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EVALUATION OF THE ELECTRICAL POWER DISTRIBUTION SYSTEM RELIABILITY IN KADUNA METROPOLIS, KADUNA STATE

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Abstract: *The study is designed to evaluate the electrical distribution system reliability. It was carried out in the entire 19 distributions feeders which consist of 33kV network in Kaduna metropolis. The reliability evaluation was done on 33kV feeders to assess the performance of the present system and compare it with Institute of Electrical and Electronic Engineers (IEEE) Minimum Standard. so as to predict reliability analysis for the future system, considering load growth and system expansion in Kaduna metropolis of Kaduna Electricity Distribution Company (KAEDCO). Descriptive Survey research design was adopted for the study. The daily outages data of the feeders for the period of 12 months (March, 2017 to February, 2018) were collected and used to compute the monthly reliability indices for each feeder. Mogadishu, Rigasa, Kawo, U/Boro, Kinkinau among other Feeders recorded the highest failure rates within the period. The high forced outages recorded are indications of unreliable performance of the system during the period under study. The findings revealed that all the three indices under study, System Average Interruption Duration Index (SAIDI) Customer Average Interruption Duration Index (CAIDI) and System Average Interruption Frequency Index were not operating normal as compare to IEEE Minimum Standard. Key recommendations made include that the number of distribution substations should be increased to reduce the incidence of transformer overloading, and that the use of hotline communications should encouraged.*

Keywords: *Evaluation, Power Distribution System, Reliability, Electrical Distribution Reliability Indices*

Introduction

Electrical power is undoubtedly a key driver of the socio-economic and technological development of every nation. Electrical power is the total energy required or generated for utilization (Gupta, 2012). The main purpose of any electric power system is to generate electrical energy as economically as possible and to transfer this energy over transmission and distribution networks with maximum efficiency for delivery to consumers at acceptable voltages, frequency and reliability (Laithwaite, 2013). Electric Power System consists of three principal segments: The Generation, Transmission, and Distribution sub-systems. The Generation connects generating plants to transmission lines through step-up and step-down transformers that increase the generation voltage to transmission levels (Brown, 2012). The Transmission systems transport electricity over long distances from generating facilities to distribution substations systems to retail customers. The Distribution sub system receives power from the transmission system and steps-down the transmission voltages using power transformers to supply the primary distribution systems. The primary purpose of an electricity distribution system is to meet the customer's demands after receiving the bulk electrical energy from transmission or sub transmission system. There are basically two major types of distribution substations in Nigeria, namely primary substation and customer substation (Patrick & Fardo, 2009). The primary substation serves as a load center and Customer substation is referred to a distribution room normally provided for the customers. It is important to note that the distribution system is a vital link between the bulk power system and its customers. Electric power distribution systems constitute the greatest risk to the interruption of power supply and however more than 90% of all customer interruptions occur due to failures in the distribution system (Labo, 2010). Challenges facing the Electrical power sector in Nigeria may be attributed to lack of proper planning of maintenance of existing facilities and equipment, poor management policy, political problem, Funding/Finance and non availability of distribution reliability information. Hence there is need for evaluation of distribution system reliability.

1. ***The Kaduna Electricity Distribution Company (KEDCO)*** is one of the eleven distribution companies that manage the electrical power distribution system in four states, namely. Kaduna, Kebbi, Sokoto and Zamfara states respectively. It has total number of eight thousand two hundred and seventy-three (8273) transformers, one hundred and thirteen (113) injection substations and eleven thousand two hundred and forty-seven (11,247) distribution substations across the state (KEDCO, 2016). Furthermore, it has power routine line of (9,467) of 33kv (2,167) of 11kv, (20,005) of 415v, and 487,264 customers across the states respectively.

2. ***Reliability*** is the probability that a system will function as designed under specified conditions for specified period (Brown, 2012).

3. ***Power System Reliability*** refers to the ability of the system to satisfy the system load requirements as economically as possible and with a reasonable assurance of continuity and quality. In the context of the study, reliability is the probability of the system to provide an acceptable level of continuity and quality of service to customers. Therefore, Reliability has to do with total electric interruptions - complete loss of voltage, not just deformations of the electric sine wave.

