



Reliability Assessment of 11kV Distribution Feeders: A Case Study of Ahmadu Bello University Injection Substation Zaria

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ABSTRACT

The reliability assessment performance of the 11kV distribution feeders of Ahmadu Bello University Zaria was carried out in this study. The daily outages data of the feeders for the period of twelve (12) months (January 2018 to December 2018) were collected and used to compute the reliability indices for the feeders. The data collected were analysed to estimate the reliability of the injection substation for a period of twelve months. The most important reliability indices like mean time to repair (MTTR), mean time to failure (MTTF), mean time between failure (MTBF), repair rate (μ), failure rate (λ) have been determined. State probabilities for each of the unit are also calculated and finally reliability and availability of 11kV of ABU injection Station was evaluated. The results obtained from the analysis of the 11kV feeders for the period under study (2018) show that electricity supply was at least reliable with overall availability of 90.16% of the system working without failure but not within the standard bench mark of the system network reliability. The reliability of the network 11kV feeder is below expectation, 72.55%.

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INTRODUCTION

Electric energy occupies the top grade in the energy hierarchy. It finds in numerable uses in home, industries, agriculture, and even in transport. The fact that electricity can be transported practically instantaneously is almost pollution free at the consumer level and that its uses can be controlled very easily, make it attractive as compared to other form of energy. The per capita consumption of electricity in any country is an index of the standard of living of the people in that country [1]. Nigeria like that countries in the world should witness rapid energy usage but over the years electricity supply in Nigeria had been epileptic due to problems ranging from funding, lack of good policy from government, lack of commitment on the part of PHCN staff, hence making Nigeria the importer of generator in the world. In

[2], studied reliability assessment of 4.2MW and [3] carried out analysis of distribution feeder outage.

The electric power system networks are means by which the electric energy generated at the power stations are transferred to the consumer by means of transmission lines. The electric power network can be subdivided into two namely, the transmission and distribution system. The distribution system connects all the individual loads in a given locality to the transmission line via, switchgear equipment, required power system assessment [4]. The distribution system may be subdivided into three based on the voltage level as follows primary distribution (33kV), secondary distribution (11kV), and tertiary distribution (415V three phase or 240V single phase). Hence, industries,



individual, small and large consumers are serviced from the distribution network.

Therefore, there is the need to improve the reliability of distribution network due to the increasing dependability of human existence on electricity [5] [6]. Reliability is the probability of a devices or a system performing it function adequately for the period of time intended and at the operating condition also intended. The concept of reliability has been found to be a veritable tool in assessing system performance [7]. Advance distribution reliability assessment engineering has also been established as effective and efficient tools for estimating the performances of power system. The two reliability levels of power system are referred to as system and component reliability.

The modern electrical power system is made up of a highly complex and sensitive set of electrical, mechanical, and electronics components. With the increasing load demand and requirement on quality from the consumers, the electric utility company will have to ensure very high availability of services from all elements in delivery of electrical power.

This paper is focus on the analysis of reliability assessment of 11kV distribution feeders of Ahmadu Bello University Zaria injection substation (main campus). Ahmadu Bello University is an institution with a steady increase in population which has been experiencing frequent and persistent power outages. In the institution the available electrical energy is not enough to meet the demands of the users leading to constant power failure in some areas. The interruptions of power due to the occurrences of fault on the system constitute major problems to the electricity consumers in the university. Therefore, the University needs a stable and reliable power supply of electricity

for economics, social, and research development.

The main aim of this study is to perform a detailed analysis on Ahmadu Bello University Main Campus injection substation (33-/11-kV Bulk Metering Unit) using analytical method to estimate the reliability of the primary and secondary distribution networks. In pursuance to study, we embark on data collection for the period of 12 months and determination of the network characteristics.

PROPOSED METHODS AND APPROACH

The Ahmadu Bello University, Zaria has three main feeders which got its supply from their Bulk Metering Unit. The proposed methodology involves the detailed description of the system of the system under study (Ahmadu Bello University injection substation), the collection of data from the daily tripping report of the three (3) feeders from the distribution station (Bulk Metering Unit) and the method used in analysing the reliability.

The System Understudy

The Ahmadu Bello University Zaria injection substation have control room , the 11kV switch panel , 33kV interchanger, 33kV remote tap changer transformer and 11kV switchgear. The interchanger and tap changer transformer work together in monitoring the supply from 33kV line to 7.5MVA power transformer. The three (3) feeders between the ends of the switchgear, are:

- i. ABU Main Feeder,
- ii. Amina Feeder and
- iii. Faculty of Medicine Feeder

Data Collection

For the purpose of this study, the statistical summary of number of outages due to tripping and preventive maintenance on 11kV institution injection substation was considered for a period of twelve (12) months 2018 are tabulated and presented in the Tables 1- 3.



