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EVALUATION OF OUTAGE MANAGEMENT AND RELIABILITY INDICES OF UGBOWO 2X15 MVA, 33/11 KV DISTRIBUTION NETWORK

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Abstract

This paper presents the outage management and reliability indices (RI) assessment of the four 11 kV feeders of the Ugbowo 2x15 MVA, 33/11 kV distribution network. The data of daily outages of the four 11 kV feeders from February 2021 to January 2022 were collated and collected from the network. The daily outage of the four 11 kV feeders were used to compute the monthly and yearly outages and performance indices of the four 11 kV feeders of the network using analytical techniques. The monthly and yearly failure rate, MTTR, MTTF, MTBF, availability, unavailability, SAIFI, SAIDI, ASAI, etc. for the period of twelve (12) months were analyzed using the Load Point Indices (LPI) and the Microsoft Excel was used graphically to interpret the results of the indices for the four 11 kV feeders of the network. The results obtained from the analyses of the four 11 kV feeders of the network showed that the yearly failure rate for the FGGC feeder is 20.66%, Uselu feeder 20.66%, Eguaedaiken feeder 21.38%, and Ugbowo feeder 20.75% respectively. The RI values for the various metrics of the FGGC, Uselu, Eguaedaiken and Ugbowo feeders respectively were MTTR 5.626 hrs, 5.626 hrs, 4.383 hrs and 4.491 hrs; MTTF 4.840 hrs, 4.840 hrs, 4.677 hrs and 4.819 hrs; MTBF 10.466 hrs, 10.466 hrs, 9.059 hrs and 9.309 hrs respectively. And also, the customers oriented indices for the four 11 kV feeders respectively was SAIFI 1.288, 0.338, 0.332 and 0.291 interruptions/cu.yr respectively, SAIDI 7.245, 1.899, 1.454 and 1.306 hours/cu.yr respectively, ASAI 46.2, 46.2, 51.6 and 51.8% respectively. These results revealed an improvement of the network compared to Akpojedje et al. [10] assessment carried out on same network but despite the improvement per-se, the performance indices of the four 11 kV feeders with the annual total outage frequency (SAIFI) and percentage availability (ASAI) were far from the recommended values of the international acceptable standard value (IASV) of 0.01 and 99.99% respectively. This shows that more improvement is needed on the network.

Keywords: *Outage management, Failure rate, Costumers Oriented indices, Reliability indices, Availability*

1. INTRODUCTION

The frequent power interruption in the Nigerian distribution system has become a recurrent issue that need to be nibbed on the board. It has opined in [1] that frequent power interruption in the distribution network of the Nigerian power system calls for serious attention by all stakeholders in the system. These frequent power interruptions are not unconnected with scheduled and unscheduled outages in the system. According to [2] the unscheduled outages are caused by system faults, while the scheduled outages which dominated the system are due to poor power generation and equipment limitations. The later has created a great limitation and gap between energy supply-demand in the Nigerian power sector, which has culminated to frequent power cut in the system through scheduled outages. The scheduled outages are predominated in the system as a result of inadequate carrying capacity of the power lines, transformers, poor power generation, etc. This has greatly affected the reliability and availability of electricity to consumers in the Nigerian grid. The frequency of power interruption in Ugbowo 2x15 MVA, 33/11 kV distribution network calls for evaluation because customers complains and

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reliability of electricity cannot overemphasis. The demand and supply of electricity should be continuously balanced so as to avoid frequent power interruption in the system [3] and to ensure the reliability of the system. Therefore, reliability is the chance that a given desirable event will occur at the very time it is required and expected to occur. Also, from engineering standpoint or point of view, reliability is defined as the probability that a system will perform required function under a given condition for a stated period of time [4]. Reliability was reference to power system by [5] as the probability that the system will continuously deliver electricity to its consumers without compromise on the quality of the power being delivered. Reliability is simply a measure of whether the users have electricity when it is needed [6]. The reliability indices are parameters used to evaluate the system performances and the reliability indices used to evaluate the performance of the distribution network through its 11 kV feeders. Consumers received electricity supply via the 11 kV feeders through the Station 33/11 kV power transformers and it's shows how outages are managed in the Ugbowo 2x15 MVA, 33/11 kV distribution network. Therefore, this study evaluates the reliability indices with relation to the outage management of the network.

