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RELIABILITY ASSESSMENT OF AGULU-OKO-UMUNZE 33KV FEEDER FOR RURAL ELECTRIFICATION: A CASE STUDY OF OKO COMMUNITY IN ORUMBA NORTH LOCAL GOVERNMENT AREA OF ANAMBRA STATE.

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Abstract.
The major problem of electricity consumers in Nigeria is as a result of frequent power outages caused by faults on the distribution line. As it is being witnessed all around Nigeria, Oko community which is fed with the 33kV Agulu-Oko-Umunze feeder is chosen as a case study. Data containing number of faults on each feeder to different villages in Oko Community and their respective downtime were collected. These data collected were analyzed mathematically to estimate the reliability of the 33KV Agulu-Oko-Umunze feeder in Oko Community for a period of five years. The reliability indices for the year 2024 and 2025 are being considered as the base study. The outages on the 33KV feeders were studied for 24 months on daily outage data collected from the station. Based on the result obtained from the data analysis illustrated with graphs, it was deduced that dedicated feeders such as Ezioko and Eziabo have the highest reliability and more available compared to others residential feeders. This can be attributed to the level of their load demands. Generally, the feeders have least reliability during the period of May to October due to high dependence of students during the academic periods. The researcher carried out this research due to the frequent outages the community always experience due to the presence of high density of student's hostels and lodges.

Keywords: Reliability, Availability, MTTR, Failure rate, Feeders.

1.1 Introduction

Since Electric energy occupies the top grade in the energy sector, it finds innumerable uses in homes, industries, agriculture and even in transportation industries. The fact that electricity can be transported practically instantaneously, it is almost pollution free at the consumer level and its uses can be controlled very easily, make it very attractive as compared to other forms 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. Nigeria's economy, like that of many other countries in the world, should witness rapid energy usage, but over the years, electricity supply in Nigeria had been unreliable due to problems ranging from poor funding, lack of good policy from government, lack of commitment on the part of Cower Holding Company of Nigeria (PHCN) staff, hence, making Nigeria the largest importer of generators in the world (Billington and James 1994). The electric power system networks are means by which the electric energy generated at the power stations are transported to the consumers. Almost two-thirds of the money invested by the utility company in supplying electric services to its consumer is spent in this process. The electric power network can be subdivided into three, namely; the generation, transmission and distribution systems (Meeuwsen and Kling 1997). The distribution system connects all the individual loads in a given locality to the transmission lines through switchgear equipment. The distribution system may be sub-divided into three, based on the voltage level as follows: primary distribution (33Kv), secondary distribution (11Kv) and tertiary distribution (415V three-phase or 220V single-phase) (Adejumobi, 2005). 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 population on electricity.

1.2 Aim and Objectives

The main aim of this research is to perform a detailed mathematical analysis on Agulu-Oko-Umunze Injection Substation (33kV/11kV) to estimate the reliability of the primary and secondary distribution networks. It is also done in order to determine the failure rate (λ), the mean time between failures (MTBF) and reliability of the network (Dillimmton and Allan 1988)

1.3 Index of Reliability

The reliability of system is a probability expression that needs to be quantified to make it suitable for scientific analysis. This quantification is carried out by introducing performance parameters which indicate the degree of reliability and are called indices of reliability. Some of them are explained are:

- **Failure rate (λ):** This is the basic index of reliability. It is a measure of the frequency at which faults occurs.
- **Mean time between failures (MTBF)**: This expresses the average time which elapses between consecutive failures of a repairable system of equipment.
- **Mean time to repair (MTTR):** This is the average time that is needed to restore an equipment or item to operate effectively, once it fails. MTTR is a function of equipment design, the expertise of the personnel and the tools available. Hence, a low value of MTTR shows good maintainability.
- **Availability (A):** It is the probability that equipment will be available to perform its required function or that it will be in a state of operational effectiveness within a given period.
- Reliability = $e^{-\lambda t}$ (Dan, 2003)

1.4 Data Collection

For the purpose of this research study, the statistical summary of number of outages due to fault and preventive maintenance on Agulu-Oko-Umunze (33kV/11kV) injection substation in Aguta, in Anambra Sate was considered. For the 33-kV distribution system, two feeders were taken and the 11-kV for a period of five years (2021-2025) as shown in tables 1 and 2 below.