Table 1: Service Hours on 11kV Feeders of Injection Substation ABU Main Campus

Months	Services hours (SH) on 11kV feeders		
	ABU Main Feeder	Amina Feeder	Medicine Feeder
January	651	649	610
February	585	609	558
Mars	648	646	607
April	567	577	550
May	595	593	554
June	661	659	620
July	537	539	510
August	440	449	399
September	625	623	608
October	716	714	675
November	635	633	575
December	629	627	588

Table 2: Number of Failures of 11kV Feeders of the University (ABU) Substation

Months	Numbers of Failures (NF) on 11kV Feeders		
	ABU Main Feeder	Amina Feeder	Medicine Feeder
January	5	6	7
February	4	1	9
Mars	1	3	11
April	6	4	18
May	6	10	13
June	10	7	14
July	18	23	26
August	11	9	21
September	17	12	16
October	3	7	7
November	5	6	11
December	6	7	9

Table 3: Forced Outage Hours on 11kV Feeders of the University (ABU) Substation

Months	Forced Outage Hours (FOH) on 11kV Feeders		
	ABU Main Feeder	Amina Feeder	Medicine Feeder
January	77	92	114
February	64	53	87
Mars	60	75	97
April	92	95	105
May	83	98	120
June	77	92	114
July	114	125	137
August	126	140	163
September	98	113	111
October	22	37	59
November	72	87	109
December	65	80	102

This study is concerned with the availability of data collected from university injection substation comprises of information on daily outage events but sum it up to numbers of days in that particular months between January 2018 to December 2018. For the purpose of analysis, the record were restructure in such a way that the manner in which they could be statistical data base. Statistical data of outages, types and the number of occurrence of outages on each feeders were recorded.

Method of Data Analysis

For the purpose of data analysis in this work, the data were collected manually from the control room of University Injection Substation using daily record logbook for the period of twelve

- i. Failure rate (λ) = $\frac{1}{MTBF}$ (1)
- ii. Mean time between failure (MTBF) = $MTTF + MTTR$ (2)
- iii. Availability(A) = $\frac{MTBF}{MTBF + MTTR}$ (3)
- iv. Mean time to repair (MTTR) = $\frac{FOH}{NF}$ (4)
- v. Mean time to failure (MTTF) = $\frac{SH}{NF}$ (5)
- vi. Services hours (SH) = $H - OH$ (6)
- vii. Repair rate (μ) = $\frac{1}{MTTR}$ (7)
- viii. Operation hours (OH) = $FOH + SH$ (8)
- ix. Unavailability(\hat{A}) = $\frac{\lambda}{\lambda + \mu}$ (9)
- x. Hours (H) = Number of days \times 24 hours (10)

(12) months (January 2018 to December 2018). The analytical method was used to compute the reliability because it centred on statistical distribution of the rate of component failure and time taken to restore it to service. The following indices were used failure rate (λ), availability (A), service hours (SH), repair rate (μ), operation hours (OH), and unavailability (\hat{A}) in computing the reliability of each feeders for the period of twelve (12) months.

In other to access the performance of the feeders, this quantification is carried out by introducing performance parameters which indicate the degree of reliability and are called indices of reliability which are given in eqns (1 – 10).

RESULTS AND DISCUSSION

A reliability study of 11kV feeder network of Ahmadu Bello University Zaria injection substation was carried out for the study. Number of outages and mean time to repair (MTTR), times losses data were collected from the substation and analysed for the computation of reliabilities of each feeders for a period of under studied.

Failure Rate

The failure rates experienced by individual feeders are presented in Figure 1. From figure 1 which shows the failure rate of each feeders per month, it clearly

shows that ABU main feeders has it lowest failure rate in the month of March (0.0014) and its highest in the month of July (0.0276). Comparing feeder failure rates, Amina Feeders has lowest in the month of February (0.0015) while highest in month of July (0.0346), then Medicine Feeders has lowest in the month of January (0.0097) and the highest in month of July (0.0402). In month of July, all the feeders recorded high number of failure because during this month heavy amount of rain fall accompany by wind storm which results to feeders failure as either overcurrent or earth fault.

