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Fault and Reliability Evaluation Model of Secondary Distribution System of Katampe 330/132/33kv Transmission Station in the FCT, Abuja

Innocent -Ogan Agnes Tamunobereni, Evans C. Ashigwuke
Department of Electrical Engineering
Faculty of Engineering
University of Abuja, Nigeria

ABSTRACT
As electricity has become one of the basic needs of people in many fast-growing technologies-inclined nations, the planning, development and maintenance of the power infrastructures to keep electricity most reliable and readily available cannot be overemphasized. However, in Nigeria, the rate of power interruptions and failures is quite high. Suppose this is not curtailed through adequate intervention of manpower and structure for a sustainable and efficient reliable system. In that case, the downturn effect may damage the nation's technological advancement. This is the reason, this research is aimed at determining the faults and evaluating the reliability of the secondary distribution of the Katampe 330/132/33kv transmission system by using network modelling of data collected from the data centre of the named substation. The data analyses for various feeders within the substation were extensively carried out and modelled using MATLAB a data virtualization tool. The result and subsequent graphical illustrations proved beyond reasonable doubt, the extent to which SAIFI, SAIDI, CAIDI, ASAI and other indexes of prominent feeders fare. In this desertification, only 9Mobile feeders exhibited the highest level of availability, followed by the Wuse, Gwarinpa, and LifeCamp feeders. In other words, the Jabi feeder was more likely to be unavailable most of the time within the period of study. Unarguably, 9mobile could be placed in the list of IEEE acceptable reliability standards. It could also be concluded that only 9mobile or the five feeders in Abuja are not sufficient enough to determine the reliability status of Nigeria's electrical power system but provide an idea of what is required to achieve that level of comparison in the global stage.

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INTRODUCTION

Electricity is the bedrock and arguably the most fundamental basis of any developed and advanced nation. In Electric Power Systems, Generation, Transmission and Distribution Systems are the very important infrastructures because they deliver electricity to users either domestic or commercial consumer.

Their nonstop and dependable execution is basic to country building and citizens' way of life. Disappointment of these Frameworks has coordinated and circuitous negative impact on day-by-day exercises and the social-economy well-being of the users. Conflicting electric control supply comes about in uneasiness, mental inconvenience, as well as smothered efficiency [1]. In this manner, the development and advancement of innovation in any advanced society is subordinate on the solidness and unwavering quality of the control frameworks that give steady power to schools, investigate organizing, businesses, healing

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

centers, water sheets, shopping centers, occasion centers, traveler centers, family units e.t.c for driving their machines, creating gear that helps investigate, gives steady power for life bolster machines (clinic ventilators), enlightening the complete building and parcels of other capacities power gives.

In this manner, power utilization has ended up a vital figure that influences the drive required for innovation to develop and to encourage the development of present day society within the confront of ever-increasing control request (due to more private buildings on modern location and populace blast), a few dispersion lines were more stacked than were planned to be when they were built. In the meantime, as the most point of a control framework is to meet the power needs of the citizens and this could as it were be accomplished when the components making up the framework are performing their expecting work appropriately for as long as the framework is in operation, it is critical that the request for power and its supply be reasonably seen and included in setting up the framework. In this manner, due to its tall effect, on the taken a toll of power and its comparing impact on users' fulfillment, conveyance unwavering quality is exceptionally critical.

However, as in any other viable engineering system, there are challenges that face power distribution system which tends to make the system unreliable. One of these is the issue of serving its main purpose which is to supply quality electricity with little or no interruptions. This problem is inevitable in power systems across the world but the way they are managed is what makes it different from country to country. For instance, in the United States, there is nearly an uninterrupted delivery of quality electricity to its numerous customers which makes it rank among the most dependable in the world. It is in management of the power systems that reliability evaluation becomes significant. Reliability evaluation does not in any way make a system more reliable but it helps in system planning and identification of weak components. With the increased loading of long distribution lines, many problems such as fault and system overloading can become a major power distribution limiting factor. Hence, the reliability of such power networks becomes a very important issue and therefore to take seriously the issue of reliability of an electric power system [2].

Katampe Transmission Substation is one of the largest substations in FCT and heavily equipped with various devices from 330/132kv supply line, 2 x 60MVA power transformers, and three 150MVA Power transformer connected to six major feeders of Suleja 1, Suleja 2 (Kubwa), Garki 1, Garki 2(Apo), Central Area 1 and Central Area 2. The substation is equipped with lots of switching and protection devices to ensure efficient operation. However, the efficient operation, stability and Reliability of the system is not 100% guaranteed owning faults, be it Natural or Man Made. Electric power interruption is largely becoming a consistent phenomenon in wide area network of electricity distribution and this is basically due to failures as a result of insufficient power generation, Transmission faults and Faults in the distribution system. Presently in Nigeria, some lines are prioritized against others due to dignitaries and personalities on particular lines thereby making power supply to the common masses to be forced out deliberately. This problem however requires solutions for equitable distribution of electricity. There are also cases of deliberate outages due to weather especially rainfall, thunder and lightning. This is to protect most residential areas from voltage surge that may enter into the power system when lightning occurs owing to the fact, electrical designs and installations in most residential houses are usually not done by professionals especially in the settlements of middle-class and the low-income earner. Considering the fact that the capacity of the installations and Generations in Nigeria cannot serve all the customers at the same time, it is expected that the available power generated be judiciously served with little or no interruptions. That is, when power is generated and available in the system, the distribution substation must be up to its task of delivering quality power to the customers. Therefore, there is the need for Fault

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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and Reliability evaluation of Katampe Transmission-Distribution substation in order to ascertain its Reliability and proffer possible solutions which can be applicable to other substations in the country. In the reliability evaluation of power systems, the collection of failure data could be one of the most difficult things due to several reasons, hence the reason the study area is chosen because of access to the data needed for this research. The research aim is to determine the fault and evaluate the reliability of secondary distribution of Katampe 330/132/33kv transmission system.

CONCEPT OF ELECTRICAL FAULT

As the electrical power system is growing in size and complexity in all sectors such as generation, transmission, distribution, and load systems; electrical networks, machines and equipment are often subjected to various types of faults while in operation. When a fault occurs, the characteristic values (such as impedance) of the machines may change from existing values to different values till the fault is cleared [3].

Fault occurrence in power system is inevitable. Hence, in every power system design procedure, these faults are considered and analyzed, their likelihood of occurrence is determined and the best ways to handle them are earmarked so as to improve system stability, ruggedness, maintenance cost and ensuring reliability of power system [4].

The fault analysis of a power system is required in order to provide information for the selection of switchgear, circuit breakers, and the setting of relays, to be used in the power systems protection. A power system is not static but changes during operation (switching on or off of generators and transmission lines) and during planning operation (addition of generators and transmission lines). Thus, fault studies need to be routinely performed by utility engineers [5].

An electrical fault is an abnormal condition, caused by equipment failures such as transformers and rotating machines, human errors, and environmental conditions. These faults cause interruption to electric flows, equipment damages, and even cause the death of humans, birds, and animals. A fault in an electric power system can also be defined as, any abnormal condition of the system that involves the electrical failure of the equipment, such as, transformers, generators, bus bars, etc.

In any case, there may be part of probabilities of issues to seem within the control framework arrange, counting lighting, wind, tree falling on lines, device disappointment. Beneath ordinary or secure working conditions, the electric hardware in a control framework organize work at ordinary voltage and current evaluations. Once the blame takes put in a circuit or gadget, voltage and current values goes astray from their supposed ranges.

The flaws in control framework causes over current, lower voltage, unbalance of the stages, reversed power and tall voltage surges. This comes about within the intrusion of the ordinary operation of the arranged distress of gear, electrical fires, etc. Ordinarily control framework systems are ensured with switchgear assurance gear such as circuit breakers and transfers in arrange to restrain the disaster of advantage due to the electrical disappointments [6].

The fault beginning too includes in separator discontents and conducting way discontents which comes about close circuit and open circuit of conductors.

Sorts of deficiencies like close circuit conditions within the control framework organize result in extreme financial disasters and decrease the unwavering quality of the electrical framework.

CONCEPT OF RELIABILITY

Reliability is the duration or probability of failure-free performance under stated conditions. It is the probability that an item can perform its intended function for a specified interval under stated conditions. Many mathematical concepts apply to reliability engineering, particularly from the areas of probability and statistics. These include the Gaussian (normal) distribution, the log-normal distribution, the Rayleigh distribution; the exponential distribution (e.g. MTTR), the Weibull distribution and a host of others have been used to estimate reliability. Mathematical

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modeling gave a rigid meaning to the concept of reliability, reducing it to its quantitative measure. No model perfectly fits the reality it seeks to describe it and it is therefore always necessary to distinguish between the phenomenon and the model, between the physical object and its measure [7].

METHODOLOGY

Overview of Katampe 132/33KV Transmission System

Katampe transmission system being the substation under study is a product of Transmission Company of Nigeria TCN which came into existence as a result of a merger from Transmission and Operation sectors of the defunct National Electric Power Authority (NEPA) in April 1, 2004. The TCN was incorporated in November, 2005 and issued a transmission License on 1st July, 2006. It was under this ladder, that the Katampe 330/132/33kv transmission system was birthed. It is made up of a double circuited transmission line which takes it source from Shiroro Generating Station through National Grid. It was designed and constructed by various companies like Energo, News Engineering e.t.c. in 2007. It comprises of 2 x 60MVA 132/33kv power transformers. The lines supply power to other towns within Abuja and its environs. It consists of 8.4km underground armored cabling that transmit power through Wuye district to 132/33kv Kukwaba-National Stadium and 330/132/33kv Apo transmission substations [3].

Below are the single line Diagrams of the 132/33kV and 330/132kV Katampe Station.

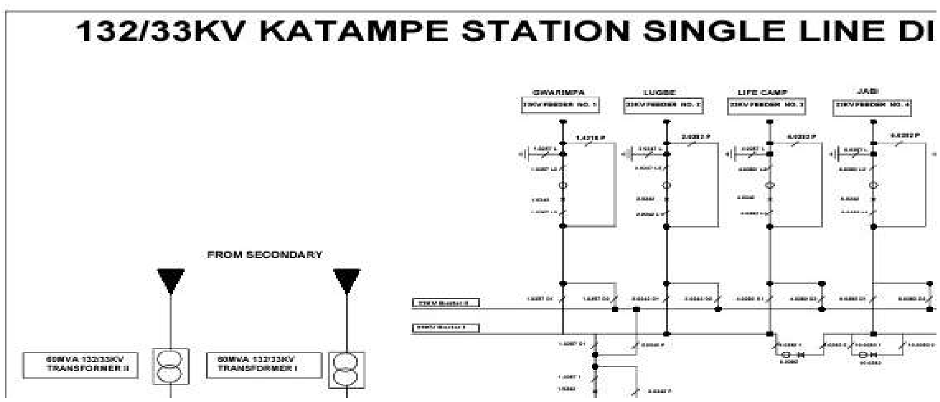

Fig. 1: Single Line Diagram of 132/33KV Transmission-Distribution Station

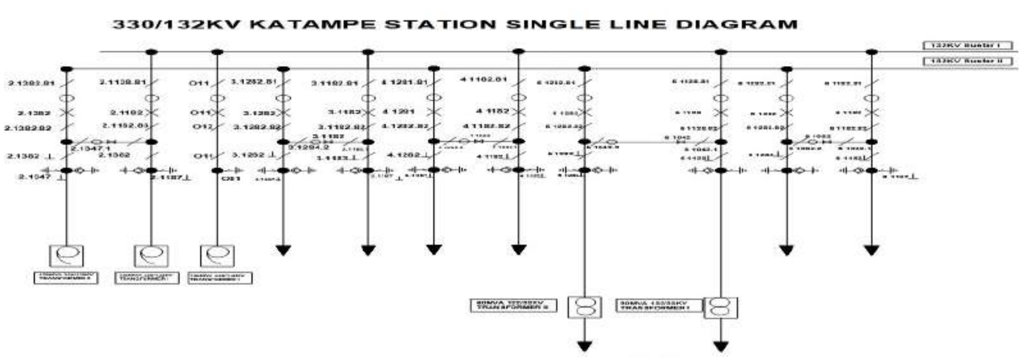

Fig. 2: Katampe 330/132kV Single Line Diagram

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Reliability Assessment, Metrics and Indices

Distribution substation system serves as the interface between utility companies and the customers served. Hence, its assessment helps to determine how reliable the system is and to what extent customers are being served. The ability of a distribution system to perform its function under stated conditions for a given period of time with little or no interruptions to service delivery is known as distribution reliability [8]. Distribution reliability usually involves critical analytical handling of well-defined metrics also known as units of measurement. Across the world, reliability indices are being used by utility companies to monitor the performance of their distribution region, and or the substation. Most utilities owned by investors are usually required by regulation to report their reliability performance as enumerated by reliability parameters. In most cases, this is done in order to reward utility companies that perform well as the trend in regulation is tending towards performance-based appraisal. Some of the utilities even pay bonuses to their managers based in part on reliability achievements [9]. Moreover, some commercial and industrial customers request for reliability indices from utility companies when planning to find a site for their firms. In addition, one thing that makes distribution system reliability very important is that, carrying out individual physical assessment on all installed equipment in the system would usually be physically tasking, expensive and time consuming.