1.1 BRIEF DESCRIPTION OF LOAD POINT INDICES (LPI)

Power supply is delivered to each customer load points starting from a substation through distribution network [7]. The Load Point Indices (LPI) makes use of the reliability indices which is a statistical tool that is deploy to evaluate the performance of electrical networks and others. The reliability of a power system is usually measured in terms of several indices [8]. They are divided into load point indices and generalized reliability indices. Load point reliability indices are evaluated at each load point of the bus bar system and they are assessed using failure rate, outage time/repair duration and the average annual outage time [8]. The LPI is an essential metrics for evaluating electrical distribution networks where consumer's points (Load Points) are assessed and evaluated to know the performance of the network under review.
The LPI is reliability Indices (RI) that makes use of classical concepts which are three primary indices tool such as failure rate, average outage duration and average annual outage. But to reflect the severity or significance [9] of the system outage at the load point, additional reliability indices called the customer-oriented indices are needed, such as SAIFI, SAIDI, CAIFI, ASAI, ASUI, etc. which reflect customer or load point behaviour.

1.2 PERFORMANCE INDICES

Performance indices (PI) are essential metrics for evaluating the distribution network or system performance. These performance indices are majorly reliability metrics which are statistical tool used to analyze data of a well-designed set of loads, component, system or customers' satisfaction. Most reliability characteristics of components, feeders or entire system are determined by their functionality using historical data. Power companies usually make use of two reliability metrics which are frequency and duration to estimate the performance of their systems or components. The following briefly describes some of the performance indices of a system [10]:

1.2.1 Failure Rate (λ): is defined as the basic index of reliability which measure the frequency at which fault occurs in the system.

$$Failure\ Rate\ (\lambda) = \frac{Frequency\ of\ Outage/year\ or\ month}{Total\ Hours\ of\ Power\ Available/year\ or\ month} \quad (1)$$

1.2.2 Mean Time to Failure ($MTTF$): is a reliability metrics that defined the function of non-repairable equipment in a given system.

$$Mean\ Time\ to\ Failure\ (MTTF) = \frac{1}{\lambda} \quad (2)$$

1.2.3 Mean Time to Repair or Recovery ($MTTR$): it is the average time needed to repair a faulty system or component and bring it back to its full operating state.

$$MTTR = \frac{Total\ System\ Downtime}{Number\ of\ Outage} = \frac{1}{\mu} \quad (3)$$

1.2.4 Mean Time between Failure ($MTBF$): it is the average time interval between consecutive failures of a repairable system or component.

$$MTBF = \frac{Total\ System\ Operating\ Hours}{Number\ of\ Outage} = MTTF + MTTR \quad (4)$$

1.2.5 Availability (A): is the probability that an equipment or system will be available to perform the desired function when needed.

$$Availability\ (A) = \frac{Uptime}{Expected\ Uptime} = \frac{\mu}{\lambda+\mu} = \frac{MTBF-MTTR}{MTBF} = \frac{MTTF}{MTTF+MTTR} \quad (5)$$

1.2.6 Unavailability (U): it is the average time interval in which a system or component is not available to perform the required function.

$$Unavailability\ (U) = \frac{MTTR}{MTTF+MTTR} = 1 - \frac{MTTF}{MTTF+MTTR} = 1 - A \quad (6)$$

1.2.7 Reliability (R): it is the probability that a system or device perform a function correctly when needed to do so.

$$R = e^{-\lambda t} \quad (7)$$

$Where\ \lambda = failure\ rate, t = time\ of\ outage$

1.2.8 System Average Interruption Frequency Index ($SAIFI$): it is the measure of how many sustained interruptions for an average consumer will experience during the period of a year.

$$SAIFI = \frac{Frequency\ of\ Outage}{Number\ of\ Customer\ Served} \quad (8)$$

1.2.9 System Average Interruption Duration Index ($SAIDI$): it defines the measure of how many interruption hours an average customer will experience during the period of a year.

$$SAIDI = \frac{Total\ Outage\ Duration\ in\ Hours}{Number\ of\ Customer\ Served} \quad (9)$$

1.2.10 Average Service Availability Index ($ASAI$): it defines the measure of the average availability of the distribution network services to customers.

$$ASAI = \frac{Customer\ Hours\ of\ Available\ Service}{Customer\ Hours\ Demanded} \quad (10)$$

1.2.11 Average Service Unavailability Index ($ASUI$): it defines the measure of the average unavailability of the distribution system services to customers.

$$ASUI = \frac{Customer\ Hours\ of\ Unavailable\ Service}{Customer\ Hours\ Demanded} = 1 - ASAI \quad (11)$$