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Table 1: 11kV Feeder Data

11kV Feeder by Feeder Outages		Year					
		2021	2022	2023	2024	2025	Total
Ezioko	Number of outages	70	67	45	51	35	268
	Number of Downtime	400.5	450.5	385.0	250.5	200.0	1686
Eziabo	Number of outages	30	41	39	38	25	173
	Number of Downtime	200.3	100.5	50.0	35.0	20.5	406.3
Ifiteoko	Number of outages	70	60	50	40	33	243
	Number of Downtime	250.5	300.5	350.0	185.5	180.0	1265.6
Ihiengwu	Number of outages	120	80	90	55	35	380
	Number of Downtime	378.5	255.5	400.5	175.8	180.5	1390.8

Source: Nibo transmission sub-Station, Anambra State

Table 2: 33kV Feeder Data

11kV Feeder by Feeder Outages		Year					
		2021	2022	2023	2024	2025	Total
Agulu	Number of outages	40	55	30	35	20	180
	Number of Downtime	20.5	35.0	30.5	75.5	33.0	194.5
Nibo	Number of outages	35	45	25	33	20	158
	Number of Downtime	30.0	35.5	20.0	25.5	15.5	126.5

Source: Nibo transmission sub-Station, Anambra State

1.5 Methodology

In other to access the performance of the feeders, the various reliability indices were computed using the following equations:

$$Failure\ Rate\ (\lambda) = \frac{cumulative\ fault\ frequency\ for\ each\ year}{Period\ of\ occurance\ for\ each\ year} \quad 1$$

Or;

$$Failure\ Rate\ (\lambda) = \frac{number\ of\ times\ that\ failure\ occure}{number\ of\ Unit - hour\ of\ operation} \quad 2$$

$$Mean\ Time\ Between\ Failure\ (MTBF) = \frac{Total\ System\ Operating\ hour}{Number\ of\ Failure} \quad 3$$

$$Mean\ Time\ To\ Repair\ (MTTR) = \frac{Total\ System\ Downtime}{Number\ of\ Failure} \quad 4$$

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$$Availability = \frac{MTBF - MTTR}{MTBF} \quad 5$$

$$Reliability\ (R) = e^{-\lambda t} \quad 6$$

Where $t = time\ in\ a\ day$

1.6 Data Analysis and Result

The focus here is to determine the failure rate, operating time, availability and reliability of the substation for each year (2021-2025). A reliability study of 33-kV/11-kV feeder network of Power Holding Company of Nigeria (PHCN), Oko Injection substation was carried out in this research. Number of outage and down time losses data were collected from PHCN Nibo and analyzed the reliabilities of each feeders for one day for each of the years were calculated.

Table 3: Summary of the 11-kV Feeder's Failure rates over five years

Feeder	2021	2022	2023	2024	2025
Ezioko	0.0109	0.0104	0.0070	0.0079	0.0054
Eziabo	0.0072	0.0099	0.0092	0.0092	0.0060
Ifiteoko	0.0120	0.0103	0.0085	0.0067	0.0057
Ihiengwu	0.0132	0.0088	0.0099	0.0060	0.0022

$$Note: Failure\ Rate\ (\lambda) = \frac{number\ of\ times\ that\ failure\ occure}{number\ of\ Unit - hour\ of\ operation} = \frac{70}{268 \times 24} = 0.0109$$

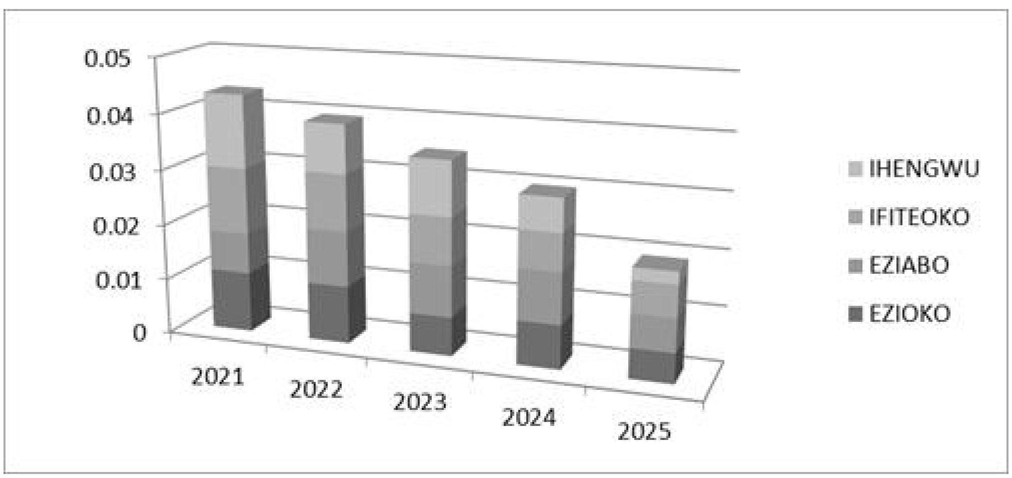

Figure 1: Component bar chart for 11-kV feeder failure rate over five years

Table 4: MTBF for 11kV feeder

Feeder	2021	2022	2023	2024	2025
Ezioko	24.09	25.16	34.47	33.06	48.17
Eziabo	13.54	9.91	10.42	10.62	16.25
Ifiteoko	18.08	21.09	31.64	31.64	38.35
Ihiengwu	11.59	17.39	15.45	25.29	39.74