4. ***Reliability Indices*** are used for evaluating components of any Electrical power distribution systems performance. These indices are System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI) and Customer Average Interruption Duration Index (CAIDI) (Layton, 2013). They provide a comprehensive indicator of the total reliability of an Electrical distribution system. SAIFI indicates how often an average customer is subjected to sustained interruption over a predefined time interval. SAIDI indicates the total duration of interruption an average customer is subjected for a predefined time interval. CAIDI indicates the average time required to restore the service.

5. ***Evaluation*** is the process of gathering information about the worth or quality of something as a way of making decisions designed to increase its worth or quality (Okoro & Chikuni, 2013). In the context of this study, therefore Evaluation is defined as a process of assessing the reliability indices and comparing them with the IEEE minimum standards with a view to making value judgement about the quality of distribution of Electrical power which will form the basis for maintenance planning. The importance of power systems reliability evaluation can never be over emphasis. However, it is very important to note that evaluating of the reliability indices in the electrical distribution system will enable KEDCO to plan and design strategies to improve and maintain system performance by comparing it to IEE minimum standards.

6. ***Frequency and Duration Outage:*** Frequency and duration of outages are relevant measures for reliability in electricity supply systems. If reliability is regarded as a technical restriction, adequate outage indices have to be evaluated. If outages are associated with costs, reliability shall be included within operating costs. The estimation of outage cost mostly used around is the customer survey approach. When comparing among alternatives of approximately equal total costs, the outage indices will be helpful in selection of the best solution (Layton 2013).

   (a) ***SAIDI and SAIFI*** – When making reliability investments, reductions in SAIDI and SAIFI are proportional to the number of affected customers. This means projects that affect many customers are preferred to those that affect few customers. However, feeders with many customers typically have better than average reliability, and feeders with few customers have worse than average reliability. Therefore, reliability investment based on SAIFI and SAIDI can drive investments towards densely populated areas where reliability is already satisfactory.

   (b) ***CAIDI*** – Although popular with many utilities and regulators, CAIDI is problematic as measure of reliability. This is because, many view CAIDI as a measure of operation efficiency; when utility responds more quickly after a fault, CAIDI will go down. In fact, CAIDI is mathematically equal to SAIDI divided by SAIFI. That is reliability could be improving in both frequency and duration, but CAIDI could be increasing. Because of the above problem, the use of CAIDI is decreasing in today's world. (Elusaki et al 2011)

Aim and objectives of the study

The aim of this study is to determine the reliability indices of the Electrical power distribution system in Kaduna. The study will assess the following indices in line with IEEE P1366:

1. The System Average Interruption Duration Index (SAIDI) of the Electricity distribution system. **IEEE Min.Std 80%**
2. The Customer Average Interruption Duration Index (CAIDI) of the Electricity distribution system. **IEEE Min.Std =70%**
3. The System Average Interruption Frequency Index (SAIFI) of the Electricity distribution system. **IEEE Min.Std >80%**

Research questions

The following research questions are formulated to guide this study;

1. What is the SAIDI of the Electrical power distribution system in Kaduna?
2. What is the CAIDI of the Electrical power distribution system in Kaduna?
3. What is the SAIFI of the Electrical power distribution system in Kaduna?

Methodology

Descriptive Research design was adopted for the study. Descriptive research design involves data collection at points in time and is more likely to identify causal relationships between variables (Shuttleworth, 2008). The study was carried out at two units of Kaduna Network comprised of Kaduna North and South respectively involving all the distribution Engineers/Technicians of the nineteen 33kv feeders. The data collected from Engineers/Technicians and KEDCO comprises of information on each feeder failure event within the period of one year (March, 2017 to February, 2018). The information was recorded in daily hourly report sheet and were translated into a statistical database. The outages were classified as forced and scheduled. Hence, data on failure rates and repair times of component used in the distribution system were compiled for reliability calculations. In addition, data on statistical information consisting of outages arising from the load shedding, system collapse, scheduled or unscheduled maintenance and hourly load shedding on each feeder were collected. These data were used to compute the reliability indices (SAIDI, CAIDI and SAIFI) using equations 1 to 3. The instrument was validated by the Engineers of the Kaduna Electricity Distribution Company (KEDCO). The reliability was found to be reliable as data were secondary source which make it authentic. The total percentage of SAIDI, CAIDI and SAIFI were computed and compared with IEEE Min.Std. SAIFI indicates how often an average customer is subjected to sustained interruption over a predefine time interval whereas SAIDI indicates the total duration of interruption an average customer is subjected for a predefined time interval. CAIDI indicates the average time required to restore the service. The results are shown in Tables 1 to 3.