1.3 SINGLE LINE DIAGRAM OF UGBOWO 2X15 MVA, 33/11 KV DISTRIBUTION NETWORK AND IT'S FEEDERS

The single line diagram (SLD) of the Ugbowo 2x15 MVA, 33/11 kV distribution network with all the four (4) 11 kV feeders and the 132/33 kV supply from Ihovbor generating station as shown in Figure 1. The Ugbowo injection substation gets it electricity supply from Oluku 33 kV feeder. The Oluku indoor 33 kV feeder control panels have two Incomers called Incomer 1 and Incomer 2 which control and distribute electricity to the Ugbowo 2x15 MVA, 33/11 kV distribution network. The Ugbowo 2x15 MVA, 33/11 kV distribution network in turn have four (4) 11 kV feeder; two (2) each connected to Incomer 1 and Incomer 2 with 15 MVA, 33/11 kV power transformer each. Incomer 1 have two (2) 11 kV feeder which are FGGC 11 kV feeder and Uselu 11 kV feeder; while Incomer 2 have two (2) 11 kV feeder which are Eguaedaiken 11 kV feeder and Ugbowo 11 kV feeder. The Oluku 33 kV feeder which feeds the Ugbowo 2x15 MVA, 33/11 kV electric power distribution network gets it electricity supply from Ihovbor Generating (Power) Station, Ihovbor, Benin City, Nigeria. The Ihovbor Power Station is a National Integrated Power Project (NIPP) built to cater for insufficient power supply in the country and Figure 1 depicts the single line diagram of the network.

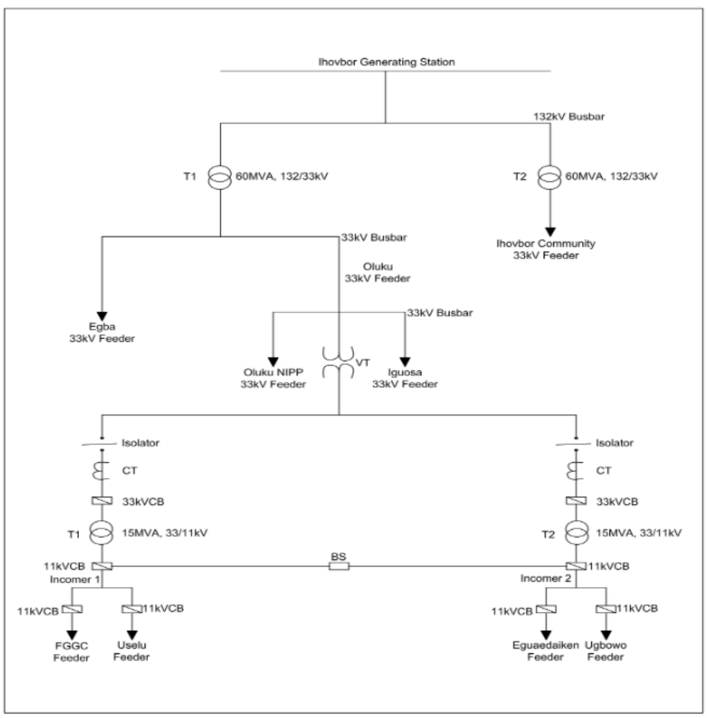

Figure 1: Single Line Diagram (SLD) of the Ugbowo 2x15 MVA, 33/11 kV Distribution Network feeders and the 132/33 kV Supply from Ihovbor Generating Station.

1.4 RELATED WORKS

The evaluation of outage management and reliability indices of electrical power system has become area of interest to researchers in Nigeria owing to epileptic power situation in the country. This interest of researchers is to find a leverage in providing solutions to epileptic power situation of the country and how best researchers have carried-out studies on the Nigerian power system at different times with the hope of contributing to the existing knowledge on the subject area. Their findings and recommendations were highlighted in this section.

Adeoye [11] investigated power quality issues and interruptions as they affect the development of Ekiti State, in Nigeria. Power interruption data was collected for six (6) months from Ekiti Feeders in Benin Electricity Distribution Company (BEDC) and the data was analyzed using the MATLAB 2015 to depict the behavioral pattern of the power interruption in the feeders. The results showed that the interrelationship between power interruptions and development as it affects domestics consumers, small and medium scale industries in the location.

Omoroghomwan et al. [12] carried-out the assessment of reliability of the 33 kV feeders of Ehor, Ubiaja and Uzebba of the Nigeria power system in order to ascertain their performances for the past four (4) years (2015 to 2018). Outage data was collected from the feeders and the load point indices (LPI) was used for the assessment of the feeders. The results showed that the failure rate of feeders were on the high side and the system reliability was depreciating with time.

Balogun et al. [13] investigated the reliability of Ganmo 33 kV feeders and find a way to improved it. Daily outages of the Ganmo 33 kV feeders were collected for a period of twenty-four (24) months and analytical method such as Markov model and load point indices (LPI) were used. The results showed that the dedicated feeders such as KAM and UNILORIN have the highest reliability compared to residential feeders and this was attributed to the level of load demand.