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$$Mean\ Time\ Between\ Failure\ (MTBF) = \frac{Total\ System\ Operating\ hour}{Number\ of\ Failure} = \frac{1686}{70}$$

$$= 24.09$$

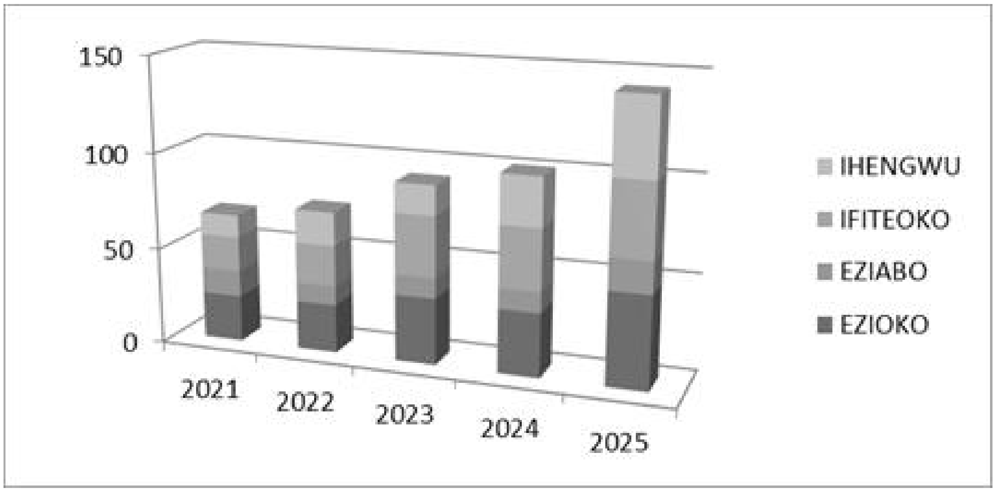

Figure 2: Component bar chart for 11-kV feeders MTBF over five years

Table 5: MTTR for 11kV feeder over five years

Feeder	2021	2022	2023	2024	2025
Ezioko	5.72	6.72	8.56	4.91	5.74
Eziabo	6.68	2.45	1.28	0.92	0.82
Ifiteoko	3.59	5.01	7.0	4.64	5.45
Ihiengwu	3.15	3.19	4.45	3.20	5.16

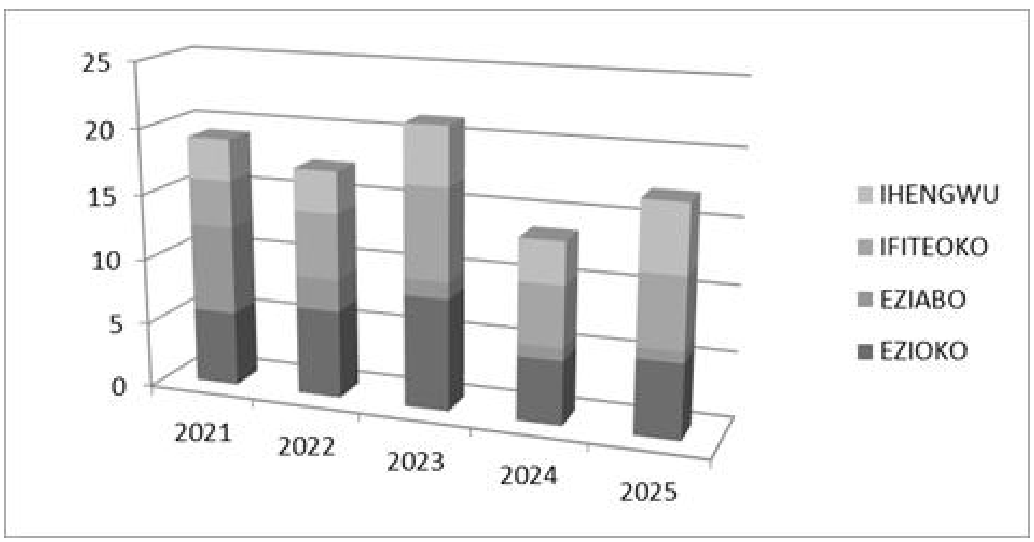

Figure 3: Component bar chart for 11-kV feeders MTTR over five years

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Table 6: Availability for 11kV feeder over five years