Results

The data were computed using the following formula for SAIDI, CAIDI and SAIFI.

SAIDI = Σ (r i * Ni) / NT ...(1)

Where: Σ =Summation function. ri = Restoration time, minutes. Ni = Total number of customers interrupted. NT = Total number of customers served.

CAIDI = Σ (ri * Ni) / Σ(Ni) ...(2)

Where: Σ = Summation function. ri = Restoration time, minutes. Ni = Total number of customers interrupted.

SAIFI= Σ (Ni) / NT ...(3)

Where: Σ = Summation function. Ni = Total number of costumers interrupted. N_T = Total number of customers served.

Table 1: Summary of SAIDI for the Period of (Mar. 2017- Feb 2018) on Each 33kv Feeders

33KVA Stations	SAIDI	IEEE Min.Std 80%	Remarks
AREWA	12.174	"	Less than Min.Std
UNTL	8.157	"	"
NARAYI	18.096	"	"
PAN	7.872	"	"
MAGADISHU	13.552	"	"
INDEPENDENCE	12.726	"	"
U/BORO	18.67	"	"
ABAKPA	11.275	"	"
WATER WORKS	7.018	"	"
NAF	10.771	"	"
DOKA	13.618	"	"
AIRPORT	7.868	"	"
RIGASA	18.929	"	"
U/DOSA	17.537	"	"
KINKINAU	14.745	"	"
GONIN GORA	18.218	"	"
KAWO	17.495	"	"
KUDENDEN	15.775	"	"
DAWAKI ROAD	15.197	"	"
TOTAL AVERAGE	**13.67%**	"	Less than IEEE Min. Std

Table 1 shows computed total SAIDI percentage across all the 33 kV feeders within Kaduna metropolis. The values presented in the table shows that the entire 19 33kv feeders has their values below IEEE Minimum Standard of > 80%. Water works has the least value of 7% while Rigasa recorded the highest value of 19% with the entire Average percentage value of SAIDI 13.6%.

Table 2: Summary of CAIDI for the Period of (March 2017- Feb 2018) on Each 33kv Feeders

33KVA Stations	CAIDI	IEEE Min.Std 70%	Remarks
AREWA	2.132	"	Less than =70%
UNTL	1.457	"	"
NARAYI	3.044	"	"
PAN	1.409	"	"
MAGADISHU	2.004	"	"
INDEPENDENCE	1.879	"	"
U/BORO	2.681	"	"
ABAKPA	1.754	"	"
WATER WORKS	1.092	"	"
NAF	1.618	"	"
DOKA	2.106	"	"
AIRPORT	1.165	"	"
RIGASA	2.887	"	"
U/DOSA	2.717	"	"
KINKINAU	2.826	"	"
			"

33KVA Stations	CAIDI	IEEE Min.Std 70%	Remarks
GONIN GORA	2.961	"	"
KAWO	2.979	"	"
KUDENDEN	2.933	"	"
DAWAKI ROAD	2.808	"	"
TOTAL AVERAGE	**2.23%**		Below the Min.Std

Table 2 presents the computed total CAIDI percentage across all the 19 33 kv feeders within Kaduna metropolis. In the table, all the 19 33kv feeders have their values below the IEEE Minimum Standard of 70%. Water works 33 kv feeder and Airport 33 kv feeder recorded the least value of 13% while Goningora, Kawo and Kudanden 33kv recorded high value of 35% this however, indicates that the customers were actually affected with poor electricity supply.