Kumar and Pindoriya [14] the study proposed an algorithm for outage detection using advanced metering infrastructure (AMI). The algorithm filters out the meter notification due to corrupted data and momentary outages of duration less than one minutes. The data filter was modelled by the fuzzy membership functions and probabilistic method. The data filters were tested for temporary and permanent outage test cases with different PSR value of the smart meters on radial test feeder.

Ajenikoko and Oyedele [15] the study evaluated the sensitivity of electrical distribution networks, such as the Ibadan, Ilorin, Ikeja, Port Harcourt, Kaduna, Kano and Benin networks were used. Ten (10) years outage data were collected and the statistical analysis method was deployed for the computation of the reliability indices of the various systems. The results of the sensitivity studies indicated that the Etete feeder of the Benin network has the highest SAIDI sensitivity value because of its prolonged customers' interruptions, while the Waterworks feeder of Ilorin system has the lowest SAIDI sensitivity value. Also, the Ikpoba Dam feeder of the Benin network recorded the highest CAIDI sensitivity value while Waterworks feeder recorded the least CAIDI sensitivity value as well.

Abdelfatah *et al.* [16] investigated the reliability of 220 kV power transformers in Egypt. Eight (8) years outage data were collected and the load point indices (LPI) method was adopted for the analysis of the data. The results showed that significant number of transformers were operated in the wear-out phase which affected their performance.

Amole *et al.* [17] investigated the reliability of some selected 11 kV feeders of Ibadan distribution network. Outage data was collected for period of four (4) years and the load point reliability indices method was used to analyzed the data. The results showed that many of these feeders were not reliable; hence extensive maintenance of the feeders was recommended.

Okorie *et al.* [18] evaluated the 11 kV feeders of the Ahmadu Bello University injection substation in Zaria. The daily outage data was collected for period of one (1) year and statistical analysis method was adopted for the analysis of the feeders' reliability. The results showed that although the availability was 90.16 % but is not within the standard benchmark and the reliability value was below standard.

Maher and Al-Maghalseh [19] investigated reliability of Medium-Voltage (MV) distribution network in the North East of England. The degree of reliability of the supply was measured using frequency, duration and magnitude of disturbances of customers as data in the study. Statistical analysis method was deployed to calculate both system indices and system worth indices and, the results showed that the failure rate of components were high due ageing and also, when automated radial feeders were used in the system reduces the total network risk (TNR) and improves the distribution system and also, the load point indices compared with manual operation.

Amadi [20] investigated the causes of incessant power outages in Port Harcourt City. Outage data and other relevant information were collected from National Bureau of Statistics (NBS), the Manufacturers Association of Nigeria (MAN), relevant literatures, interviews with resident of the city and personal observations for period of twelve (12) months. The descriptive and non-parametric simple percentages methods were used in analyzing the data collected and the results depicts inadequate power generating capacity, shortage of gas, weak and dilapidated electrical transmission and distribution networks, inadequate infrastructure facilities were the chief causes of incessant power outages in the city and solutions were recommended.

Akpojedje and Ogujor [10] the study investigated frequent power cut on the 11 kV feeders of Ugbowo 2x15 MVA, 33/11 kV electric power distribution network. Daily power outage data was collected for the period of twelve (12) months and load point indices (LPI) method was used to analyzed the data collected and the results depicted the reliability metrics were far cry from international acceptable standard and the power supply services in the network was unreliable.
Akpojedje *et al.* [21] the study investigated the tripping profile of the Oluku 33 kV feeder of Ugbowo 2x15 MVA, 33/11 kV distribution network. Daily outage data of the 33 kV feeder was collected for the period of twelve (12) months and load point indices (LPI) method was used for analyzing the reliability metrics of the feeder. The results revealed that the reliability performance indices of the 33 kV feeder were a far cry from the recommended international acceptable standard and this is inimical to the reliability and availability of electricity to consumers.
Akpojedje *et al.* [22] the paper evaluated the reliability metrics of the 11 kV feeders of the Ugbowo 2x15 MVA, 33/11 kV distribution system. Daily power interruptions of the 11 kV feeders were collected for the period of twelve (12) months and the daily outages were computed. The network was modelled in ETAP software and data collected were analyzed using LPI technique to estimate the reliability indices of the feeders. The results showed that the system performance indices (SPI) was a far cry from the recommended international acceptable standard value.
Akpojedje and Odiase [23] the study evaluated the major causes of frequent power interruptions in the Nigerian power system using a case study. The study carried out the concise overview of demand side management scheme and its modelling for matching electricity supply with ever-growing energy demand in the Nigeria power system since the gap created between available electricity supply and energy demand is huge. Various types of customers were modelled in the network and binary particle swarm optimization (BPSO) algorithm was adopted for optimizing the models and; the load shifting method was used in the system. The results showed that the method can match the available electricity supply with ever-growing energy demand.
Akpojedje and Ogujor [1] evaluated the frequent power outages in the Nigerian power system especially in the distribution network and how to alleviate the power shortages or deficits in the system. The peak load of the network under study was evaluated and peak supply and energy demand data was collected for the period of twelve (12) months. The demand side management (DSM) strategy was deployed in a Simulink environment using the BPSO algorithm as optimization tool in the system. The results of the simulations revealed that proposed technique has the capacity to bring the load curve close to an objective or desired load curve in the system thereby reducing the blackout areas of the network per outage scheduling in the system.