Feeder	2021	2022	2023	2024	2025
Ezioko	0.76	0.73	0.76	0.85	0.88
Eziabo	0.51	0.75	0.88	0.91	0.89
Ifiteoko	0.80	0.76	0.78	0.85	0.86
Ihiengwu	0.72	0.82	0.71	0.79	0.89

$$Availability = \frac{MTBF - MTTR}{MTBF} = \frac{24.09 - 5.72}{24.09} = 0.76$$

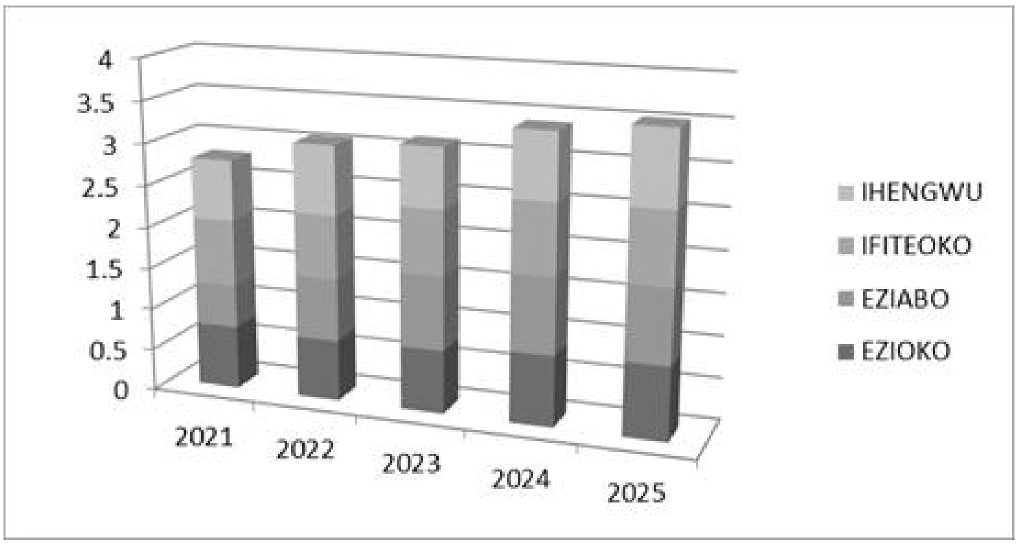

Figure 4: Component bar chart for 11-kV feeders Availability over five years

Table 6: Reliability for 11kV feeder over five years

Feeder	2021	2022	2023	2024	2025
Ezioko	0.98	0.99	0.76	0.85	0.88
Eziabo	0.51	0.75	0.88	0.91	0.89
Ifiteoko	0.80	0.76	0.78	0.85	0.86
Ihiengwu	0.72	0.82	0.71	0.79	0.89

$$Reliability\ (R) = e^{-\lambda t} = e^{-0.0109 \times 1} = 0.98$$

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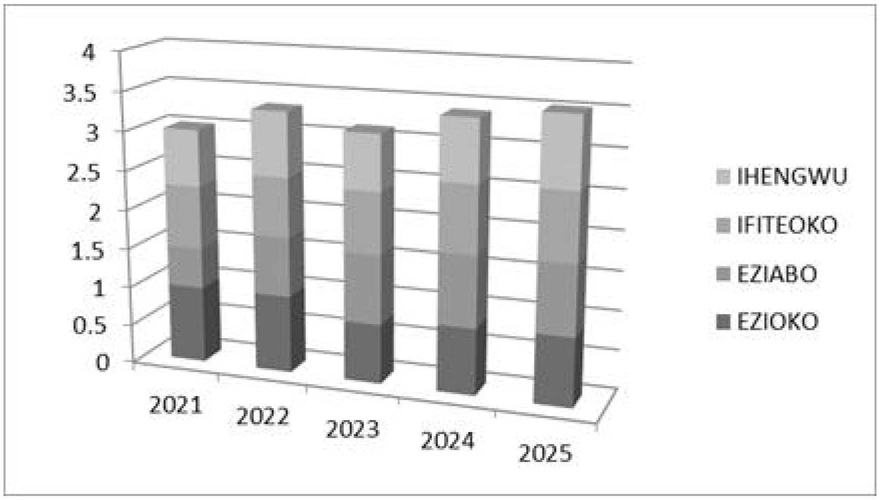