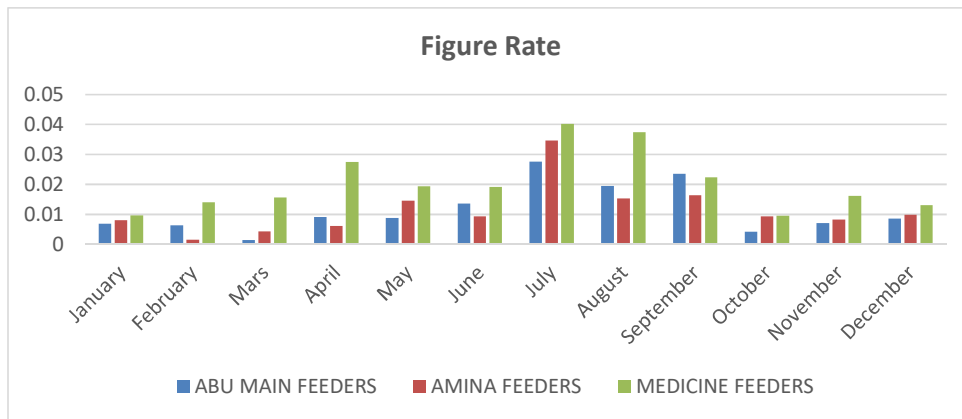


Figure 1: Figure Rate of the Feeders.

Mean Time to Repair (MTTR)

Figure 2 present the Mean time to repair for the period of study. From figure 2 which show the mean time to repair (MTTR) of each of the feeders per months, it show that all the feeders recorded the lowest mean time to repair (MTTR) in the month of September 5.7647 for ABU Main Feeder, 5.2857 in

the month of October for Amina Feeder, while 5.2692 for Medicine Feeder in the month of July respectively and the highest in the month of March (60.0000) for ABU Main Feeder, (53.0000) in the month of February for Amina Feeder and (16.2857) in the month of January for Medicine Feeder.

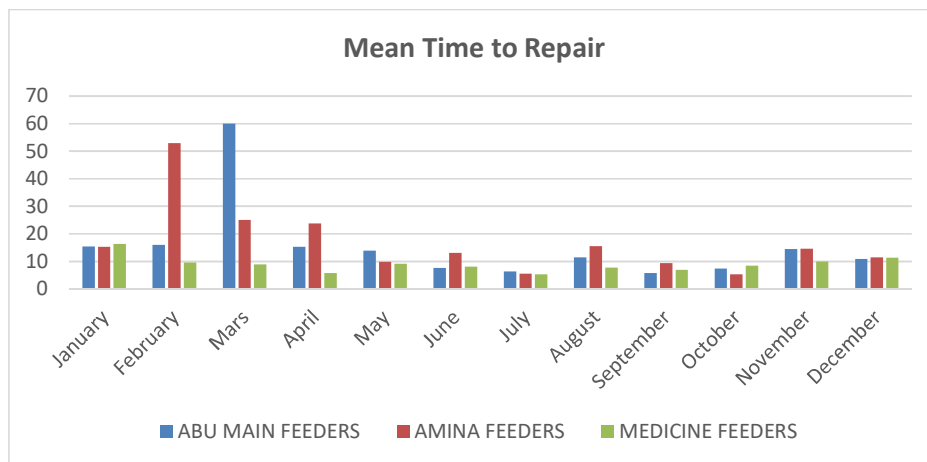


Figure 2: Mean time to repair of the Feeders.

Mean Time between Failure (MTBF)

Figure 3 show the mean time between failure (MTBF) of each feeder per month, it shows that all the feeders recorded their lowest mean time between failure in the month of July (36.17) for ABU main feeder, (28.87) in

July for Amina feeder and (24.88) in the month of July for Medicine Feeder while the highest mean time between failure of ABU main Feeder was (708.00) in march, for Amina Feeder was (662.00) in February, while for Medicine Feeder was (104.86) in the month of October.