Reliability Analysis

Reliability analysis of electrical distribution system is viewed as a tool for the planning engineer to ensure a reasonable quality of service and to choose between different system expansion plans that, cost wise, were comparable considering system investment and cost of losses [10]. There are two major methods employed in the analysis of distribution system reliability, namely Simulation method (Monte Carlo) and Analytical methods. The Monte Carlo technique usually takes time as a result of the huge number of inferences needed to arrive at precise results. The analytical approach is centered on statistical distributions of the rate of component failure and time taken to restore it to service. The method that is most often used in evaluating reliability indices is analytical approach which is based on failure modes assessment and the use of equations for series and parallel networks. The common indices used for evaluation: the expected failure rate (λ), the average outage time (r), and the expected annual outage time/ unavailability (U) which are suitable to the simple radial system. Distribution systems contain grids which are either radial or meshed. These networks are for the most part operated radially and this makes them simple to assess. The process is further complex for other network configurations.

The main theory for reliability analysis used in this dissertation is discussed below.

Network Modeling

An electrical system can usually be viewed as a network of its components connected together either in series, parallel, meshed or a combination of these. The structural relationships between a system and its components are considered in this technique. Modeling the failure behavior of the system is one of the major challenges in reliability analysis. Hence, failure mode and effect analysis (FMEA) has become the widely accepted means for reliability evaluation of distribution systems. By carrying out analysis on each component that makes up the system, this approach presents all the imminent failure modes and then pin-points their resulting effects on the system. This method determines at least those components within a system which result in an interruption of service at the load-point of interest. This is the method used in the analysis of the components in the substation analyzed in this dissertation. It determines the load-point indices and aggregates them to get the system wide indices. A radial system basically consists of set of series components such as breakers, lines, switches, transformers and at the end “Customers” [11].

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Series System

From reliability viewpoint, all the components in a series system must be working together to ensure system success or the failure of one leads to entire system failure. This therefore implies that a series system is a non-redundant system. The Figure 3 describes a series system:

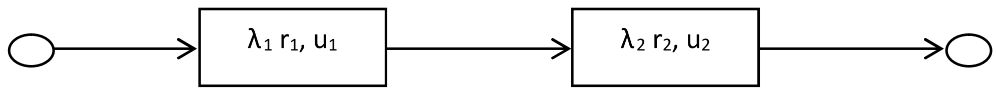

Fig.3: Series System

[23] provided the formulae used in the calculations involved in the series system shown in the figure 3.3 above and are given in equations (1) to (3); where the expected failure rate U = the annual outage time r = the average outage time

$$\lambda s = \lambda_1 + \lambda_2 = \sum_{i=1}^{2} \lambda i \tag{1}$$

$$\mu_s = \lambda_1\mu_1 + \lambda_2\mu_2 = \sum_{i=1}^{2} \lambda_i\mu_i \tag{2}$$

$$r_s = \frac{\mu_s}{\lambda_s} \tag{3}$$

Parallel System

The components in a set are said to be in parallel from a reliability point of view if only one needs to be working for system success or all must fail for system failure. This is a fully redundant system.

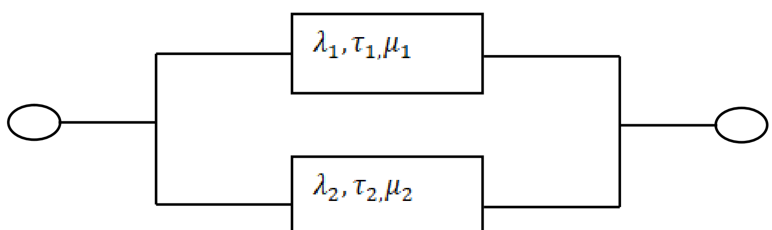

Fig.4: Parallel System

Figure 4 Typical Diagram of a Parallel System. The calculations involved in the parallel system shown in the figure 3.4 above are given in equations (4) to (6);

$$\lambda_p = \lambda_1\lambda_2(\tau_1 + \tau_2) \tag{4}$$

$$\mu_p = \lambda_1\lambda_2\tau_1 \tag{5}$$

$$\tau_p = \frac{\mu_p}{\lambda_p} \tag{6}$$

It suffices to say that equation (4) to (6) are for simple radial systems and more indices are computed for general distribution systems. Network technique using the series system is used in calculating the failure rates of all components making up the distribution system.

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✉ agnesinnocentogan@gmail.com
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Also, the following reliability parameters in equations (1) to (6) will be used in determining the availability of each component and the overall availability of the substation using the data collected.

Reliability Indices

Reliability indices are statistical aggregations of reliability data for a well-defined set of loads, components or customers. Reliability indices are often the mean value of a specific reliability feature for an entire system, operating region, or feeder. The sections below describe the most important reliability indices used by most utility companies and system planners.

System Average Interruption Duration Index (Saidi)

This is defined as the average interruption duration for customers served during a specified time period. The unit is "minutes". This index helps the utility company 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:

$$SAIDI = \frac{Total\ Outage\ Duration\ in\ Hours}{Number\ of\ Customers\ Supplied} \qquad (7)$$

System Average Interruption Frequency Index (Saifi)

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 expressed as

$$SAIFI = \frac{Frequency\ of\ Outages}{Number\ of\ Customers\ Supplied} \qquad (8)$$

Customer Average Interruption Duration Index (Caidi)

This is defined as the average length of an 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:

$$CAIDI = \frac{Sum\ of\ Customers\ Interruptions\ Durations}{Total\ Number\ of\ Customers\ Interrupted}$$

$$= \frac{SAIDI}{SAIFI} \qquad (9)$$

Average Service Availability Index (ASAI)

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:

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$$ASAI = \frac{Customers\ Hours\ Service\ Availability}{Customers\ Hours\ Service\ Demanded} \quad (10)$$

Average Service Unavailability Index (Asui).

$$ASUI = \frac{Duration\ of\ Outages\ in\ Hours}{Total\ Hours\ Demanded} \quad (11)$$

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

DATA COLLECTION

The data collected was for twelve-month component outage duration beginning from May, 2021 to June 2022. Outages recorded in the utility outage logbook is presented in Excel format which include in the energy meter reading were given as a result of customers' complaints to the utility company. The substation system, like other substations in Nigeria, does not have intelligent devices that can alert the distribution company whenever there is failure of any equipment or any form of interruption to the delivery of electricity to the customer. Only forced outages, outages due to faults and failures, were taken into consideration for this dissertation work to avoid extraneous circumstances. Outages due to scheduled maintenance and load shedding were not taken into consideration. This is so because scheduled outage or load shedding in the substation is intentional and cannot be attributed to any component failure which makes it hard for analysis to pin-point weak component if used. The dissertation focuses on the substation's inability to deliver electricity as a result of its own deficiency when there is electricity available for distribution.

In the Table 1, the data consist of the following columns: Month, Name of Station, Name of Bursar, Feeder location, Total number of tripping, Number of customer served, Number of customer interrupted, Total time loss (in minutes, in hours), Total load loss (in Megawatts), Total load loss (in Megawatts Hour), Present Energy Meter Reading, Previous Energy Meter Reading, Difference Energy Meter Reading.

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Table 1: Energy meter reading for Katampe 2 Substation [12]

TEMPLATE OF MONTHLY OPERATIONAL REPORT FOR THE AREA CONTROL										
MONTH	STATION	TRANS 33KV BUS	33KV FEEDER	TOTAL NO OF TRIPPING	TOTAL TIME LOSS	TOTAL LOAD LOST (MW)	TOTAL LOAD LOST (MWH)	ENERGY METER READING		
								PRESENT	PREVIOUS	DIFFERENCE
				OUTAGE	HR	LOSS (MW)	LOSS (MWH)			
Jun-21	KATAMPE 2	BUSBAR1	WUSE2	29	23:56:00	296.3	235.53	818798.84	810098.9	8699.94
			JABI	61	103:26:00	465.2	678.97	374904.96	369760.4	5144.96
		BUSBAR 2	GWARINPA	38	78:30:00	499.1	1005.17	615318.65	606087.6	9231.05
			LIFE CAMP	50	80:53:00	266.5	375.78	410534.29	406659.94	3874.34
			9 MOBILE	12	43:23:00	9.19	37.69	392574.08	391919.52	654.56
Jul-21	KATAMPE 2	BUSBAR1	WUSE2	11	26:13:00	119.7	293.255	827146.22	818798.84	8347.38
			JABI	64	96:25:00	461.1	677.352	379445.38	374904.96	4540.42
		BUSBAR 2	GWARINPA	25	11:03:00	276.3	141.367	624204.94	615318.65	8886.29
			LIFE CAMP	33	16:22:00	164.9	325.247	414208.12	410534.29	3673.83
			9 MOBILE	4	4:38:00	2.2	2.667	393401.22	392574.08	827.14
Aug-21	KATAMPE 2	BUSBAR1	WUSE2	2	6:06:00	26.8	83.8667	836087.08	827146.2	8940.86
			JABI	69	78:46:00	476.8	530.8133	384354.18	379445.4	4908.8
		BUSBAR 2	GWARINPA	37	43:21:00	415.2	492.4164	633015.64	624204.9	8810.7
			LIFE CAMP	34	79:16:00	173.1	305.2967	417894.84	414208.12	3686.71
			9 MOBILE	11	26:58:00	6.9	23.545	394156.91	393401.22	755.69
Sep-21	KATAMPE 2	BUSBAR1	WUSE2	10	11:20:00	124.7	148.713	844797.5	836087.08	8710.42
			JABI	75	115:22:00	492.9	669.61	388777.41	384354.18	4423.23
		BUSBAR 2	GWARINPA	37	61:40:00	393.1	654.39	641167.67	633015.64	8152.03
			LIFE CAMP	46	62:31:00	237.2	324.57	421595.23	417894.84	3700.4
			9 MOBILE	11	26:00:00	10.2	25.86	394963.58	394156.91	806.67
Oct-21	KATAMPE 2	BUSBAR1	WUSE2	4	6.983333	68.3	125.393	855474.09	844797.5	10676.59
			JABI	68	124.55	537.4	1073.3967	394103.53	388777.41	5326.12
		BUSBAR 2	GWARINPA	36	46.963333	482.9	635.32997	651942.27	641167.67	10774.6
			LIFE CAMP	36	32.35	217.7	202.3267	426413.98	421595.23	4818.75
			9 MOBILE	9	15.683333	7.9	12.26	395792.24	394963.58	828.66
Nov-21	KATAMPE 2	BUSBAR1	WUSE2	3	5.9333	56.3	112.09	866667.73	855474.09	11193.64
			JABI	62	89.95	525.4	695.08168	399964.67	394103.53	5861.14
		BUSBAR 2	GWARINPA	59	98.8	785.5	1334.915	662258.02	651942.27	10315.75
			LIFE CAMP	23	16.7	146.6	83.275	431598.1	426413.98	5184.12
			9 MOBILE	3	3.1167	3.3	2.601667	396661.37	395792.24	869.13
Dec-21	KATAMPE 2	BUSBAR1	WUSE2	11	12.7	162.8	238.765	877521.66	866667.73	10853.93
			JABI	49	55.133	418.3	463.512	406253.09	399964.67	6288.42
		BUSBAR 2	GWARINPA	37	27.767	524.4	357.89	672986.05	662258.02	10728.03
			LIFE CAMP	27	29.733	184.9	202.719	436807.42	431598.1	5209.32
			9 MOBILE	2	0.45	2.1	0.43	397607.59	396661.37	946.22
1-Jan	KATAMPE 2	BUSBAR1	WUSE2	16	14.166667	232.2	227.8934	882153.45	877521.66	4631.79
			JABI	55	76.83333	469.4	615.698	409080.39	406253.09	2827.3
		BUSBAR 2	GWARINPA	23	17.25	285.9	233.7333	677774.78	672986.05	4788.73
			LIFE CAMP	55	81.616667	340.6	516.1818	439030.22	436807.42	2222.8
			9 MOBILE	2	2.9333333	2	3.6	398068.12	397607.59	460.53
1-Feb	KATAMPE 2	BUSBAR1	WUSE2	6	8.0833333	95.7	106.6083	897945.72	882153.45	15792.27
			JABI	44	52.55	385.7	378.49667	418019.14	409080.39	8938.75
		BUSBAR 2	GWARINPA	44	68.566667	587.6	594.69943	692192.13	677774.78	14417.35
			LIFE CAMP	34	41.433333	235	305.935	446655.56	439030.22	7625.34
			9 MOBILE	6	10.816667	9.9	14.921667	399379.97	398068.12	1311.85
1-Mar	KATAMPE 2	BUSBAR1	WUSE2	30	52.45	564.9	905.35667	909686.94	897945.72	11741.22
			JABI	103	107.46667	1034.3	1115.1033	425002.68	418019.14	6983.54
		BUSBAR 2	GWARINPA	80	74.33331	1319.3	894.585	702781.05	692192.13	10588.92
			LIFE CAMP	58	63.2	525	595.56167	453634.12	446655.56	6978.56
			9 MOBILE	12	20.41667	14.7	27.441667	400314.13	399379.97	934.16
Apr-22	KATAMPE 2	BUSBAR1	WUSE2	42	41.6	845.8	743.47	921732.09	909686.94	12045.15
			JABI	84	169.35	918.9	1822.257	431267.52	425002.68	6264.84
		BUSBAR 2	GWARINPA	84	87.166667	1315.6	1356.0933	712643.69	702781.05	9862.64
			LIFE CAMP	47	58.95	452.8	617.225	460532.45	453634.12	6898.33
			9 MOBILE	18	24.666667	13.5	18.191667	401123.44	400314.13	809.31
May-22	KATAMPE 2	BUSBAR1	WUSE2	30	46.51667	547.2	826.8567	932942.58	921732.09	11210.49
			JABI	79	200.81667	874	2196.128	437497.52	431267.52	6230
		BUSBAR 2	GWARINPA	86	96.016667	1109.9	1458.8383	722131.92	712643.69	9488.23
			LIFE CAMP	75	108.38333	690.4	1007.3	467156.64	460532.45	6624.19
			9 MOBILE	22	38.716667	19.8	27.505	401900.69	401123.44	777.25