Table 3: Summary of SAIFI for the Period of (March 2017- Feb 2018) on Each 33kv Feeders

33KVA Stations	SAIFI	IEEE Min.Std 80%	Remarks
AREWA	5.755	"	Less than 80%
UNTL	5.838	"	"
NARAYI	6090	"	"
PAN	6.176	"	"
MAGADISHU	6.898	"	"
INDEPENDENCE	6.781	"	"
U/BORO	6.762	"	"
ABAKPA	6.854	"	"
WATER WORKS	6.714	"	"
NAF	6.710	"	"
DOKA	6.571	"	"
AIRPORT	6.738	"	"
RIGASA	6.896	"	"
U/DOSA	6.565	"	"
KINKINAU	5.835	"	"
GONIN GORA	6.141	"	"
KAWO	5.960	"	"
KUDENDEN	5.350	"	"
DAWAKI ROAD	5.622	"	"
TOTAL AVERAGE	**6.33%**		Less than 80%

Table 3 shows the computed SAIFI across all the 19 33 kV feeders within kaduna metropolis. It was observed that Mogadishu, Independence, U/Boro, Abakpa, Water works, NAF, Airport and Rigasa 33kv feeders has the highest values of above 6% while the rest were less.

Findings of the study

1. The System Average Interruption Duration Index (SAIDI) was found not to be normal in the entire 19 33kv feeders and all the valves and Average are below the IEEE Min. Std of 80%.
2. The Customer Average Interruption Duration Index (CAIDI) was found not operating normal because all the values and Average are below IEEE Min. Std of 70%.
3. The System Average Interruption Frequency Index (SAIFI) was not normal which also indicated that all the valves and Average less than 80% of IEEE Minimum Standard.

Discussion of the findings

The findings on System Average Interruption Duration Index (SAIDI) revealed that the average interruption duration for customers served during a specified time period. This index enables the utility to report how many minutes' customers would have been out of service if all customers were out at one time. The finding on SAIDI revealed that IEEE Minimum Standard was not actually made in which the entire 19 33KV feeders has their values less than 80%. However, Okorie and Abdu (2015) carried out similar research in Kano metropolis in which four indices SAIDI, CAIDI, SAIFI and ASAI were evaluated. But the result of the study shows that all the indices values were below the IEEE Min.Std but it was not compared to make a valid judgment about normality of the above indices (SAIDI). Therefore, there was no any final decision or remark as to whether the SAIDI is operating normal or not.

In the same vein Franklin and Gabriel (2014) carried out research on the five distributions Reliability indices of (SAIDI, CAIDI, SAIFI, ASAI and ASUI). The SAIDI values was found to be within the ranged of IEEE Min. Std and the result of the indices were not compared to the IEEE Min.Std and therefore final decisions or remarked are not established to identify the working conditions of the system. The average value of SAIDI of the entire nineteen 33kv feeders is 13.67% which is less than 80% of IEEE Min.Std, this indicated that the SAIDI system is not operating normal. From the findings on Customer Average Interruption Duration Index (CAIDI); This is 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 was observed that the entire 19 33kv feeders have their values below the IEEE Min.Std of 70%. The values ranged from 1% to 3% which is less than 70% of IEEE Min. Std.

Franklin and Gabriel (2014) carried out similar research work in which five distribution indices were analysed and the result shows that the value of CAIDI is below and not compared to IEEE Min.Std, therefore the Decision or Remarks were not made to know whether the system is operating within 'the limit. It only highlighted the causes of power interruption and recommendation to those problems. However, CAIDI values were below the IEEE Min, Std. CAIDI is customer centre system which deals with the efficiency of electrical supply. Therefore, CAIDI provides the authority, the needs of the customers for efficiency of electrical power supply. The entire average value of CAIDI is less than the IEEE Min.Std of 70%. It has proofed that the CAIDI system is not operating normal. Dorji (2012) conducted a research on Reliability Assessment of Distribution Systems on Wangdue Distribution System in Bhutan, United State and discovered that when CAIDI and SAIDI values are below Minimum Standard it has great effect on the Distribution System.