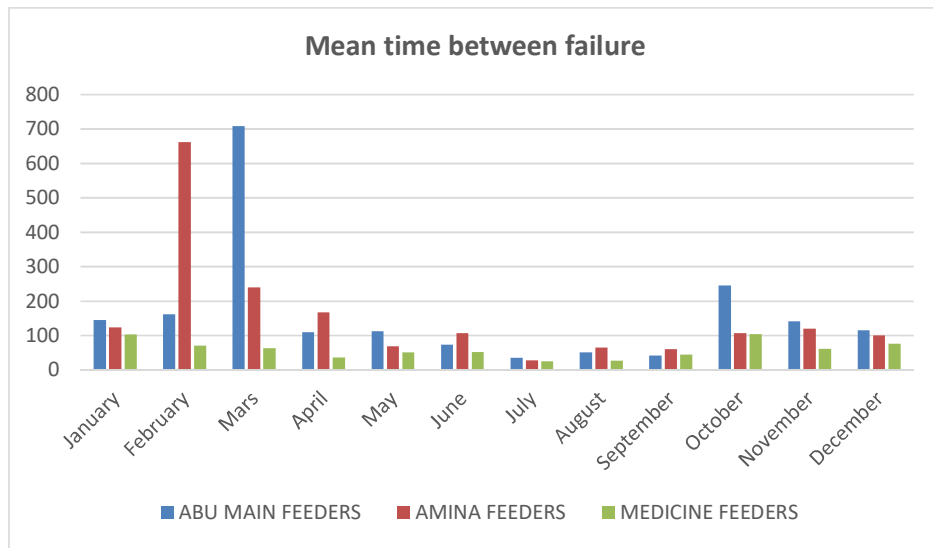


Figure 3: Mean Time between Failures of the Feeders.

Mean Time to Failure (MTTF)

Mean time to failures of the 11kV for the year 2018 characteristics is as shown in Figure 4. ABU Main feeder recorded the highest among other

feeders in the month of March, 646hrs, follow by Amina feeder in the month of February, 609hrs, while the least was recorded in the of August by Medicine feeder, 19hrs.

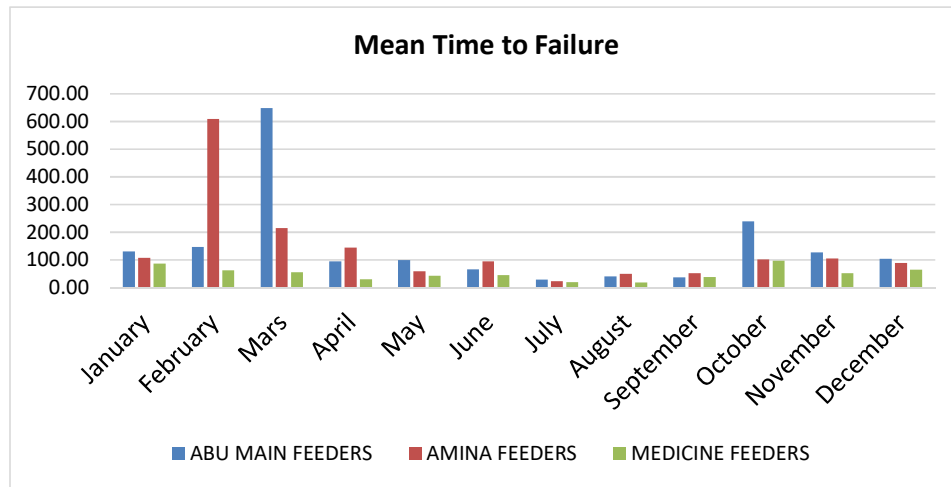


Figure 4: Mean time to failure of the Feeders.

Reliability

Figure 5 shows the highest reliability in March (96.67%) and lowest reliability in July (51.50%) for ABU Main Feeder, for Amina Feeder the highest is in

February (96.44%) and the lowest is in July (43.55%) and for the Medicine Feeder, the highest is in October (79.54%) while the lowest is in July (38.12%).