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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RESULTS AND DISCUSSION

This section presents the results and discussion of the finding from this research work.

Description of Data Collected and Analysis

The data utilized in this research were obtained over a period of 12 consecutive months, spanning from June 2021 to May 2022, at the Katampe Station located in Abuja. The recorded data specifically pertained to two distinct 33kV Busbars: Busbar 1 and Busbar 2. Busbar 1 encompassed two feeders, Wuse 2 and Jabi, whereas Busbar 2 facilitated transmission to three feeders: Gwarinpa, Life Camp, and 9 Mobile. A detailed representation of the collected data from each feeder can be found in Tables 2a-e followed by the corresponding descriptive statistics showing the Mean, standard deviation, variance, and median.

Table 2a: shows the data collected from Wuse 2 Feeder [12]

Month	Number of Tripping	Total Time Lost (Hr)	Total Load Lost (MW)	Total Load Lost (MWH)	Present Energy Reading	Previous Energy Reading	Diff. in Present and Previous Energy Reading
JUN	29	23.93	296.3	235.53	818798.84	810098.9	8699.94
JUL	11	26.10	119.70	293.26	827146.22	818798.84	8347.38
AUG	2	6.05	26.80	83.87	836087.08	827146.2	8940.88
SEP	10	11.45	124.70	148.71	844797.5	836087.08	8710.42
OCT	4	6.98	68.30	125.39	855474.09	844797.5	10676.59
NOV	3	5.93	56.30	112.09	866667.73	855474.09	11193.64
DEC	11	12.70	162.80	238.77	877521.66	866667.73	10853.93
JAN	16	14.17	232.20	227.89	882153.45	877521.66	4631.79
FEB	6	8.08	95.70	106.61	897945.72	882153.45	15792.27
MAR	47	107.47	944.60	1910.98	42546.95	31610.6	10936.35
APR	43	81.63	792.90	1225.13	53778.35	42546.95	11231.4
MAY	30	46.52	547.20	826.86	932942.58	921732.09	11210.49

Statistics

Variable	Mean	StDev	Varian
No_of_tripping	17.67	15.72	246.
Total_time_lost_(Hr)	29.25	33.09	1094.
Total_load_lost_(MW)	289.0	306.6	9402(
Total_load_lost_(MWH)	461	572	3275
Present_Energy_Reading	727988	319132	1.01846E+

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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Table 2b: shows the data collected from Jabi Feeder [12]

Month	Number of Tripping	Total Time Lost (Hr)	Total Load Lost (MW)	Total Load Lost (MWH)	Present Energy Reading	Previous Energy Reading	Diff. in Present and Previous Energy Reading
JUN	61	103.43	465.2	678.97	374904.96	369760.4	5144.56
JUL	64	96.42	461.1	677.352	379445.38	374904.96	4540.42
AUG	69	78.77	476.8	530.8133	384354.18	379445.4	4908.78
SEP	75	4.81	492.9	669.61	388777.41	384354.18	4423.23
OCT	68	124.55	537.4	1073.3967	394103.53	388777.41	5326.12
NOV	62	89.95	525.4	695.081676	399964.67	394103.53	5861.14
DEC	49	55.13	418.3	463.512	406253.09	399964.67	6288.42
JAN	55	76.83	469.4	615.698	409080.39	406253.09	2827.3
FEB	44	52.55	385.7	378.49667	418019.14	409080.39	8938.75
MAR	108	328.03	1304.6	3869.17	498263.34	491914.63	6348.71
APR	97	260.16	1235.1	3303.37	504561.29	498263.34	6297.95
MAY	79	200.82	874	2196.128	437497.52	431267.52	6230

Statistics

Variable	Mean	StDev	Varian
No._of_tripping	69.25	18.59	345.4
Total_time_lost_(Hr)	122.6	93.8	8792
Total_load_lost_(MW)	637.2	320.2	102537
Total_load_lost_(MWH)	1263	1191	14179
Present_Energy_Reading	416269	43404	18838866

Table 2c shows the data collected from Gwarinpa Feeder [12]

Month	Number of Tripping	Total Time Lost (Hr)	Total Load Lost (MW)	Total Load Lost (MWH)	Present Energy Reading	Previous Energy Reading	Diff. in Present and Previous Energy Reading
JUN	38	78.50	499.1	1005.17	615318.65	606087.6	9231.05
JUL	25	11.05	276.3	141.367	624204.94	615318.65	8886.29
AUG	37	43.35	415.2	492.4164	633015.64	624204.9	8810.74
SEP	37	2.57	393.1	654.39	641167.67	633015.64	8152.03
OCT	36	46.96	482.9	635.32997	651942.27	641167.67	10774.6
NOV	59	98.80	785.5	1334.915	662258.02	651942.27	10315.75
DEC	37	27.77	524.4	357.89	672986.05	662258.02	10728.03
JAN	23	17.25	285.9	233.7333	677774.78	672986.05	4788.73
FEB	44	68.57	587.6	594.69943	692192.13	677774.78	14417.35
MAR	81	203.97	1517.3	3288.28	814090.14	804711.46	9378.68
APR	77	177.05	1113.3	2543.89	823485.77	814090.14	9395.63
MAY	86	96.02	1109.9	1458.8383	722131.92	712643.69	9488.23

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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Statistics

Variable	Mean	StDev	Varian
No._of_tripping	48.33	21.89	479.
Total_time_lost_(Hr)	72.7	63.8	4066
Total_load_lost_(MW)	666	388	1506
Total_load_lost_(MWH)	1062	968	9370
Present_Energy_Reading	685881	68917	47495907

Table 2d: shows the data collected from Life Camp Feeder [12]

Month	Number of Tripping	Total Time Lost (Hr)	Total Load Lost (MW)	Total Load Lost (MWH)	Present Energy Reading	Previous Energy Reading	Diff. in Present and Previous Energy Reading
JUN	50	80.88	266.5	375.78	410534.29	406659.94	3874.35
JUL	33	16.37	164.9	325.247	414208.12	410534.29	3673.83
AUG	34	79.27	173.1	305.2967	417894.84	414208.12	3686.72
SEP	46	2.60	237.2	324.57	421595.23	417894.84	3700.39
OCT	36	32.35	217.7	202.3267	426413.98	421595.23	4818.75
NOV	23	16.70	146.6	83.275	431598.1	426413.98	5184.12
DEC	27	29.73	184.9	202.719	436807.42	431598.1	5209.32
JAN	55	81.62	340.6	516.1818	439030.22	436807.42	2222.8
FEB	34	41.43	235	305.935	446655.56	439030.22	7625.34
MAR	87	279.53	1082.1	3425.25	527101.13	520310.43	6790.7
APR	82	212.93	918.2	2129.57	533556.99	527101.13	6455.86
MAY	75	108.38	690.4	1007.3	467156.64	460532.45	6624.19

Statistics

Variable	Mean	StDev	Varian
No._of_tripping	48.50	21.92	480.
Total_time_lost_(Hr)	81.8	84.5	7143
Total_load_lost_(MW)	388.1	322.2	103815
Total_load_lost_(MWH)	767	1005	10107
Present_Energy_Reading	447713	41598	17304176

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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Table 2e: shows the data collected from 9 Mobile Feeder [12]

Month	Number of Tripping	Total Time Lost (Hr)	Total Load Lost (MW)	Total Load Lost (MWH)	Present Energy Reading	Previous Energy Reading	Diff. in Present and Previous Energy Reading
JUN	12	43.38	9.19	37.69	392574.08	391919.52	654.56
JUL	4	4.63	2.20	2.67	393401.22	392574.08	827.14
AUG	11	26.97	6.90	23.55	394156.91	393401.22	755.69
SEP	11	26.00	10.20	25.86	394963.58	394156.91	806.67
OCT	9	15.68	7.90	12.26	395792.24	394963.58	828.66
NOV	3	3.12	3.30	2.60	396661.37	395792.24	869.13
DEC	2	0.45	2.10	0.43	397607.59	396661.37	946.22
JAN	2	2.93	2.00	3.60	398068.12	397607.59	460.53
FEB	6	10.82	9.90	14.92	399379.97	398068.12	1311.85
MAR	12	42.17	6.30	16.23	409622.8	409045.9	576.9
APR	12	47.77	7.60	30.87	410124.94	409622.8	502.14
MAY	22	38.72	19.80	27.51	401900.69	401123.44	777.25

Statistics

Variable	Mean	StDev	Variance	Median
No._of_tripping	8.83	5.81	33.79	10.00
Total_time_lost_(Hr)	21.89	17.84	318.11	20.84
Total_load_lost_(MW)	7.28	4.99	24.89	7.25
Total_load_lost_(MWH)	16.52	12.59	158.51	15.58
Present_Energy_Reading	398688	5838	34086362	397134
Previous_Energy_Reading	397911	5917	35012603	396227
Difference_in_Energy_Meter	776.4	225.7	50948.5	792.0

Based on the descriptive statistics provided in the table, it becomes evident that the various feeders exhibit distinct characteristics influenced by the variables presented. Notably, Jabi feeder demonstrates the highest incidence of tripping, with an average of approximately 69 power outages occurring within a year. Additionally, the statistical analysis indicates a positive correlation between the average number of trips and the total duration of power loss measured in hours, suggesting that as the average number of trips increases, the corresponding total time lost also increases. However, 9mobile feeder recorded the least number of tripping within the same time frame.

DATA NORMALIZATION AND VISUALIZATION

An analytical approach was employed to gain deeper insights into the data and facilitate the identification of trends and similarities among the feeders. Specifically, the data were subjected to normalization techniques using MATLAB, which enabled the scaling and standardization of the dataset. This normalization process ensured that the data from different feeders could be effectively compared and analyzed. Furthermore, MATLAB's visualization capabilities were utilized to generate graphical representations that visually depicted the trends present within the normalized data. Fig.5 shows the line graphs from the feeders.