1.4.1 SUMMARY OF RELATED WORKS

The literatures reviewed revealed that outage management and evaluation of reliability indices have been carried out separately in-depth on the distribution network with various intent but nor has applied the two techniques simultaneously to evaluate the network. Therefore, this study aims to fill this gap. The goal is to evaluate how outage management has impact on reliability of the system.

2.0 MATERIALS AND METHODS

The materials and method used in this study are presented in subsection 2.1 and 2.2 respectively.

2.1 MATERIALS

The materials used in this study include personal consultative and interview of electric energy consumers, staff of the Benin Electricity Distribution Company (BEDC) domiciled in the injection substation. Data were collected for the period of twelve (12) months (February 2021 to January 2022) from the following materials as input data:

1. Daily shift report logbook
2. Daily report logbook of faults recorded in the network
3. Hourly report logbook of the feeders operations

2.2 METHOD

The hourly and daily failure outage data of the four (4) 11 kV feeder of the network were collated using analytical method for the period under study. The tripping profile of the four (4) 11 kV feeders were computed and the data collected were analyzed using Load Point Indices (LPI) to estimate the failure rate of the feeders, mean time between failure, availability, etc., while the SAIFI, SAIDI, CAIDI, ASAI, ASUI, etc., were used to determine the performance indices (PI) of the four (4) 11 kV feeders and the results obtained were interpreted graphically using Microsoft Excel and outage management system of the network was evaluated using analytical method and interaction with the Distribution System Operator (DSO).

3.0 RESULTS AND DISCUSSION

This section of the research presents the results and discussion expressly. The results were related to outages that were occurring in the network and the outage management system of the network was discussed.

3.1 RESULTS

The results showed the load point indices, customer-oriented indices and system performance indices of the respective feeders of the network and the issue of frequent power cut was substantiated from the outage management of the network. The following tables present the monthly and annual failure rate of the feeders, customers oriented indices, reliability indices and outage management techniques of the network:

Table 1: Ugbowo Distribution Network Outage Management Techniques

FGGC Feeder	Uselu Feeder	Eguaedaiken Feeder	Ugbowo Feeder
ON	**ON**	**OFF**	**OFF**
36.62% of the area of the network supplied with electric power		63.38% of the area of the network is on blackout	
OFF	**OFF**	**ON**	**ON**
36.62% of the area of the network is on blackout		63.38% of the area of the network supplied with electric power	

Table 2: Monthly Failure Rate of each Feeder of Ugbowo 2x15 MVA, 33/11 kV Injection Substation from February 2021 to January 2022.

Months / Feeders	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN
FGGC	0.2026	0.2754	0.1914	0.1935	0.1821	0.2026	0.2168	0.1954	0.1786	0.2179	0.2106	0.1559
Uselu	0.2026	0.2754	0.1914	0.1935	0.1821	0.2026	0.2168	0.1954	0.1786	0.2179	0.2106	0.1559
Eguaedaiken	0.1877	0.1586	0.2636	0.2235	0.2314	0.2292	0.2467	0.2487	0.1853	0.2248	0.2068	0.1888
Ugbowo	0.1859	0.1582	0.2326	0.1823	0.2222	0.2122	0.2174	0.2707	0.1936	0.2246	0.2139	0.1887

Table 2: Reliability Indices from February 2021 to January 2022

Description / Feeders	Frequency of Outages	Outage Duration	Annual Failure Rate (λ)	MTBF	MTTF	MTTR	Availability *(A)*	Unavailability *(U)*
FGGC	837	4,709	0.2066	10.466	4.840	5.626	0.462	0.538
Uselu	837	4,709	0.2066	10.466	4.840	5.626	0.462	0.538
Eguaedaiken	967	4,238	0.2138	9.059	4.677	4.383	0.494	0.506
Ugbowo	941	4,226	0.2075	9.309	4.819	4.491	0.518	0.482

Table 3: Customer Oriented Indices from February 2021 to January 2022.