Figure 5: Component bar chart for 11-kV feeders Reliability over five years

Table 7: 33kV failure rate over five years

33kV Feeder by Feeder Outages	Year				
	2021	2022	2023	2024	2025
Agulu	0.0093	0.0127	0.0069	0.0081	0.0046
Nibo	0.0081	0.0104	0.0058	0.0076	0.0046

$$Note: Failure\ Rate\ (\lambda) = \frac{number\ of\ times\ that\ failure\ occure}{number\ of\ Unit - hour\ of\ operation} = \frac{40}{180 \times 24} = 0.0093$$

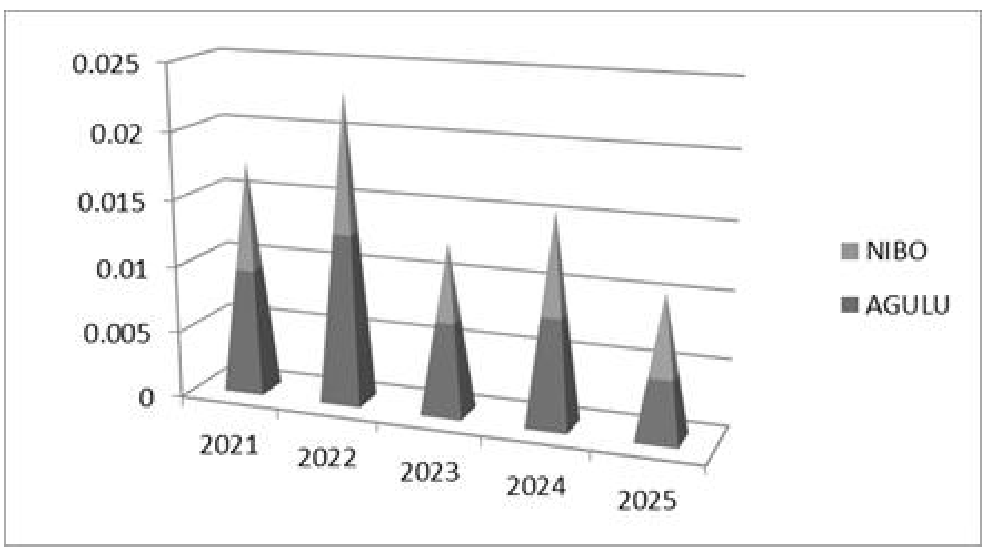

Figure 6: Component pyramid chart for 33kV feeder failure rate over five years

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Table 8: MTBF for 33kV feeder over five years

33kV Feeder by Feeder Outages	Year				
	2021	2022	2023	2024	2025
Agulu	4.86	3.54	6.48	5.56	9.76
Nibo	4.51	3.51	6.32	4.79	7.90

$$Mean\,Time\,Between\,Failure\,(MTBF) = \frac{Total\,System\,Operating\,hour}{Number\,of\,Failure} = \frac{194.5}{40}$$

$$= 4.86$$

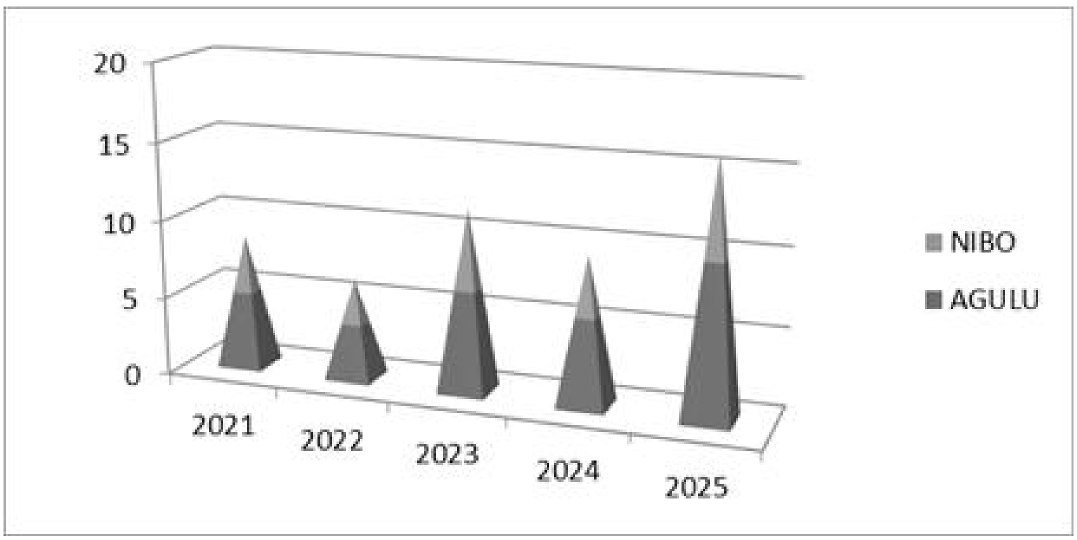

Figure 7: Component pyramid chart for 33kV feeders MTBF over five years

Table 9: MTTR for 33kV feeder over five years

33kV Feeder by Feeder Outages	Year				
	2021	2022	2023	2024	2025
Agulu	4.50	3.27	6.00	5.14	9.00
Nibo	3.61	2.81	5.06	3.83	6.31

