhr/yr
Spintex	4	2.1254	7.74	16.440	59.1984
Ijede	4	2.1254	7.74	16.440	39.4656
UNTL	3	2.1254	7.74	16.440	35.5190
Agbowa	3	2.1254	7.74	16.440	65.7760
Industrial	3	2.8260	6.75	19.0730	78.9311
Pulpit	5	2.8260	6.75	19.0730	30.5168
Ibeshe	5	2.8260	6.75	19.0730	45.7752
Dangote	5	2.8260	6.75	19.0730	76.2921
Igbogbo	5	2.8260	6.75	19.0730	30.5186
Fakale	5	2.1254	7.74	16.4440	22.8876
Dwutu	2	2.1254	7.74	16.4440	32.8880

AIR: Average interruption rate, AvOD: Average outage duration, AOD: Annual outage duration, ENS: Energy not supplied

Table 3: Calculated CBI from ETAP

CBI	Values
SAIFI (f/customer.yr)	2.4439
SAIDI (hr/customer.yr)	17.6390
CAIDI (hr/customer interruption)	7.218
ASAI (pu)	0.9980
ASUI (pu)	0.00201
EENS (MWhr/yr)	517.767
ECOST ($/yr)	386, 429.50
AENS (MWhr/customer.yr)	47.0697
IEAR ($/kW hr)	0.746

CBI: Customer based indices, ETAP: electrical transient analyzer program, SAIFI: System average interruption frequency index, SAIDI: System average interruption duration index, CAIDI: Customer average interruption duration index, ASAI: Average service availability index, ASUI: Average service unavailability index, EENS: Expected energy not supplied, AENS: Average energy not supplied index, IEAR: Interrupted energy assessment rate, ECOST: Expected interruption cost

Annual Outage Duration (AOD) at Load Point *i*, U_i (hr/yr)

This is expressed as:

$$U_i = \sum_{j \in N_e} \lambda_{e,j} r_{ij} \quad (3)$$

Where; r_{ij} is the failure duration at load point i due to a failed element *j*.

Average Outage Duration (AvOD) at Load Point I, r_i (hr)

$$r_i = U_i/\lambda_i \quad (4)$$

Expected Energy Not Supplied (ENS) Index at Load Point I, $EENS_i$ (MWhr/yr)

This is expressed as:

$$EENS_i = P_i U_i \quad (5)$$

Where;

P_i is the average load of load point i.

Expected Interruption Cost Index at Load Point *i*, $ECOST_i$ ($/yr)

This is expressed as:

$$ECOST_i = P_i \sum_{j \in N_e} f\left(r_{ij}\right) \lambda_{e,j} \quad (6)$$

Where;

$f(r_{ij})$ is the sector customer damage functions, i.e., the interruption costs for several discrete outage durations

Interrupted Energy Assessment Rate Index at Load Point I, $IEAR_i$($/kWhr)

This is expressed as:

$$IEAR_i = \frac{ECOST_i}{EENS_i} \quad (7)$$

System Average Interruption Frequency Index (f/customer.yr)

This is defined as the average number of times that a customer is interrupted during a specified time period. The resulting unit is "interruptions per customer." It is given as

$$SAIFI = \frac{\text{Total number of customer interruptions}}{\text{Total number of customer served}} = \frac{\sum \lambda_i N_i}{\sum N_i} \quad (8)$$

Where;

N_i is the number of customers at load point *i*.

System Average Interruption Duration Index, (hr/customer.yr)

This is defined as the average interruption duration for customers served during a specified period. This index helps the utility to report for how many minutes' customers would have been out of service if all customers were out at one time. It is expressed as

$$SAIDI = \frac{\text{Sum of customer interruption durations}}{\text{Total number of customer served}} = \frac{\sum U_i N_i}{\sum N_i} \quad (9)$$

Customer Average Interruption Duration Index (hr/customer interruption)

This is defined as the average duration of interruption, weighted by the number of customers affected, for customers interrupted during a specific time period. The index enables utilities to report the average duration of a customer outage for those customers affected. It is expressed as:

$$CAIDI = \frac{\text{Sum of customer interruption durations}}{\text{Total number of customer interruptions}} = \frac{\sum U_i N_i}{\sum N_i \lambda_i} \quad (10)$$

ASAI (pu)

This is a measure of the average availability of the distribution system that serves customers. It is usually represented in percentages. It is expressed as:

$$ASAI = \frac{\begin{array}{c}Customer\ hours\ of\\ available\ service\end{array}}{\begin{array}{c}Customer\ hours\\ demanded\end{array}} = \frac{\sum N_i \times 8760 - \sum N_i U_i}{\sum N_i \times 8760} \quad (11)$$

Where; 8760 is the number of hours in a calendar year.