Description / Feeders	Frequency of Outage	Outage Duration	SAIFI	SAIDI (HRS)	CAIDI (HRS)	ASAI (PU)	ASUI (PU)
FGGC	837	4,709	1.288	7.245	5.626	0.462	0.538
Uselu	837	4,709	0.338	1.899	5.618	0.462	0.538
Eguaedaiken	967	4,238	0.332	1.454	4.380	0.516	0.484
Ugbowo	941	4,226	0.291	1.306	4.488	0.518	0.482

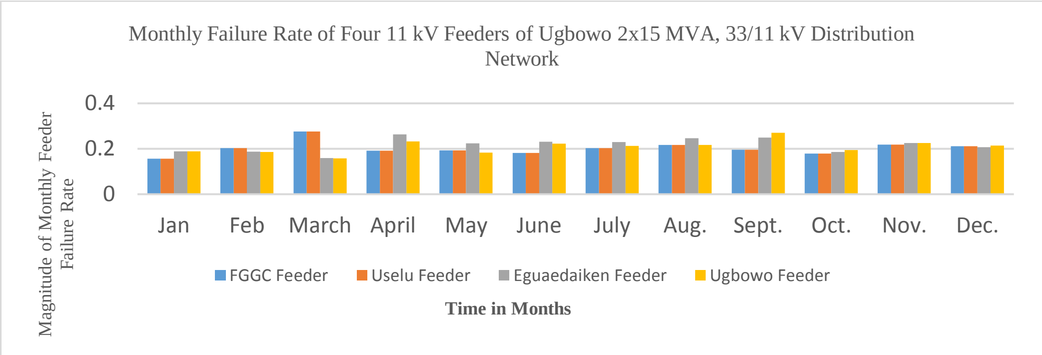

Figure 2: Monthly Failure Rate of 11 kV Feeders of Ugbowo 2x15 MVA, 33/11 kV Distribution Network

Evaluation of Outage… *France and Oluwafemi* ***J. of NAMP***

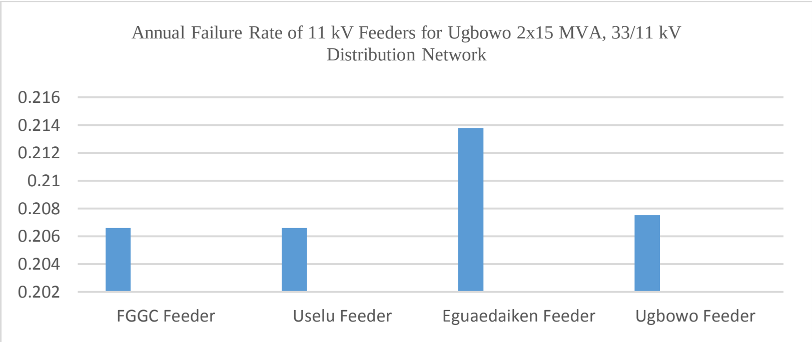

Figure 2: Annual Failure Rate of 11 kV Feeders of Ugbowo 2x15 MVA, 33/11 kV Distribution Network