Based on the findings on System Average Interruption Frequency Index (SAIFI); This is the average number of times that a customer is interrupted during a specified time period. The finding indicates that the entire 19 33kv feeders have values less than 80% of IEEE Min.Std. However, Mogadishu, Independence, U/Boro, Abakpa, Water works, NAF, Airport and Rigasa 33kv feeders have their values high among others which all are less than 80% as compared to IEEE Min.Std. The Average percentage also recorded 6.33% of the entire 19 33kv feeders which is less than 80% of IEEE Min. Std. This indicated that the SAIFI system is not operating normal.

Jibrin and Ekandayo (2013) carried out research work on the Reliability Assessment of 33kv Kaduna Electricity Distribution Feeders. The study highlighted the reliability indices and the causes of power interruption within the distribution feeders. However, no decisions and remarks were made to finalized the normality of the system or not. In a similar study conducted by Okorie and Abdu (2015) title reliability evaluation of power distribution network system in Kano metropolis who reported that the SAIFI is not operating normal as compared with the IEEE min. std. due to the in balance of SAIDI and CAIDI. However, there is no significant power supplied to the consumers which result to load scheduling, age of equipment and component and as well as lack of proper record of all happenings within the distribution system. However, SAIFI would never be stable if the two other indices SAIDI and CAIDI are not performing normal.

Conclusion

From the study, it was found out that system average interruption duration indices (SAIDI) is not operating within the IEEE Minimum. Standard of 80%. This however indicates that there is no sufficient power supply to the 33kv feeders. However, the customer average interruption duration index (CAIDI) has all the values below IEEE minimum standard of 70%. These shows that the demands of the customers are not met due to problems within distribution System which include age of the equipment and components, environment and human factors among others. It was also noticed that the System Average interruption Frequency Indices (SAIFI) values are below the IEEE Minimum. Standard of 80%, which also affect the reliability of power supply in Kaduna metropolis. This indicates that unbalance of SAIDI and CAIDI affected the performance of SAIFI.

In the modern time the world continues to depend more on the supply of electrical energy and its distribution across the nations. However, it has been noted that electrical power is still in the research and in the development phase, even though electrical power distribution system is simultaneously emanating promising benefits to society, the economy, the environment and as well as science and technology. Hence electrical distribution is a topic worthy of further expansion. Power maintenance in electrical distribution feeder stations causes disruption to customers and reduced electrical energy to be used. Electrical distribution system has the potential to impact every individual who uses it in daily affair. Based on the importance of electrical power distribution system reliability the study identifies the following implications to the management of KAEDCO, Engineers/ Technicians consumers and the society at large.

The study highlights the proper maintenance schedule of equipment in the 33kv distribution feeders, thus:

(1) It has the impacts on the utility authority to plan and study the needs of 33kv feeders.

(2) It also alerts the supply authority the need for replacement of bad equipment and components in the 33kv distribution feeders.

(3) The study also provides necessary information about electrical energy supplied to the customers.

(4) It also acquits the supply authority about the important of distribution indices in the distribution system. (SAIDI, SAIFI and CAIDI).

(5) The study assists in identifying where to spend money wisely.

(6) It helps in identifying the nature of environment and customers within the area.

(7) It also provides necessary information about the expansion of the distribution system.

Recommendations

1. More investment in human and financial resources is needed to maintain the equipment and components. If an efficient and reliable supply is to be made, the Feeders should be constructed in pairs so that in the event of a failure of one, the standby can be switched on to avoid long time interruption of electricity supply to consumers which may result to inefficiency of power supply so that System Average Interruption Duration Index (SAIDI) value can be maintain within IEEE Min Std.

2. The number of distribution substation should be increased to reduce the incidence of the transformer overloading and components so as to achieve the reliability performance of the system and use of hot line communications should be practically practiced for the benefit of both customer and utility authority so that Customer Average Interruption Duration Index (CAIDI) would operate within the IEEE Min. Std.

3. The failure of individual components in the system should be maintained and replaced so that the probability of failure of all the events should be specific in order to obtained the actually value of System Average Interruption Frequency Index (SAIFI) within the regulation of IEEE P1366 Min.Std.

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