Average Service Unavailability Index (pu)

It provides the fraction of time customers are without electricity throughout the predefined interval of time. It is expressed as

ASUI = 1-ASAI (12)

Average ENS, (MWhr/customer.yr)

This is expressed as:

$$AENS = \frac{\begin{array}{c}Total\ energy\ not\\ supplied\ by\ the\ system\end{array}}{\begin{array}{c}Total\ number\ of\\ customers\ served\end{array}} = \frac{\sum EENS_i}{\sum N_i} \quad (13)$$

RESULTS AND DISCUSSION

The one-line diagram obtained from ITS is shown in Figure 1, this was eventually modeled on the ETAP environment as shown in Figure 2. The simulation was eventually carried out as shown in Figure 3; the bus input data are shown in Table 1 while Table 2 gives the average interruption rate, AvOD, AOD, as well as the ENS by the feeder while Figures 3 and 4 presents the calculated CBI performed by ETAP while Table 3 summarizes the obtained results. Results show that the Industrial feeder has the highest amount of ENS while Fakale feeder recorded the lowest ENS. The fact that Industrial feeder feeds the industry is not a yardstick for it to record the highest ENS rather it should have recorded the lowest ENS because the customers are always ready to pay for the energy consumed. From the results obtained, it is, therefore, necessary to improve the maintenance strategy to optimize the feeder for better productivity. Further results show that the issue of energy wastages as a result of incessant downtime needs to be addressed. In addressing these issues, ITS ASAI can be made to meet up with the world standard.

CONCLUSION

This paper is centered on reliability analysis of power system network with emphasis on the primary distribution line. The first part of the work introduces the topic while the second part reviews literatures that are relevant to the study. The method used in the research was captured in the third part of the work while the results obtained were discussed in part four and the study was concluded in part five. This research work has exposed the lack of maintenance in some feeders in ITS. It is paramount to put in place maintenance strategies across all the feeders in the transmission station to meet with international standard.

REFERENCES

1. Airoboman AE, Peter A, Augustus EI, Olayinka A. Economic implication of power outage in Nigeria: An industrial review. Int J Appl Eng Res 2016;11:4930-3.
2. Garba A, Kishk M. Economic assessment of biomass gasification technology in Providing Sustainable Electricity in Nigerian Rural Areas. In: Gorse C, Dastbaz M, editors. International Sustainable Ecological Engineering Design for Society Conference (SEEDS) Conference, 17-18 September 2015. Leeds Sustainability Institute, Leeds Beckett University: Leeds; 2015. p. 554-65.
3. Sambo AS. Matching Electricity Supply with Demand in Nigeria. International Association for Energy Economics, Fourth Quarter; 2008. p. 32-6. Available from: http://www.iaee.org/en/publications/newsletterdl.aspx?id=56. [Last accessed on 2018 Mar 26].
4. Allan BL, Eriksson RR. A reliability centered asset maintenance method for assessing the impact of maintenance in power distribution systems. IEEE Trans Power Syst 2005;20:45-53.
5. Moubray J. Introduction to Reliability-Centered Maintenance. New york: industrial press incorporated, 1997: Plant Maintenance Resource Center; 2007. p. 1-13.
6. Okaro I, Tao L. Reliability analysis and optimization of subsea compression system facing operational covariate stresses. Reliabil Eng Saf Syst 2016;156:159-74.
7. Ryan C, Stewarta M, Spencer N, Lic Y. Reliability assessment of power pole infrastructure incorporating deterioration and network maintenance. Reliabil Eng Syst Saf 2014;132:261-73.
8. Edward G, Richard A. Reliability and Validity Assessment" Sage University Paper Series on Quantitative Applications in the Social Sciences. Vol. 07. Beverly Hills and London: Sage Production; 1987. p. 1-36.
9. Airoboman AE, Ogujor EA, Okakwu IK. Reliability Analysis of Power System Network: A Case Study of Transmission Company of Nigeria, Benin City. IEEEPES-IAS Conference Accra Ghana; 2017. p. 99-104.
10. Melodi AO, Momoh JA, Oyinlola AO. Transmission System Reliability Modeling and Assessment for Nigerian Electric Grid IEEEPES-IAS Conference Accra Ghana; 2017. p. 40-5.
11. Uhunmwagho R, Okedu K. Issues and challenges in the Nigerian electricity distribution company. J Energy Technol Policy 2014;4:35-9.
12. Jibril Y, Ekundayo K. Reliability Assessment of 33kV Kaduna Electricity Distribution Feeders, Northern Region, Nigeria. San Francisco, USA: Proceedings of the WCECS; 2013. p. 3-7.
13. Sulaiman K, Ali U. Reliability analysis of distribution transformer: A case study of gwiwa business unit, Sokoto. Greener J Sci Eng Technol Res 2013;3:88-92.
14. Odior A, Oyawale F, Ovuworie G. Some operations of electric power supply system in Benin City area of Nigeria. Am J Sci Ind Res 2010;1:636-42.
15. Ngaja MB, Kali BT, Tijani B. Outage analysis on distribution feeder

in north east Nigeria. J Multidiscip Eng Sci Technol 2015;2:149-52.
16. Adoghe A, Awosope C, Daramola SA. Critical review of reliability-centered maintenance (RCM) for asset management in electric power distribution system. Int J Eng Technol 2012;2:1020-6.
17. Airoboman AE, Ogujor EA, Okakwu IK. On the centralization of reliability in maintenance practices in the Nigeria power system network: A review. Int J Eng Works 2016;3:68-72.
18. Ahmed T. Reliability centered maintenance modeling on power systems.Int J Adv Technol Eng Sci 2015;3:42-8.
19. Airoboman AE, Oriaifo P, Ogujor EA. A Maintenance Framework in Power System Network Using RCM"2017 IEEE 3rd International Conference on Electro-Technology for National Development (NIGERCON); 2017. p. 893-7.