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

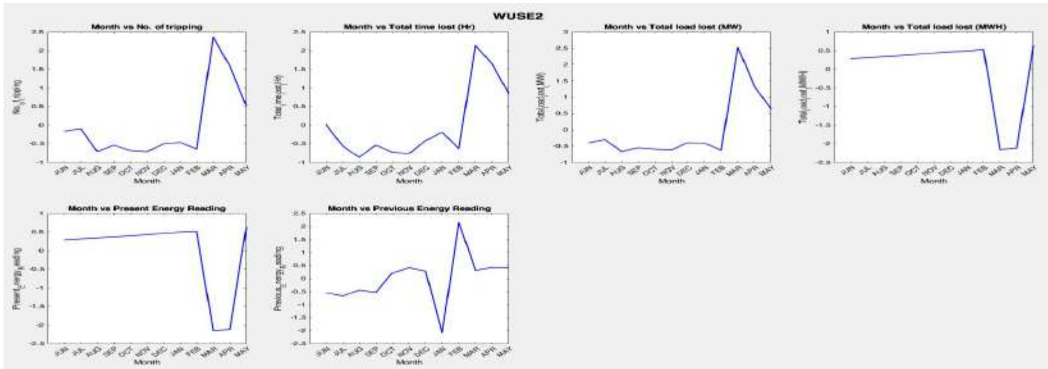

Fig. 5a shows the line graphs of Months vs. the other variables in Wuse 2 Feeder.

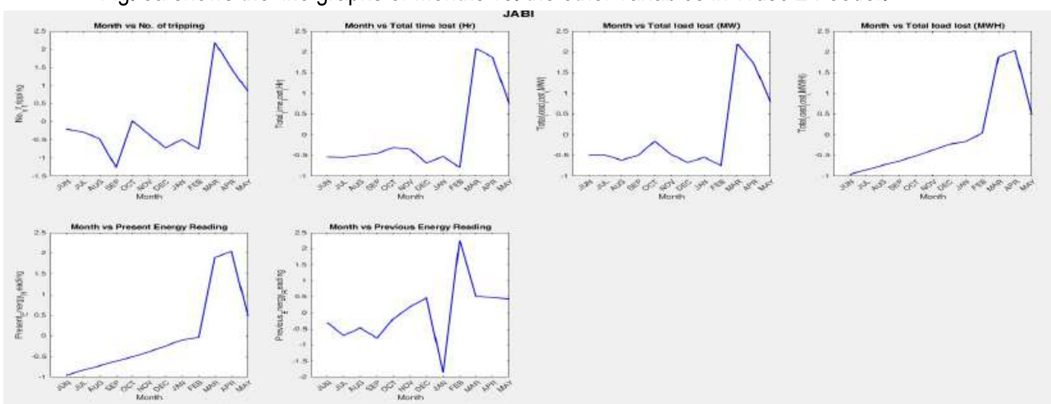

Fig. 5b shows the line graphs of Months vs. the other variables in Jabi Feeder.

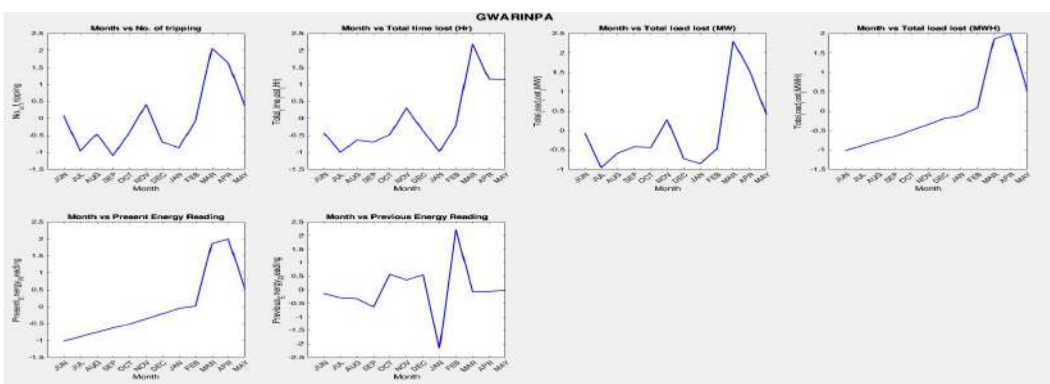

Fig. 5c shows the line graphs of Months vs. the other variables in Gwarinpa Feeder.

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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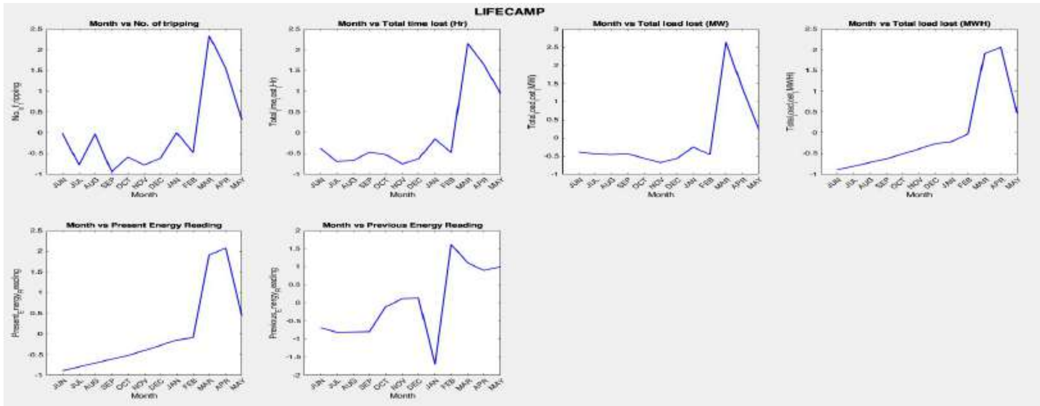

Fig. 5d shows the line graphs of Months vs. the other variables in Life Camp Feeder.

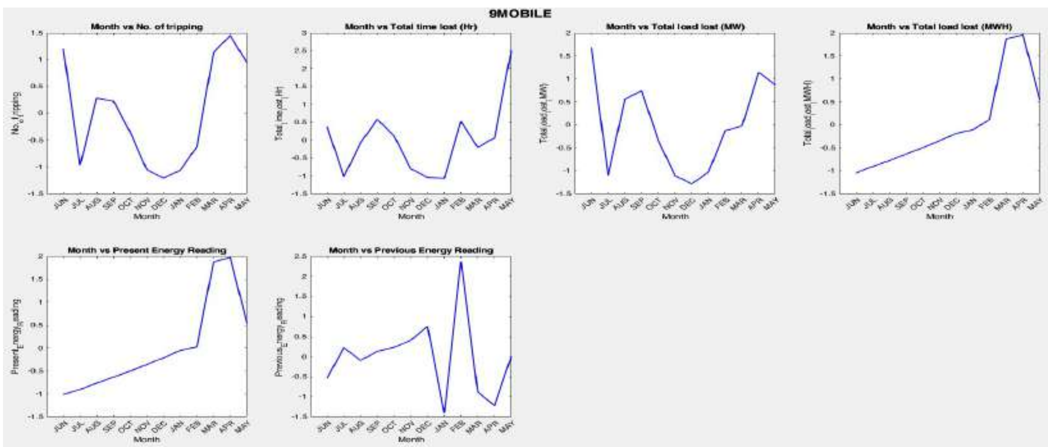

Fig. 5e shows the line graphs of Months vs. the other variables in 9Mobile Feeder.

Based on analysis of the data pertaining to tripping events, total time lost, and total load lost among the feeders during March 2022, a deeper understanding of the underlying dynamics emerges. While the initial analysis pinpointed heightened power demand as a primary factor contributing to the observed disparities, a more nuanced exploration reveals additional intricacies at play. Notably, the distribution of loads across feeders, historical load growth trends, and the condition of infrastructure components all significantly influence feeder performance. Furthermore, the effectiveness of protection systems, voltage stability considerations, and the impact of weather and environmental factors must be considered to grasp the full extent of the observed variations. Operational strategies and load shedding protocols also play a pivotal role in shaping outage response and system resilience.

EVALUATION OF RELIABILITY INDICES FOR INDIVIDUAL FEEDERS

The data got from the Twelve-month component outage duration of the substation anre the variables used for the analysis. The variables were used to compute the various reliability indices; SAIDI, SAIFI, CAIDI, Availability, ASUI, ASAI and Failure Rate. The Mean Time to Restore (MTTR) and the Mean

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

Time between Failure (MTBF) were also computed. These analyses were computed differently for each of the five feeders as shown in Table 3a to Table 3e.

Table 3a shows the Reliability Indices for Wuse Feeder

ANALYSIS FOR WUSE FEEDER														
Month	No. of tripping	Total time lost (Hr)	Total Hour Demanded	Customers Hours curtailed	No. of Consumer	SAIDI	SAIFI	CAIDI	Availability	ASUI	Failure Rate	MTTR	MTBF	ASAI
JUN	29	23.93	720.00	693.97	270	0.0886	0.1074	0.8252	0.9678	0.0332	1.2119	0.8252	24.8276	0.999706591
JUL	11	26.10	744.00	287.10	270	0.0967	0.0407	2.3727	0.9661	0.0351	0.4215	2.3727	67.6364	0.999878615
AUG	2	6.05	744.00	12.10	270	0.0224	0.0074	3.0250	0.9919	0.0081	0.3306	3.0250	372.0000	0.999994884
SEP	10	11.45	720.00	114.50	270	0.0424	0.0370	1.1450	0.9843	0.0159	0.8734	1.1450	72.0000	0.99995159
OCT	4	6.98	744.00	27.93	270	0.0259	0.0148	1.7458	0.9907	0.0094	0.5728	1.7458	186.0000	0.99998819
NOV	3	5.93	720.00	17.80	270	0.0220	0.0111	1.9778	0.9918	0.0082	0.5056	1.9778	240.0000	0.999992474
DEC	11	12.70	744.00	139.70	270	0.0470	0.0407	1.1545	0.9832	0.0171	0.8661	1.1545	67.6364	0.999940935
JAN	16	14.17	744.00	226.67	270	0.0525	0.0593	0.8854	0.9813	0.0190	1.1294	0.8854	46.5000	0.999904166
FEB	6	8.08	696.00	48.50	270	0.0299	0.0222	1.3472	0.9885	0.0116	0.7423	1.3472	116.0000	0.999979494
MAR	47	107.47	744.00	5051.09	270	0.3980	0.1741	2.2866	0.8738	0.1444	0.4373	2.2866	15.8298	0.997864413
APR	43	81.63	720.00	3510.09	270	0.3023	0.1593	1.8984	0.8982	0.1134	0.5268	1.8984	16.7442	0.998515944
MAY	30	46.52	744.00	1395.50	270	0.1723	0.1111	1.5506	0.9412	0.0625	0.6449	1.5506	24.8000	0.999409986
Total	212	351.01	8784.00	11524.95	3240	0.1083	0.0654	1.6557	0.9616	0.0400	0.6040	1.6557	41.4340	0.997378135