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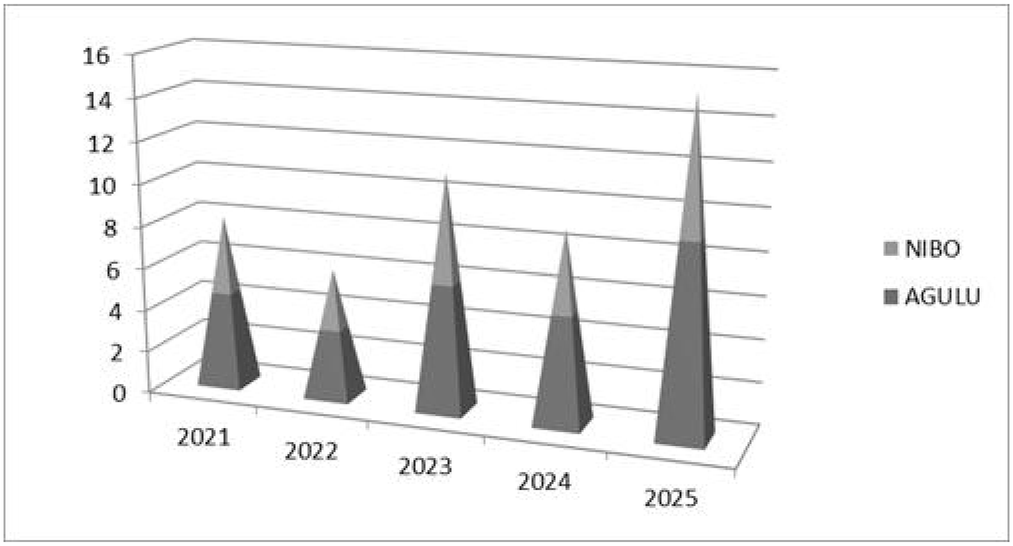

Figure 8: Component pyramid chart for 33kV feeders MTTR over five years

Table 10: Availability for 33kV feeder over five years

33kV Feeder by Feeder Outages	Year				
	2021	2022	2023	2024	2025
Agulu	0.0740	0.0763	0.0741	0.0755	0.0779
Nibo	0.1996	0.1994	0.2006	0.2004	0.2013

$$Availability = \frac{MTBF - MTTR}{MTBF} = \frac{4.86 - 4.50}{4.86} = 0.0740$$

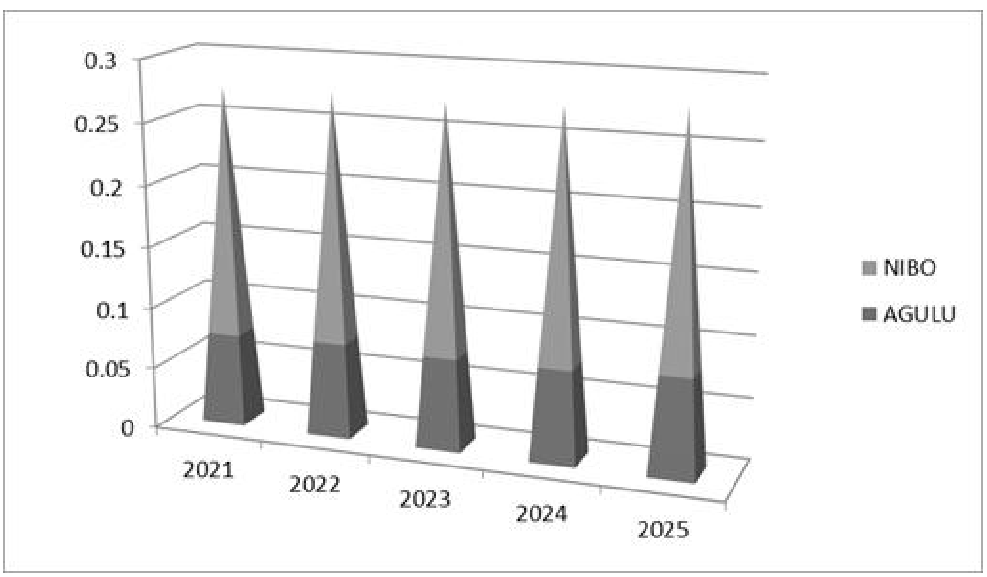

Figure 9: Component pyramid chart for 33kV feeders Availability over five years

Table 11: Reliability for 33kV feeder over five years

33kV Feeder by Feeder Outages	Year				
	2021	2022	2023	2024	2025
Agulu	0.9907	0.9874	0.9931	0.9919	0.9954
Nibo	0.9919	0.9897	0.9942	0.9924	0.9954