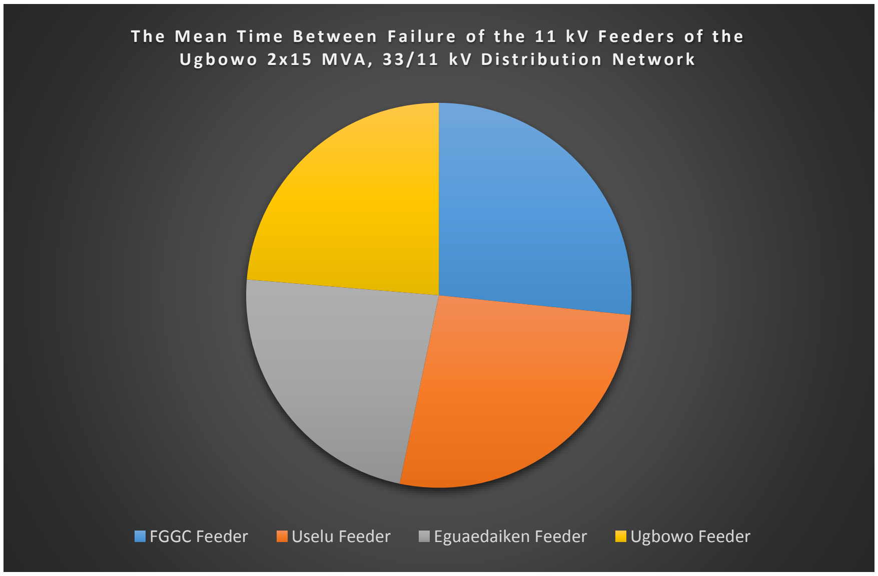

Figure 3: The Pie Chart of MTBF of the Ugbowo Four 11 kV Feeders

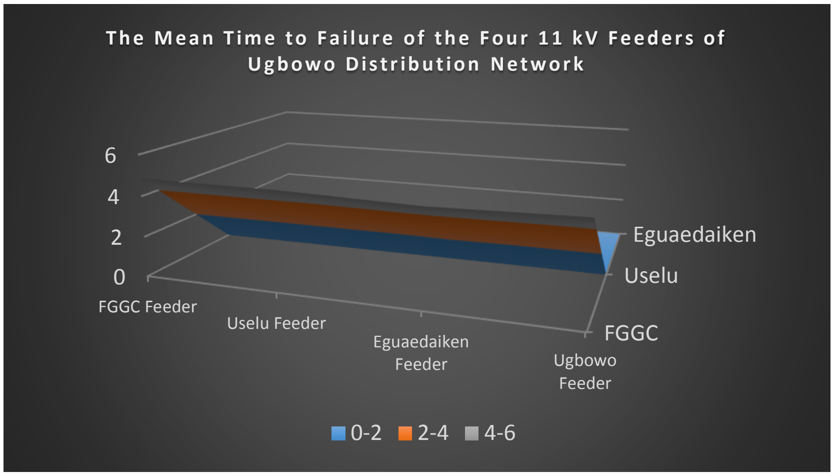

Figure 4: The MTTF of the 11 kV Feeders of the Ugbowo 2x15 MVA, 33/11 kV Distribution Network

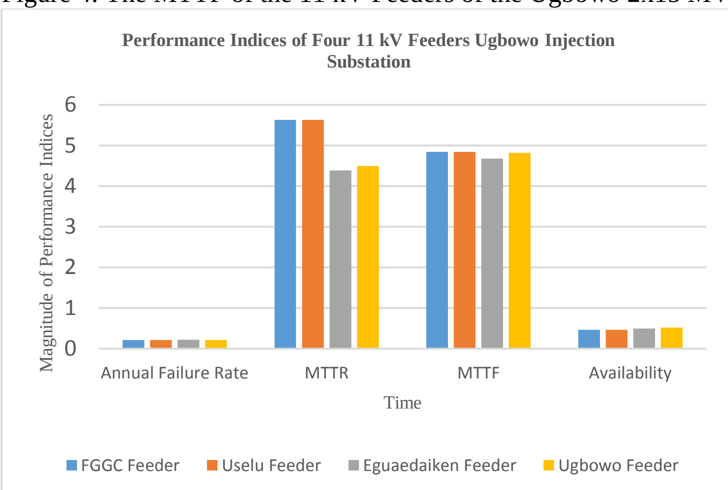

Figure 5: Performance Indices of Four 11 kV Feeders of Ugbowo 2x15 MVA, 33/11 kV Distribution Network.

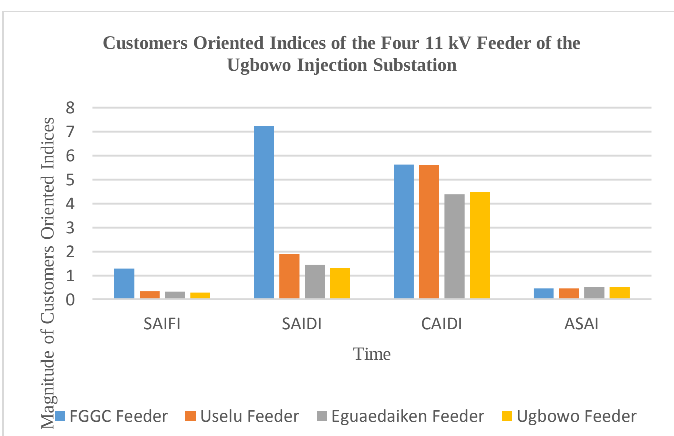

Figure 6: Customers Oriented Indices of the Four 11 kV Feeders of Ugbowo 2x15 MVA, 33/11 kV Distribution network

3.2 DISCUSSION OF RESULTS

Results of the evaluation of outage management (OM) and reliability indices (RI) of the Ugbowo 2x15 MVA, 33/11 kV electric power distribution network was discussed extensively in two perspectives in the following subsections.