Table 3b shows the Reliability Indices for Jabi Feeder

ANALYSIS FOR JABI FEEDER														
Month	No. of tripping	Total time lost (Hr)	Total Hour Demanded	Customers Hours curtailed	No. of Consumer	SAIDI	SAIFI	CAIDI	Availability	ASUI	Failure Rate	MTTR	MTBF	ASAI
JUN	61	103.43	720.00	6309.23	320	0.3232	0.1906	1.6956	0.8744	0.1437	0.5898	1.6956	11.8033	0.997749276
JUL	64	96.42	744.00	6170.88	320	0.3013	0.2000	1.5066	0.8853	0.1296	0.6638	1.5066	11.6250	0.99779863
AUG	69	78.77	744.00	5435.13	320	0.2462	0.2156	1.1416	0.9043	0.1059	0.8760	1.1416	10.7826	0.998061098
SEP	75	4.81	720.00	360.52	320	0.0150	0.2344	0.0641	0.9934	0.0067	15.6024	0.0641	9.6000	0.99987139
OCT	68	124.55	744.00	8469.40	320	0.3892	0.2125	1.8316	0.8566	0.1674	0.5460	1.8316	10.9412	0.996978667
NOV	62	89.95	720.00	5576.90	320	0.2811	0.1938	1.4508	0.8889	0.1249	0.6893	1.4508	11.6129	0.998010524
DEC	49	55.13	744.00	2701.52	320	0.1723	0.1531	1.1252	0.9310	0.0741	0.8888	1.1252	15.1837	0.999036274
JAN	55	76.83	744.00	4225.83	320	0.2401	0.1719	1.3970	0.9064	0.1033	0.7158	1.3970	13.5273	0.998492497
FEB	44	52.55	696.00	2312.20	320	0.1642	0.1375	1.1943	0.9298	0.0755	0.8373	1.1943	15.8182	0.999175157
MAR	108	328.03	744.00	35427.24	320	1.0251	0.3375	3.0373	0.6940	0.4409	0.3292	3.0373	6.8889	0.987361858
APR	97	260.16	720.00	25235.52	320	0.8130	0.3031	2.6821	0.7346	0.3613	0.3728	2.6821	7.4227	0.990997603
MAY	79	200.82	744.00	15864.52	320	0.6276	0.2469	2.5420	0.7875	0.2699	0.3934	2.5420	9.4177	0.994340569
Total	831	1471.45	8784.00	118088.89	3840	0.3832	0.2164	1.7707	0.8565	0.1675	0.5647	1.7707	10.5704	0.963649433

Table 3c shows the Reliability Indices for Gwarinpa Feeder

ANALYSIS FOR GWARINPA FEEDER														
Month	No. of tripping	Total time lost (Hr)	Total Hour Demanded	Customers Hours curtailed	No. of Consumer	SAIDI	SAIFI	CAIDI	Availability	ASUI	Failure Rate	MTTR	MTBF	ASAI
JUN	38	78.50	720.00	2983.00	300	0.2617	0.1267	2.0658	0.9017	0.1090	0.4841	2.0658	18.9474	0.998864916
JUL	25	11.05	744.00	276.25	300	0.0368	0.0833	0.4420	0.9854	0.0149	2.2624	0.4420	29.7600	0.999894882
AUG	37	43.35	744.00	1603.95	300	0.1445	0.1233	1.1716	0.9449	0.0583	0.8535	1.1716	20.1081	0.999389669
SEP	37	2.57	720.00	95.07	300	0.0086	0.1233	0.0694	0.9964	0.0036	14.4000	0.0694	19.4595	0.999963824
OCT	36	46.96	744.00	1690.68	300	0.1565	0.1200	1.3045	0.9406	0.0631	0.7666	1.3045	20.6667	0.999356667
NOV	59	98.80	720.00	5829.20	300	0.3293	0.1967	1.6746	0.8793	0.1372	0.5972	1.6746	12.2034	0.997781887
DEC	37	27.77	744.00	1027.38	300	0.0926	0.1233	0.7505	0.9640	0.0373	1.3325	0.7505	20.1081	0.999609064
JAN	23	17.25	744.00	396.75	300	0.0575	0.0767	0.7500	0.9773	0.0232	1.3333	0.7500	32.3478	0.99984903
FEB	44	68.57	696.00	3016.93	300	0.2286	0.1467	1.5583	0.9103	0.0985	0.6417	1.5583	15.8182	0.998852004
MAR	81	203.97	744.00	16521.57	300	0.6799	0.2700	2.5181	0.7848	0.2742	0.3971	2.5181	9.1852	0.993713253
APR	77	177.05	720.00	13632.85	300	0.5902	0.2567	2.2994	0.8026	0.2459	0.4349	2.2994	9.3506	0.994812462
MAY	86	96.02	744.00	8257.43	300	0.3201	0.2867	1.1165	0.8857	0.1291	0.8957	1.1165	8.6512	0.996857902
Total	580	871.85	8784.00	55331.07	3600	0.2422	0.1611	1.5032	0.9097	0.0993	0.6652	1.5032	15.1448	0.983965157

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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Table 3d shows the Reliability Indices for Life Camp Feeder

ANALYSIS FOR LIFECAMP FEEDER														
Month	No. of tripp	Total time lost	Total Hour Demand	Customers Hours curtailed	No. of Cons umer	SAIDI	SAIFI	CAIDI	Availa bility	ASUI	Failure Rate	MTTR	MTBF	ASAI
JUN	50	80.88	720.00	4044.00	290	0.2789	0.1724	1.6176	0.8990	0.1123	0.6182	1.6176	14.4000	0.998408125
JUL	33	16.37	744.00	540.21	290	0.0564	0.1138	0.4961	0.9785	0.0220	2.0159	0.4961	22.5455	0.999787352
AUG	34	79.27	744.00	2695.18	290	0.2733	0.1172	2.3315	0.9037	0.1065	0.4289	2.3315	21.8824	0.998939073
SEP	46	2.60	720.00	119.82	290	0.0090	0.1586	0.0566	0.9964	0.0036	17.6593	0.0566	15.6522	0.999952833
OCT	36	32.35	744.00	1164.60	290	0.1116	0.1241	0.8986	0.9583	0.0435	1.1128	0.8986	20.6667	0.999541568
NOV	23	16.70	720.00	384.10	290	0.0576	0.0793	0.7261	0.9773	0.0232	1.3772	0.7261	31.3043	0.999848803
DEC	27	29.73	744.00	802.79	290	0.1025	0.0931	1.1012	0.9616	0.0400	0.9081	1.1012	27.5556	0.99968399
JAN	55	81.62	744.00	4488.92	290	0.2814	0.1897	1.4839	0.9011	0.1097	0.6739	1.4839	13.5273	0.998232988
FEB	34	41.43	696.00	1408.73	290	0.1429	0.1172	1.2186	0.9438	0.0595	0.8206	1.2186	20.4706	0.999445468
MAR	87	279.53	744.00	24319.11	290	0.9639	0.3000	3.2130	0.7269	0.3757	0.3112	3.2130	8.5517	0.990427055
APR	82	212.93	720.00	17460.26	290	0.7342	0.2828	2.5967	0.7718	0.2957	0.3851	2.5967	8.7805	0.993126964
MAY	75	108.38	744.00	8128.75	290	0.3737	0.2586	1.4451	0.8728	0.1457	0.6920	1.4451	9.9200	0.996800209
Total	582	981.80	8784.00	65556.47	3480	0.2821	0.1672	1.6869	0.8995	0.1118	0.5928	1.6869	15.0928	0.981255961

Table 3e shows the Reliability Indices for 9mobile Feeder

ANALYSIS FOR 9MOBILE FEEDER														
Month	No. of tripp ing	Total time lost (Hr)	Total Hour Demand ed	Costomers Hours curtailed	No. of Cons umer	SAIDI	SAIFI	CAIDI	Availa bility	ASUI	Failure Rate	MTTR	MTBF	ASAI
JUN	12	43.38	720.00	520.56	200	0.2169	0.0600	3.6150	0.9432	0.0603	0.2766	3.6150	60.0000	0.999702877
JUL	4	4.63	744.00	18.52	200	0.0232	0.0200	1.1575	0.9938	0.0062	0.8639	1.1575	186.0000	0.999989429
AUG	11	26.97	744.00	296.67	200	0.1349	0.0550	2.4518	0.9650	0.0363	0.4079	2.4518	67.6364	0.999830668
SEP	11	26.00	720.00	286.00	200	0.1300	0.0550	2.3636	0.9651	0.0361	0.4231	2.3636	65.4545	0.999836758
OCT	9	15.68	744.00	141.15	200	0.0784	0.0450	1.7426	0.9794	0.0211	0.5739	1.7426	82.6667	0.999919435
NOV	3	3.12	720.00	9.35	200	0.0156	0.0150	1.0389	0.9957	0.0043	0.9626	1.0389	240.0000	0.999994663
DEC	2	0.45	744.00	0.90	200	0.0023	0.0100	0.2250	0.9994	0.0006	4.4444	0.2250	372.0000	0.999999486
JAN	2	2.93	744.00	5.87	200	0.0147	0.0100	1.4667	0.9961	0.0039	0.6818	1.4667	372.0000	0.999996651
FEB	6	10.82	696.00	64.90	200	0.0541	0.0300	1.8028	0.9847	0.0155	0.5547	1.8028	116.0000	0.999962957
MAR	12	42.17	744.00	506.04	200	0.2109	0.0600	3.5142	0.9464	0.0567	0.2846	3.5142	62.0000	0.999711164
APR	12	47.77	720.00	573.24	200	0.2389	0.0600	3.9808	0.9378	0.0663	0.2512	3.9808	60.0000	0.999672808
MAY	22	38.72	744.00	851.77	200	0.1936	0.1100	1.7598	0.9505	0.0520	0.5682	1.7598	33.8182	0.999513832
Total	106	262.64	8784.00	3274.96	2400	0.1094	0.0442	2.4777	0.9710	0.0299	0.4036	2.4777	82.8679	0.998675823

VISUALIZATION OF SIMULATION'S RESULT OF THE RELIABILITY OF INDIVIDUAL FEEDERS

A comprehensive examination of the reliability of the aforementioned feeders reveals a deeper understanding of the observed fluctuations over a span of 12 months. Through meticulous analysis, it has been determined that the average interruption duration for customers within a yearly timeframe, as depicted in Figures 6a and 6b, exposes notable insights. Notably, the Jabi feeder consistently exhibited relatively high System Average Interruption Duration Index (SAIDI) values across the majority of months. Conversely, the Wuse 2 and 9mobile feeders demonstrated the lowest level of interruptions. Meanwhile, the SAIDI values for the Gwarinpa and Life Camp feeders exhibited fluctuating patterns, oscillating between varying degrees of interruption durations. These findings shed light on the distinct reliability profiles of the different feeders under investigation.

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

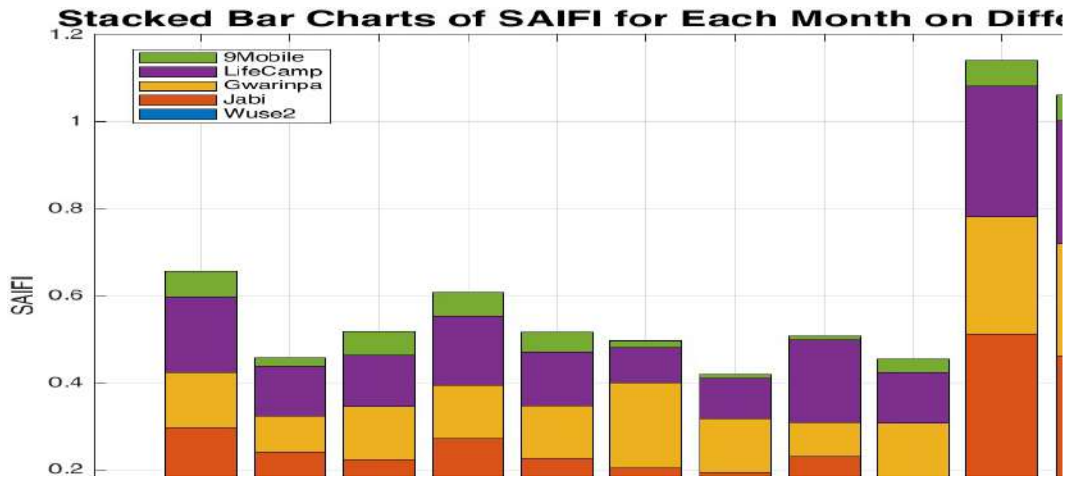

Fig. 6a shows the staked bar charts of SAIDI within a year on different feeders.