$$Reliability\ (R) = e^{-\lambda t} = e^{-0.0093\times 1} = 0.990$$

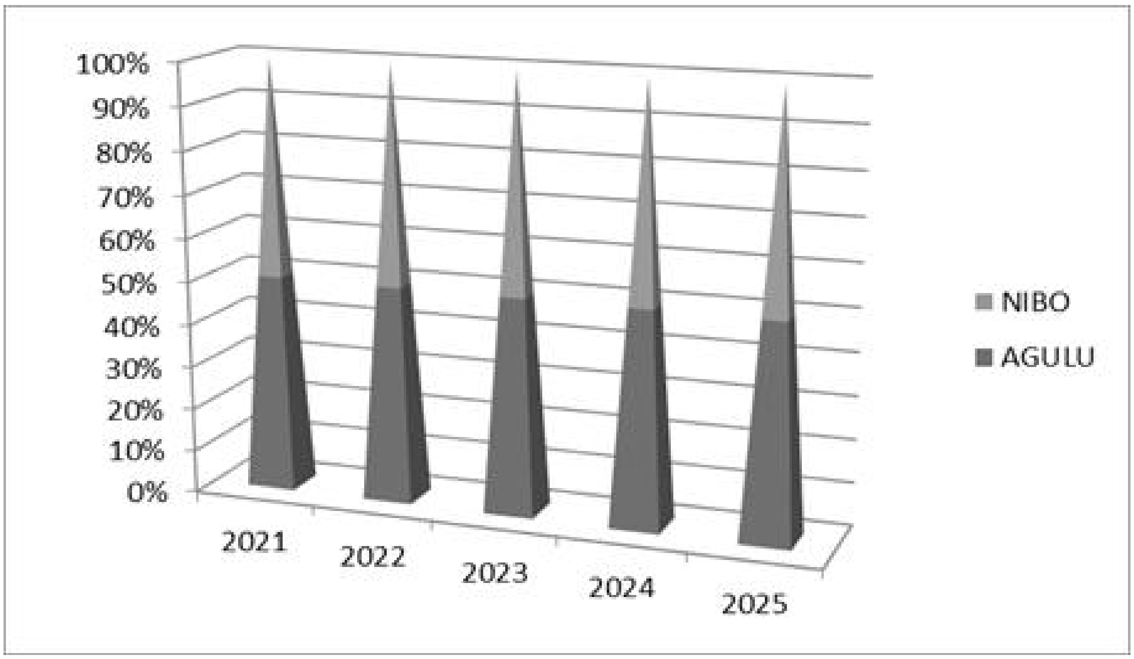

Figure 10: Component pyramid chart for 33kV feeders Reliability over five years

Table 12: Five years feeders by feeder 11-kV down time in hours

YEAR	FEEDERS			
	EZIOKO	EZIABO	IFITEOKO	IHIENGWU
2021	400.5	200.3	250.5	378.5
2022	450.5	100.5	300.5	255.5
2023	385.0	50.5	350.0	400.5
2024	250.5	35.0	183.3	175.8
2025	200.0	20.5	180.0	180.3