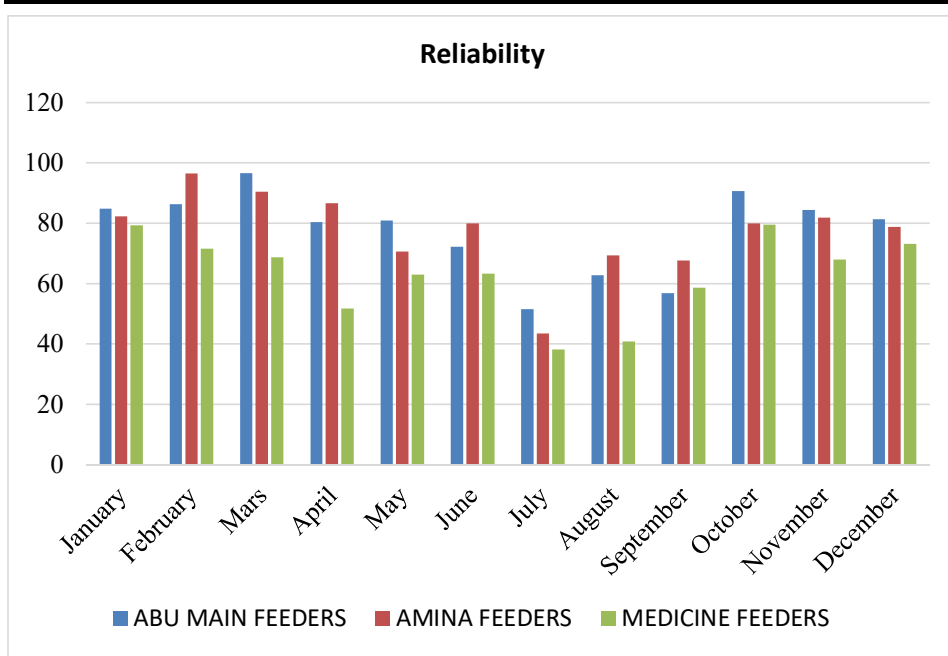


Figure 5: Reliability of the Feeders

Availability

Figure 6 show the availability of each of the feeders per months, it show that all the feeder recorded their lowest availability in August for ABU main feeder (77.74%) Amina feeder (76.23%) while

Medicine feeder (71.00%) and they recorded their highest feeder in October all, for ABU main feeder (97.02%), Amina feeder (95.07%) while Medicine feeder (91.96%)

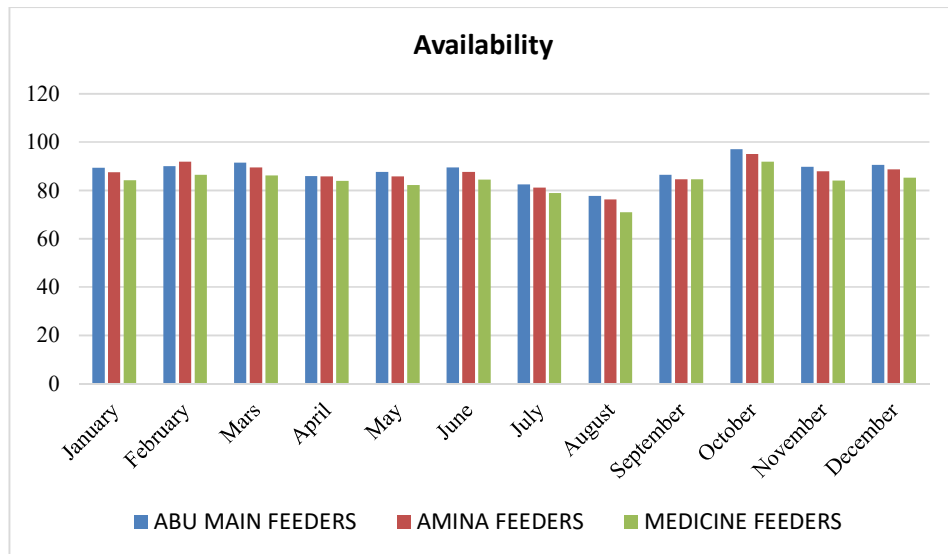


Figure 6: Availability of the Feeders.

The results of the Study

The results from the study are presented in Table 4 and Figure 7 respectively.

Table 10: Reliability indices, 11kV of ABU for the year 2018.

Months	Failure Rate (hr)	MTTR (hr)	MTTF (hr)	MTBF (hr)	Reliability (%)	Availability (%)
January	0.0082	15.67	108.50	124.18	82.14	88.79
February	0.0072	26.22	272.42	298.64	84.74	91.92
March	0.0071	31.27	306.17	337.44	85.30	91.51
April	0.0142	14.97	89.77	104.74	72.92	87.49
May	0.0142	10.95	67.03	77.98	71.49	87.68
June	0.0140	9.66	68.18	77.84	71.82	88.96
July	0.0342	5.68	24.29	29.97	44.39	80.65
August	0.0240	11.59	36.30	47.89	57.60	84.06
September	0.0207	7.37	42.23	49.60	61.04	87.06
October	0.0076	7.02	145.70	152.71	83.40	95.61
November	0.0105	12.94	94.92	107.86	78.08	89.29
December	0.0105	11.20	86.58	97.78	77.74	89.72
For a period of 1 year	0.01	13.71	111.84	125.55	72.55	90.16

From table 4, it can be deduced that the closer the value of MTTF to the MTBF, the longer the service hours and the shorter the outage duration, thereby minimizing the value of MTTR. The service hour can be increased by increasing the overall system performance. This simply means that the feeder with shortest MTTR and longest MTTF has the highest availability and is the most reliable as shown in table 4. It was observed that 11kV Medicine feeder have the highest

failure rate due to their frequent outages occurrences. These indicate that the outage of those feeders brings about the highest loss of energy, as well as the highest monetary worth of loss when compared to the other feeders.