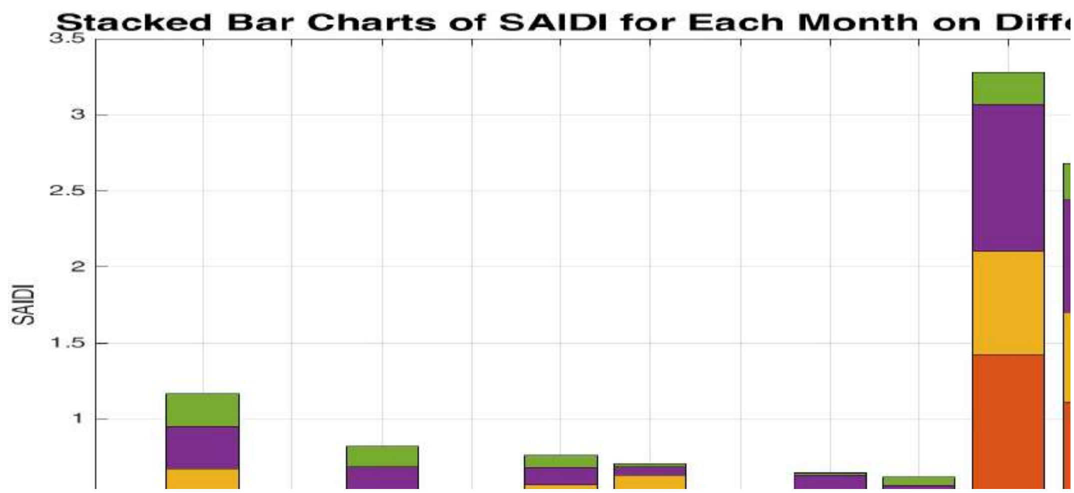

Fig. 6b shows the line graph of SAIDI within a year on different feeders

The study further investigated the average number of interruptions encountered by customers within the designated time frame, as measured by the System Average Interruption Frequency Index (SAIFI). Similarly, to the SAIDI analysis, compelling patterns emerged among the feeders under scrutiny. Notably, the Jabi feeder consistently exhibited a relatively high SAIFI over the course of the 12-month period. Conversely, the Wuse 2 and 9Mobile feeders showcased lower SAIFI values, with the 9Mobile feeder demonstrating the lowest frequency of interruptions. These findings underscore the differential performance of the feeders, shedding light on their varying levels of reliability in terms of interruption frequency experienced by customers, as shown in Figures 7a and 7b.

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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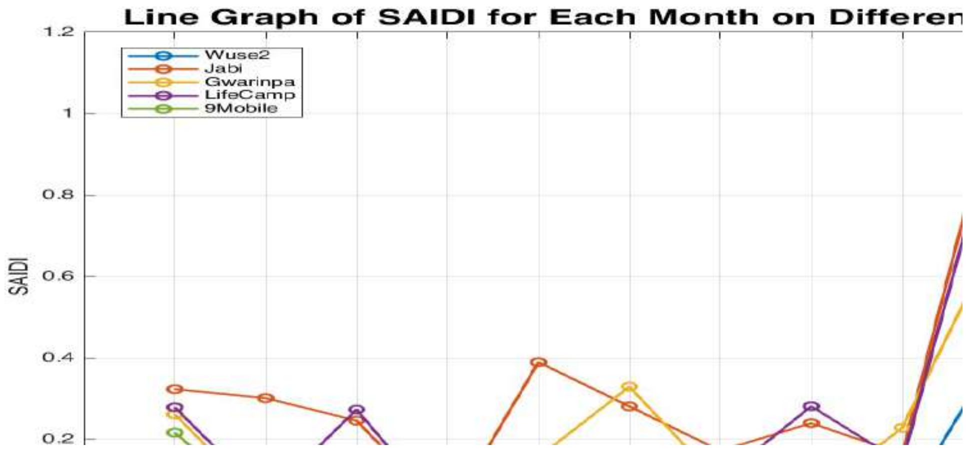


Fig. 7a shows the stacked bar charts of SAIFI within a year on different feeders.

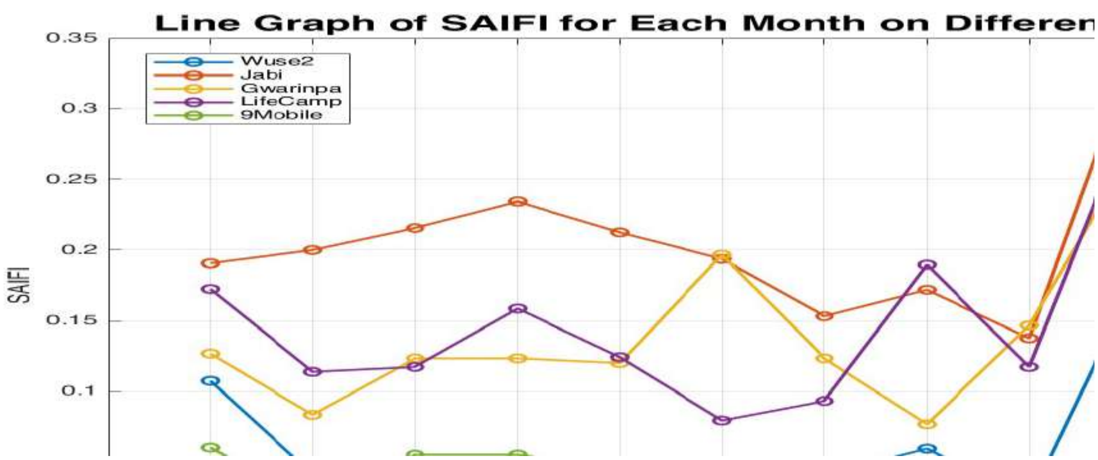


Fig. 7b shows the line graph of SAIFI within a year on different feeders.

In contrast to the aforementioned analyses, the investigation into the average duration of interruptions, weighted by the number of customers affected, revealed a distinct trend. The System Average Interruption Duration Index (SAIDI) took a divergent trajectory in this regard. Remarkably, the 9Mobile feeder emerged as the feeder with the highest CAIDI, denoting prolonged interruption durations for customers impacted. Following closely behind, the Jabi feeder exhibited the second-highest CAIDI values. Meanwhile, the Wuse 2 and LifeCamp feeders occupied an intermediary position in terms of CAIDI, with varying degrees of interruption duration. Interestingly, the Gwarinpa feeder showcased the lowest CAIDI, indicating comparatively shorter interruption durations experienced by customers. These findings underscore the divergent reliability performance of the feeders under scrutiny, particularly with regard to the weighted interruption durations experienced by customers, as shown in Figures 8a and 8b.

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

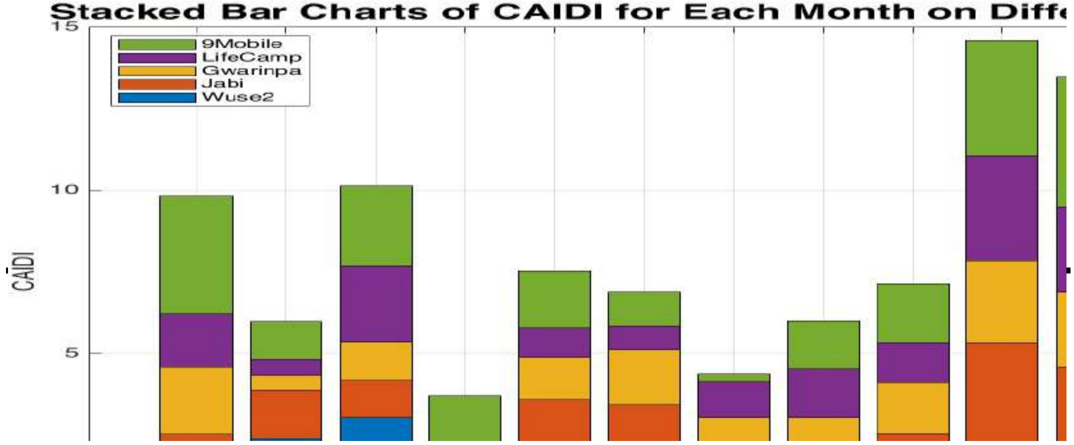


Fig. 8a shows the stacked bar charts of CAIDI within a year on different feeders.

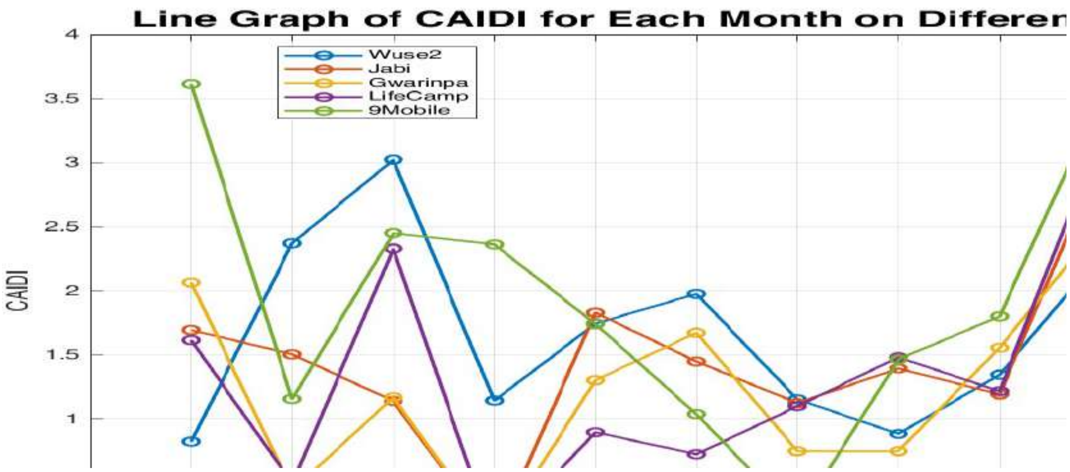
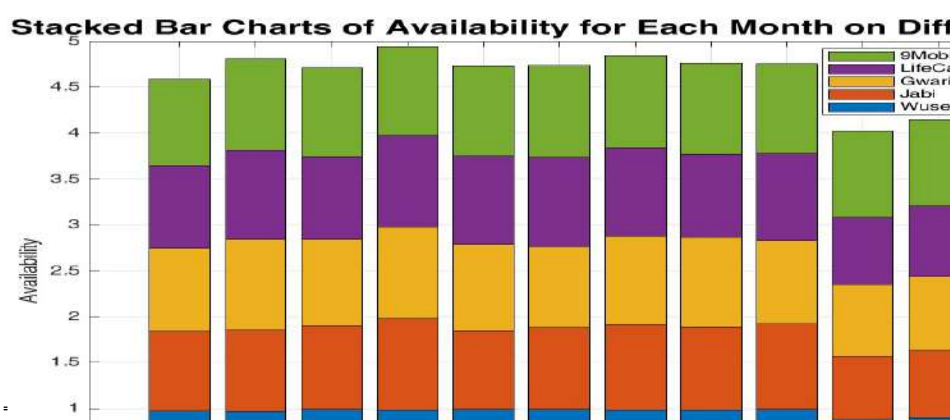


Fig. 8b shows the line graph of CAIDI within a year on different feeders.

The evaluation of operational durations for the individual components comprising each feeder provides valuable insights into their availability. The results indicate that the 9Mobile feeder exhibited the highest level of availability, followed by the Wuse, Gwarinpa, and LifeCamp feeders. In contrast, the Jabi feeder demonstrated the lowest availability among the examined feeders. These findings are visually represented in Figures 9a and 9b, which depict the availability patterns across the different feeders. These figures serve as visual representations of the data, enabling a clear understanding of the varying availability levels observed in the study.



agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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Fig. 9a shows the stacked bar charts of Availability within a year on different feeders.

Fig. 9b shows the line graph of availability within a year on different feeders

In addition, a comprehensive examination was conducted to determine the fraction of time during which customers were deprived of electricity across the different feeders. Notably, the analysis revealed distinct patterns in the Average System Unavailability Index (ASUI) for each feeder. Customers connected to the Jabi feeder encountered the highest ASUI, indicating a relatively larger proportion of time without electricity. Following Jabi, the LifeCamp, Gwarinpa, and Wuse2 feeders demonstrated progressively lower ASUI values, indicating comparatively lesser durations of unavailability for customers. Remarkably, the 9Mobile feeder exhibited the lowest ASUI, signifying the least amount of time customers spent without electricity. These findings provide valuable insights into the variations in service reliability experienced by customers across the different feeders as shown in Figure 10a and 10b.