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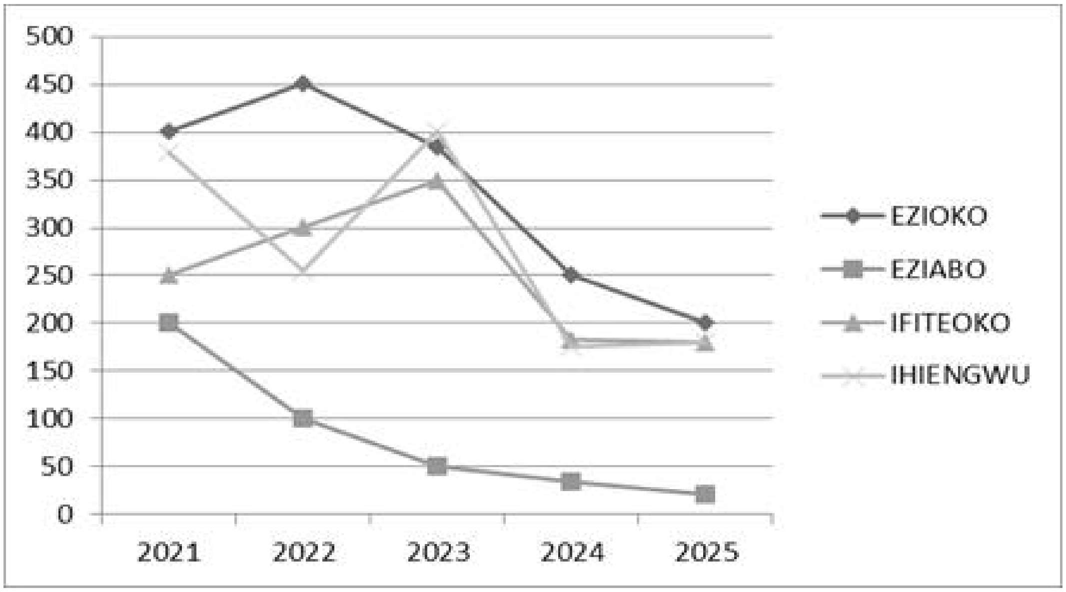

Figure 11: graph of five years feeders by feeder 11-kV down time in hours

Table 13: Five years feeders by feeder 11-kV outages due to fault

YEAR	FEEDERS			
	EZIOKO	EZIABO	IFITEOKO	IHIENGWU
2021	70	30	70	120
2022	67	41	60	80
2023	45	39	50	90
2024	51	38	40	55
2025	33	25	33	35

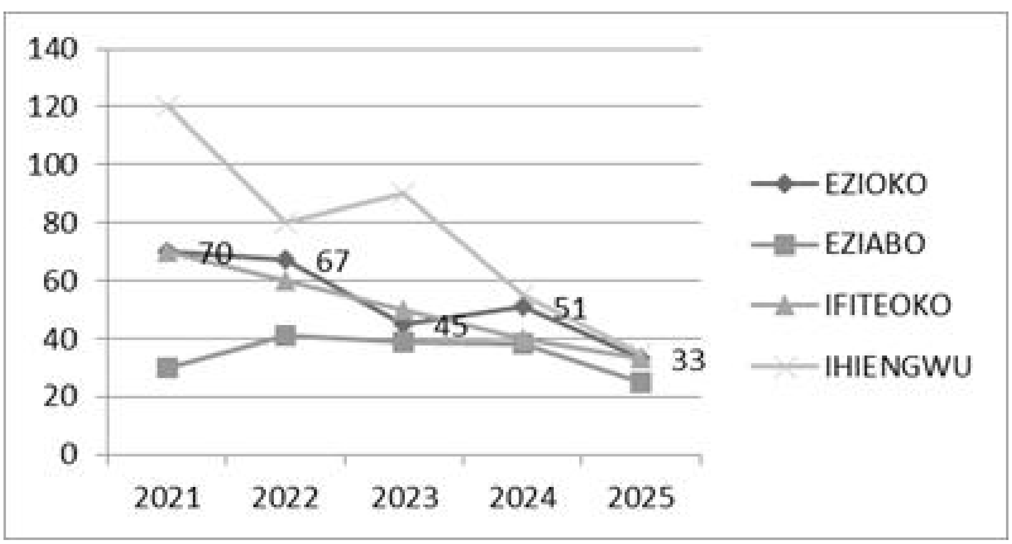

Figure 12: graph of five years feeders by feeder 11-kV outages due to fault

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Table 14: Calculated value of 11-kV reliability indices for the year 2021-2025

Year	λ	MTBF	MTTR	Reliability	Availability
2021	0.0108	16.83	4.79	0.78	0.69
2022	0.0099	18.39	4.34	0.83	0.77
2023	0.0087	23.00	5.32	0.78	0.78
2024	0.0075	25.15	3.42	0.85	0.85
2025	0.0048	35.63	4.29	0.78	0.88

Conclusion

Reliable power supply to consumers is important for progressive and advancement of the standard of living, hence, the need for system reliability. In order to achieve this, careful monitoring of power system is important in order to help the operator detect and control dangerous conditions that might damage or cause loss of service. From the analysis carried out on the outage data due to faults that were obtained at the Nibo distribution substation from 2021 to 2025. The result shows that the frequency of faults is extremely low for all the months on the 33-kV lines. This trend makes the reliability to be very high which is good for the system. Therefore, reliability of power being available at the substation is very poor because the power generated is smaller when compared to the power demand.

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