On the other hand, 11kV ABU Main and Amina feeders respectively have the least outages occurrence which implies that a customer served by these feeders' experience least interruption of power supply for that period of study.

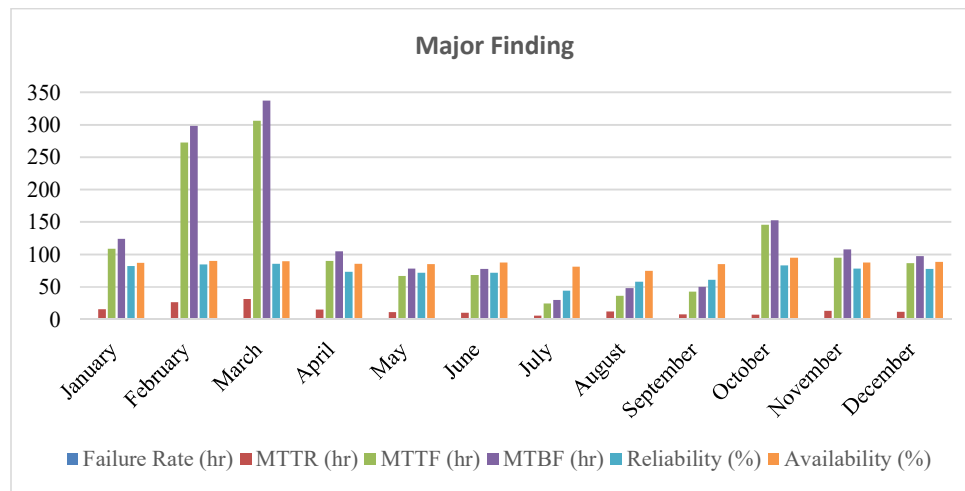


Figure 7: Reliability indices of 11kV of ABU for the year 2018.



CONCLUSION

The outages on the 11kV distribution network of the Ahmadu Bello University, Zaria Injection Sub-station has been studied for the period of twelve (12) Months based on daily outage data collected from the injection sub-station at the University. It can be deduced from the study that Medicine Feeder experienced the highest number of failures in the month of July and August, due to over current and earth fault because of the high amount of rain fall and breeze at that time of the year. To prevent such occurrences in future trimming down of trees which are hazardous to transmission lines should be embark. ABU Main feeder has a highest number of failures although there are transient in nature and the failures on Amina feeder is mostly due to earth fault because of the underground connections.

REFERENCE

- [1]. Niu, S., Jia, Y., Wang, W., He, R., Hu, L., & Liu, Y. (2013). Electricity consumption and human development level: A comparative analysis based on panel data for 50 countries. *International Journal of Electrical Power & Energy Systems*, 53, 338-347.
- [2]. Adegboye, B. A., and K. R. Ekundayo. "Reliability assessment of 4.2 MW single shaft typhoon gas fired turbine power generation station (2003–2008)." In *Advanced Materials Research*, vol. 367, pp. 143-150. Trans Tech Publications Ltd, 2012.
- [3]. Musa, B. U. "Outage analysis on distribution feeder in North East Nigeria." *EMERGENCY* 4, no. 5 (2015):
- [4]. Diamenu, G., & Kwarteng, J. (2019). Electric Power Distribution Network Performance Assessment Based on Reliability Indices.
- [5]. Airoboman, A. E., Ogujor, E. A., & Kokakwu, I. (2017, June). Reliability analysis of power system network: A case study of Transmission Company of Nigeria, Benin City. In *2017 IEEE PES Power Africa* (pp. 99-104). IEEE.
- [6]. Okhaifoh, J. E., & Aghelegin, J. (2018). Reliability Assessment of the Etete and GRA 33kV Feeders in Benin Transmission Station, Benin City, Nigeria. *Advances in Electrical and Telecommunication Engineering (AETE) ISSN: 2636-7416*, 1(2), 85-92.
- [7]. Franklin, Onime, and A. Gabriel. "Reliability analysis of power distribution system in Nigeria: a case study of Ekpoma network, Edo state." *Int. Journal of Elect. Elect. Engin* 2, no. 3 (2014).