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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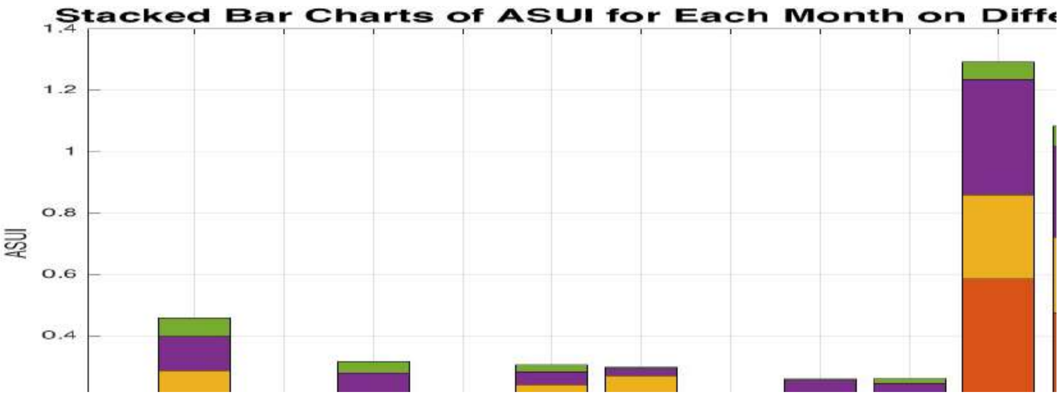

Fig. 10a shows the stacked bar charts of ASUI within a year on different feeders

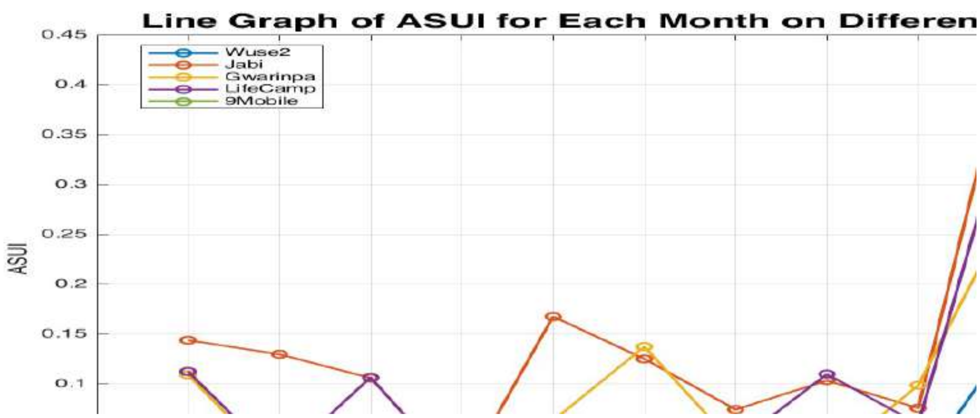

Fig. 10b shows the line graph of ASUI within a year on different feeders.

The investigation into the number of outages encountered by the various feeders revealed notable fluctuations within the operational timeframe. Notably, in September 2021, the Jabi, Gwarinpa, and LifeCamp feeders experienced the highest failure rates. Conversely, the 9Mobile feeder exhibited its highest failure rate in December 2021. In contrast, the Wuse2 feeder consistently maintained a relatively low failure rate throughout the entire 12-month period. These findings emphasize the temporal variability in the occurrence of outages across the different feeders as shown in Figure 11a and 11b.

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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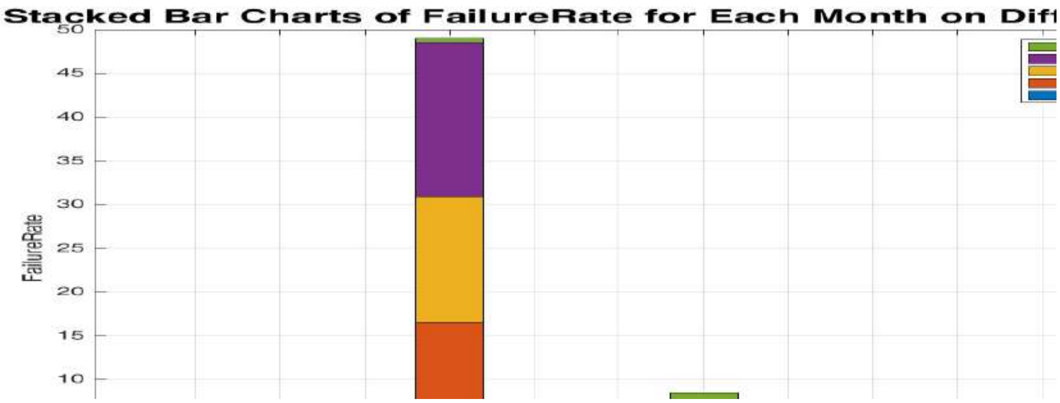

Fig. 11a shows the stacked bar charts of failure rate within a year on different feeders
Fig. 11b shows the line graph of failure rate within a year on different feeders.

In addition to investigating the variations in failure occurrences among the feeders, the study also analyzed the time required to restore the feeders to normal operation, as illustrated in Figures 12a and 12b. The examination revealed notable differences in the Mean Time to Restore (MTTR) for each feeder. On average, the 9Mobile feeder exhibited the highest MTTR, indicating a relatively longer restoration time. Following 9Mobile, the Jabi, LifeCamp, and Wuse2 feeders displayed progressively higher MTTR values, suggesting relatively slower restoration processes for these feeders. Interestingly, the Gwarinpa feeder consistently demonstrated the lowest MTTR in most of the months, indicating a relatively faster recovery time. These findings provide valuable insights into the efficiency and effectiveness of the restoration procedures employed for the different feeders.

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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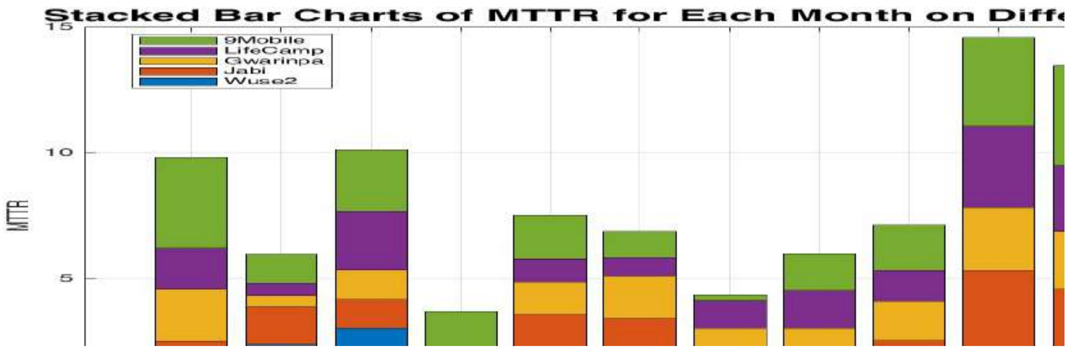

Fig. 12a shows the stacked bar charts of MTTR within a year on different feeders.

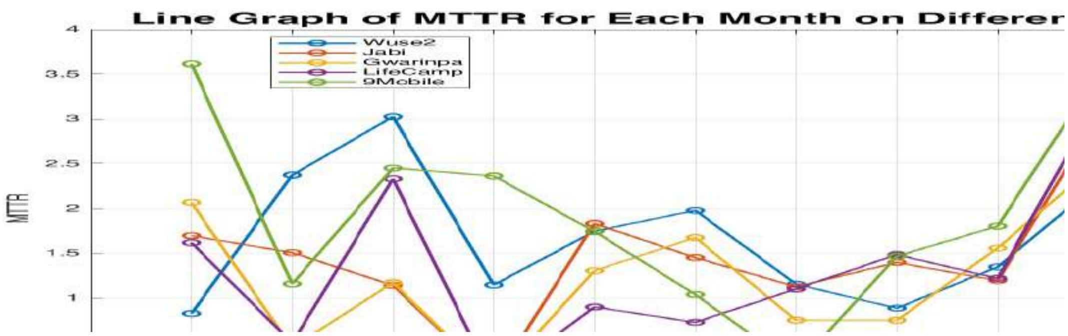

Fig. 12b shows the line graph of MTTR within a year on different feeders.

Furthermore, an evaluation of the Mean Time between Failures (MTBF) for the different feeders revealed distinct patterns. Notably, the MTBF was consistently high for both the Wuse2 and 9Mobile feeders throughout the months under investigation. This indicates a longer duration between failures, suggesting a higher level of reliability and stability for these two feeders. In contrast, the remaining three feeders, namely Jabi, Gwarinpa, and LifeCamp, exhibited relatively lower MTBF values. These findings underscore the varying levels of reliability and the frequency of failures experienced by the different feeders. The higher MTBF values for Wuse2 and 9Mobile suggest a more robust and resilient infrastructure, whereas the lower MTBF values for the other three feeders highlight the need for further analysis and potential improvement strategies to enhance their reliability performance.

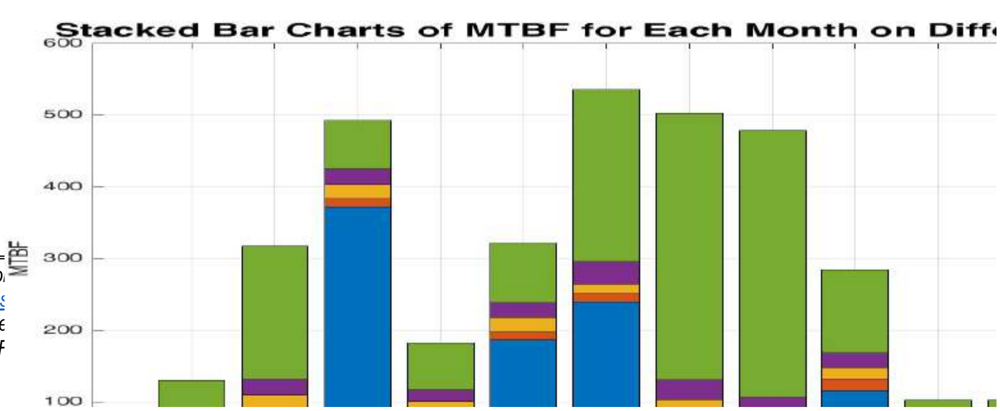

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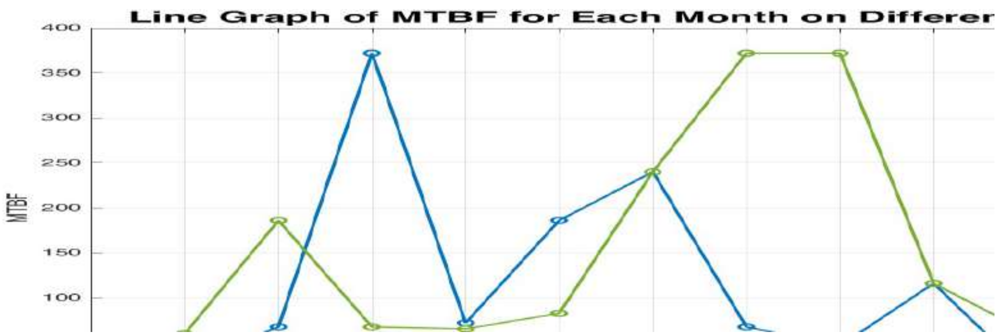
Fig. 13a shows the stacked bar charts of MTBF within a year on different feeders.

Fig. 13b



shows the line graph of MTBF within a year on different feeders.

These discoveries advance authenticate the information displayed in Figures 14a and 14b, which outline the number of stumbling incidents over the distinctive feeders. The investigation affirms that the Jabi feeder reliably experienced the most elevated number of stumbling occasions, taken after by the Gwarinpa and LifeCamp feeders. In differentiate, both the Wuse2 and 9Mobile feeders illustrated the least occurrences of stumbling. The visual representation within the figures gives a comprehensive diagram of the stumbling designs, emphasizing the particular execution of each feeder in terms of electrical steadiness. These discoveries serve to approve and fortify the perceptions made with respect to the number of stumbling occurrences experienced by the feeders, shedding light on their unwavering quality and operational characteristics.

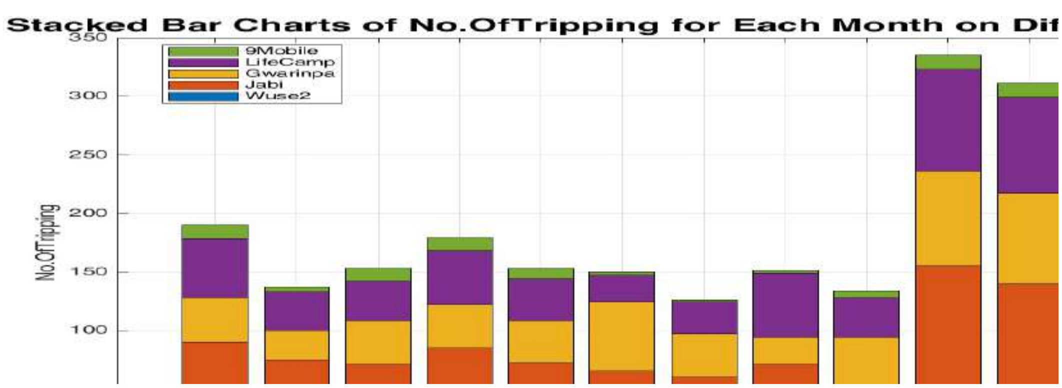


Fig. 14a shows the stacked bar charts of the number of tripping within a year on different feeders.