3.2.1 EVALUATION OF OUTAGE MANAGEMENT OF THE NETWORK

The Ugbowo Injection Substation which is located along FGGC Road, Ugbowo, Benin City, is one of the biggest and oldest injection substation in Edo State with its coverage areas of Ugbowo and environs, FGGC and environs, Uselu and environs, Eguaedaiken and environs, etc. The substation was built by the British and handover to the Nigerian government. The substation covers over one hundred and fifty-nine outdoor power transformers and still counting. Scheduled outage system is deployed by the energy provider to manage the inadequate power generation and equipment limitations of the network. This was done by load scheduling or load-shedding using the 11 kV feeders circuit breakers which were originally met for protection of the downstream in the event of fault(s) in the system. The 11 kV circuit breakers were actually provided as a means of protection to completely isolate the downstream network in the event of a fault. Using these 11 kV circuit breakers as a means of load management is not desirable as it disconnects the power supply to a very large segment of the network (Akpojedje, 2021). Using these 11 kV circuit breakers for taking outages and restoration cause blackout over a large section of the network and it affects the reliability indices. From Table 1, it showed the outage management of the injection substation solely depends on the 11 kV circuit breakers; the DSO used it as tool for load-shedding (outage) and restoration of electricity to the feeder he/she deem fit to supply energy. The Table 1 shows that FGGC and Uselu feeders were in service (ON), then, the Eguaedaiken and Ugbowo feeders will be out of service (OFF) vice-versa using the 11 kV circuit breakers to manage the energy demand and supply of the network, thereby using the 11 kV circuit breakers as outage management system in the network. This has a lot of disadvantages on the system reliability and performance.

3.2.2 ESTIMATION OF RELIABILITY AND SYSTEM PERFORMANCE INDICES

The reliability indices of the distribution network have been assessed and the results interpreted graphically using the spreadsheet and tabular forms. The results shown in Table 2 presented the monthly failure rate of the four 11 kV feeders of the network with the FGGC feeder and Uselu feeder having the highest failure rate of 27.54% in the month of March 2021, followed by the Ugbowo 11 kV feeder of 27.07% and the Eguaedaiken 11 kV feeder of 26.36%. The four 11 kV feeders' failure rate witnessed improvement compared to the analysis carried-out by Akpojedj and Ogujor (2020) and Akpojedje et al. (2021). This can be attributed to the installation of new 33/11 kV panels and circuit breakers which are more efficient and reliable than the old oil circuit breakers that were in use before the change was effected and Figure 2 showed the graphical interpretation of the monthly failure rate of the four 11 kV feeders. Table 3 and Figure 3 presented the annual failure rate of the four 11 kV feeder and the reliability indices. The mean time between failure (MTBF) of the four 11 kV feeders is depicted in Figure 3 with the FGGC and Uselu feeders having the highest value, followed by Ugbowo feeder and Eguaedaiken feeder having the least value. Same applied to the mean time to failure (MTTF) with the FGGC and Uselu feeders having the highest value, followed by Ugbowo feeder and Eguaedaiken feeder having the least value, as well as mean time to repair (MTTR) respectively.

The availability of the four 11 kV feeder were depicted with FGGC and Uselu feeders having 46.2%, followed by Eguaedaiken feeder 49.4% and Ugbowo feeder 51.8%. The customers' oriented indices of the four 11 kV feeder is presented on Table 4 and Figure 4 with the FGGC feeder having the highest SAIFI, followed by Uselu feeder, Eguaedaiken feeder and the Ugbowo feeder having the lowest SAIFI. Same apply to SAIDI but for CAIDI, FGGC feeder have the highest value, followed by Uselu feeder, Ugbowo feeder and Eguaedaiken feeder has the lowest CAIDI value.

The Ugbowo 11 kV feeder has the highest ASAI value, followed by the Eguaedaiken 11 kV feeder and the FGGC and Uselu 11 kV feeders have the same ASAI value. From Table 4, the value of SAIDI, SAIFI and ASAI of the network is far from the international acceptable standard value (IASV) of 2.5 hrs, 0.01f/cu.yr and 99.99% respectively.

4.0 CONCLUSION

The outage management and reliability indices of the four 11 kV feeders of the Ugbowo 2x15 MVA, 33/11 kV distribution network have been evaluated for the period of twelve (12) months based on daily outage data collected from the network. It is clear from Table 2 that FGGC and Uselu feeders have the highest failure rate in the month of March 2021; followed by the Ugbowo feeder and Eguaedaiken feeder having the least failure rate. It is also observed that network operators make use of the 11 kV circuit breakers as a means of outage management (taking outage and restoration of electric power to consumers) vis-à-vis load shedding which is originally met for protection of the downstream. This system of practice by the network operators caused a large blackout to the system as specified in Table 1 and also, affect the reliability, system performance and customers oriented indices of the network. The frequent opening and closing of 11 kV circuit breakers have great effect on the porcelain of the 11 kV circuit breakers. Therefore, the authors recommend appropriate actions should be taken and installation of automated outage management system as well as optimal network reconfiguration is required in the network to avoid damages to 11 kV circuit breakers and to minimize blackout areas per outage scheduling in the network.

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