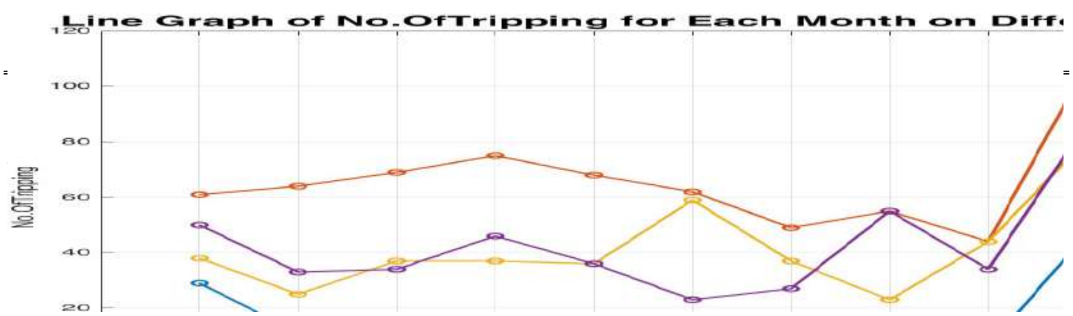


Fig. 14b shows the line graph of the number of tripping within a year on different feeders

Additionally, an examination of the total time lost in the feeders further emphasizes the differences in reliability performance. Figure 4.13 presents compelling evidence that the Jabi, Gwarinpa, and LifeCamp feeders incurred relatively high cumulative downtime compared to the Wuse2 and 9Mobile feeders. These findings shed light on the overall impact of interruptions and failures experienced by customers connected to each feeder. The data presented in Figure 15 serves as quantitative evidence supporting the notion that Jabi, Gwarinpa, and LifeCamp feeders result in a greater loss of service availability and electrical supply continuity. Conversely, the Wuse2 and 9Mobile feeders exhibit a more favorable performance, with significantly lower cumulative downtime.

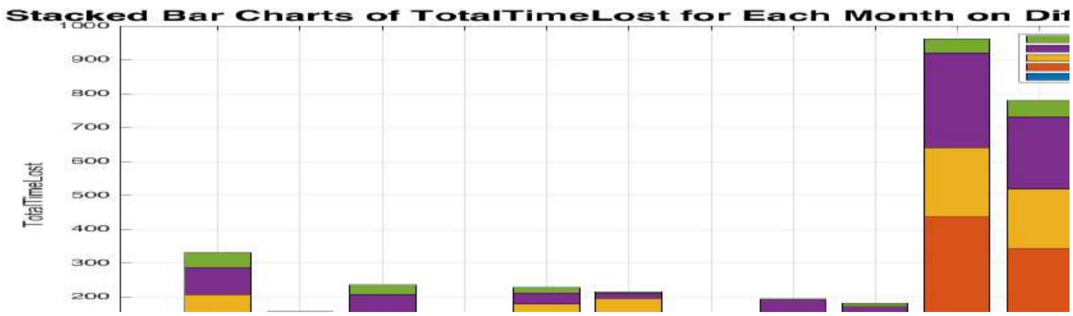


Fig. 15a shows the stacked bar charts of the total time lost within a year on different feeders.

Fig. 15b shows the line graph of the total time lost within a year on different feeders

Lastly, the study assessed the average availability of the distribution system, as represented by the Average System Availability Index (ASAI), which directly impacts customers' experience. The analysis revealed that customers connected to the 9Mobile and Wuse2 feeders enjoyed higher levels of system availability compared to those connected to the Jabi, Gwarinpa, and LifeCamp feeders. The ASAI metric provides a comprehensive measure of the overall reliability and performance of the distribution system in delivering uninterrupted electricity supply to customers as shown in Figure 16.

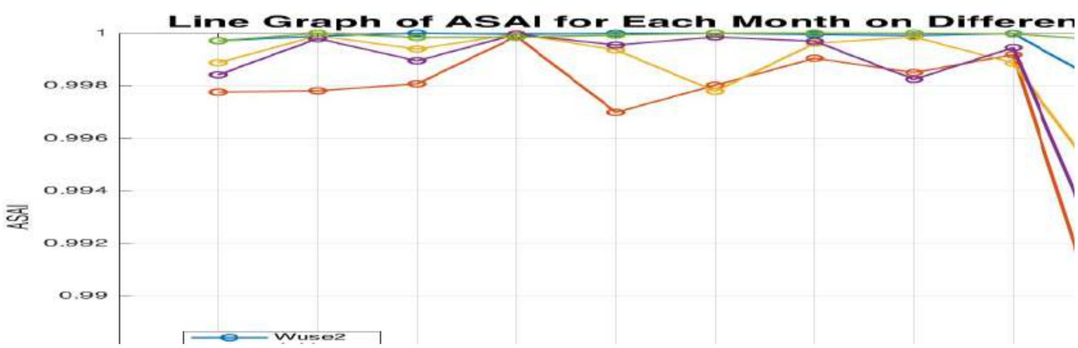


Fig. 16 shows the line graph of ASAI within a year on different feeders.

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

Comparison of Results with International Benchmark for Reliability Indices

The results obtained from the analysis of the five feeders discussed above are further compared to international standards of reliability indices. This comparative analysis provides a valuable framework for critically evaluating the reliability assessment. In order to facilitate this evaluation, the study employed the IEEE Guide for reliability standardization as a benchmark. The reliability indices of the five feeders were compared to similar indices obtained from nine other countries. By comparing the results with international standards, a comprehensive assessment of the reliability performance of the feeders can be achieved.

Table 4: Benchmark of Reliability Indices [13]

Country	SAIDI	SAIFI	CAIDI
United States	240	1.5	123
UK	90	0.8	100
Italy	58	2.2	106
Spain	104	2.2	114
Austria	72	0.9	112
Netherlands	33	0.3	75
Denmark	24	0.5	70
France	62	1	58
Gwarinpa	0.2422	0.1611	1.5032
Jabi	0.3832	0.2164	1.7707
9Mobile	0.1094	0.0442	2.4777
Wuse 2	0.1083	0.0654	1.6557
Life Camp	0.2821	0.1672	1.6869

CONCLUSION

When considering a research study center to determine reliability on power substations, Katampe transmission-distribution substation was preferred and chosen in this dissertation due to its wide coverage within the heart of Abuja and its environs which was believed to be a moderate symbol for what is obtainable in the Nigerian power sector where high level of reliability should be obtained. The substation was viewed to be in isolation from the rest of the power system. That is, the effect of insufficient generation was not considered and the impact of transmission subsystem failure not considered on standard grid. Although, the data component does not include the causes of each outage but the personnel in charge of monitoring control panels recorded and pointed out the major causes of outages to be forced outage due to priority to certain feeders or maintenance purposes. The substation has only one failure mode since it is designed as single-end fed radial network system. Hence, failure of a single component is sufficient enough to cause interruption of power supply on the whole line.

The component reliability analysis of the substation interruption data also saw through an interesting and distinctive results based on each feeder being analyzed. It is also important to note that the disparities and trends in the results were as a result of the variability of the input data. It is worthy of note that each feeder has a distinct number of customers. Hence, Jabi feeder notably, demonstrates the highest incidence of tripping, with an average of approximately 69 power outages occurring within a year, while 9mobile feeder recorded the least number of tripping within the same time frame. However, other feeders like Wuse2, Life Camp and Gwarinpa have at various stages exhibited different forms of changes on ladder of analysis charts.

Therefore, various reliability components were computed and analyzed with Jabi having SAIDI, SAIFI and CAIDI values as 0.3832, 0.2164 and 1.7707 respectively. These

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.

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values characterize how highly unavailable the feeder behaves as against other feeders in the same 330/132/33kV transmission/distribution substation. Life camp which ranks second also follow similar trends but higher than that of Gwarinpa with SAIDI, SAIFI and CAIDI values maintained at 0.2821, 0.1672 and 1.6869 respectively with significant increase in the value of ASUI as 0.1118. Similarly, Gwarinpa which came third in terms of interruption index showed that the SAIDI, SAIFI and CAIDI values portrays similar trend as 0.2422, 0.1611 and 1.5032 respectively with its corresponding value of ASUI as 0.0993. Conversely, Wuse2 has lesser values and showed that its SAIDI, SAIFI, CAIDI ASUI values being 0.1083, 0.0654, 1.6557 and 0.0400 with it ASAI value maintained at 0.997378. On the other hand, 9Mobile which maintained the least interruption duration amongst others presents its SAIDI, SAIFI and CAIDI values as 0.1094, 0.0442 and 2.4777 with the highest value of ASAI as 0.9988 and the least value of ASUI as 0.0299.

In essence, 9mobile and Wuse2 have lesser values of interruptions with 9mobile having the least of them all. The emphasis on the 9Mobile being the least and which showed a good example how feeders ought to be, showed a great deal of adoptive features which many feeders in Nigeria needs to take a reference point. However, these values of SAIDI, SAIFI and CAIDI are not a total reflection of the behavior of the Nigerian Power System performance as many feeders fall below what these values under study produced. Therefore, comparing the aforementioned indexes of Jabi, Wuse2, Life camp, Gwarinpa and 9Mobile with that of the developed nations indexes (see table 4.1) is indicative of how the power system in the country is still underperforming and it may suffice to say that Nigerian power industry is still being grossly mismanaged; and in a state of low capacity requiring urgent actions to be taken in order to remove this looming and frequent interruptions leading to unavailability of power supply.

REFERENCES

[1] R.J Thomas (2005). "Managing Relationships Between Electric Power Industry Restructuring and Grid Reliability," P.S.E.R.C Report [Online]. Available:www.pserc.wisc.edu/documents.

[2] S. Obatola, J. Tang, and S. Ibrahim (2020). "Reliability and Fault Analysis of Electrical Distribution System: A Case Study of Kafanchan Distribution Substation in Kaduna State, Nigeria". *American Journal of Engineering Research*, Vol.9, Issue-1, pp-180-188.

[3] A.A. Akintola, "A Critical Review of Distribution Substation System Reliability Evaluations". *International Journal of Advancements in Research & Technology*, 2017. 6(6): p. 6-11.

[4] J. Moubray (1997). Reliability Centered Maintenance Second Edition. Industrial Press [Online]. Available: https://www.amazon.com/Reliability-Centered-Maintenance-Second-John-Moubray/dp/0831131462

[5] Elprocus (Jan., 2020). Types of Faults and Effects in Electrical Power Systems articles of elprocus [Online]. Available: https://www.elprocus.com/.

[6] L. Xingping, Distribution transformers health condition monitoring and evaluation methods, Chongqing, 2013.

[7] R. A. Walling, R. Saint, R. C. Dugan, J. Burke, and L. A. Kojovic. Summary of Distributed Resources Impact on Power Delivery Systems. IEEE Transactions on Power Delivery, 23(3):1636–1644, July 2008.

[8] R. Billinton and R. N. Allan. Reliability Evaluation of Power Systems. New York and London: Plenum Press, 1996.

[9] Eisinga, R.; Te Grotenhuis, M.; Pelzer, B. (2012). "The reliability of a two-item scale: Pearson, Cronbach's or Spearman-Brown?" (PDF). *International Journal of Public Health. 58* (4): 637–642

[10] Okorie, P. U. Reliability Assessment of Power Distribution of Abakpa Network Sub-Station of Kaduna Disco. International Journal of Innovative Research in Education, Technology and Social Strategies. Vol.2,No.1 , 78-84, 2016

[11] Krish G. and T. Short. Handbook of Power Quality. England: John Wiley and Sons, Ltd, 2008.

[12] TCN Data Report Sheet, Katampe 330/132/33kV Substation Abuja, page 7-18, 2022.

[13] Ritter, N. Understanding a widely misunderstood statistic: Cronbach's alpha. Paper presented at Southwestern Educational Research Association (SERA) Conference, New Orleans, LA, 2010, ED526237.

Corresponding author: Innocent-Ogan, Agnes Tamunobereni
agnesinnocentogan@gmail.com
Department of Electrical Engineering, Faculty of Engineering, University of Abuja.