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Reliability Evaluation of Power Distribution Network System in Kano Metropolis of Nigeria

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Abstract
The electric utility industry is moving toward a deregulated, competitive environment where utilities must have accurate information about system performance to ensure that maintenance fund are spent wisely and that customer expectations are met. To measure system, the electric utility industry has developed several performance measures of reliability indices which include outage duration, frequency of outages and system availability. Keeping a log of outages in a distribution system is very important for the utilities to compute reliability indices and for developing operation and maintenance strategies to improve system performance. An evaluation of outage data gathered by utilities in Kano Distribution Company of Power Holding Company of Nigeria PLC for the power distribution system is presented in this paper. Causes of outages are analyzed, to determine the most significant causes. The trend in outages in different months of the year is examined. The results show that the environmental factors cause more than 50% of the outages on distribution lines.

1. Introduction

Continuous electric power supply is essential for modern living. Any interruption in availability of electricity causes major disruption in people lives. The level of disruption is a function of dependency of people on electricity, which can be very high for a developed country and not as much for developing countries. Interruption can be planned or forced. If the available supply is not enough to meet the demands, the utilities have to implement rolling blackouts. Forced interruptions are due to failures in the system caused by:

- intrinsic factors, such as age of equipment, manufacturing defects,
- environmental factors, such as trees, birds/animals, wind, lightning, ice,
- human factors, such as vehicular accidents, accidents caused by utilities or contractor work crew, vandalism, etc. [1,2].

Utilities can minimize the forced interruptions with proper design and maintenance of the system; however, it is impossible to avoid interruptions completely. It is worth noting that, the causes of incorrect behaviour of protection and control systems, and that of circuit breakers are somewhat more complicated. Utilities commonly use indices such as System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI), Customer Average Interruption Frequency Index (CAIFI), Customer Interrupted per Interruption Index (CIII) and Average Service Availability Index (ASAI) to track reliability of their distribution system [3]. Computation of these indices requires

complete log of all the interruptions. In addition to time, duration, protective device operation, and number of customers interrupted, the utilities also record the likely cause of outage and weather during outage. Utilities have been using their own procedures including the list of causes of outages for recording data on interruption [4]. Recently there has been some effort to standardize the reporting procedures [5]. Attributing an outage to a specific cause is a subjective process and thus prone to error. In many cases if no evidence is present for an outage, the linemen report the cause of outage as unknown or other.

Geographic location of the utility plays a significant role in amount and type of interruptions experienced by a utility, for example, a utility located in a windy region will experience larger damage due to winds and similarly other weather factors affect outages. Utilities typically take weather factors into consideration while designing their system. However, it is almost impossible to completely safeguard the system from weather and other natural phenomena. In most cases, environmental factors, such as weather, vegetation, and animals are a large part of the causes of outages for the utilities.In this paper an evaluation of outage data gathered in Kano the 33kV feeders' distribution system is presented. The systems of Kano include both urban and rural electrifications, both overhead and underground network systems. Also, the data were recorded over a different period of time by this utility, show that environmental factors make the largest contribution to outages in both the systems. The paper is structured into four sections. Section II is outage evaluation; section III is reliability index analysis; and section IV is conclusion.

2. Outage Evaluation of Kano

The authorities monitored one or more feeders and thus some total numbers of lines with kilometer route length were included in the study. The operating voltages of these lines are 33KV, 11kV and 415V. The experience is that the amount of published distribution system component reliability data based on operational experience is quite limited. Although, reliability data published during the period (1993 through 2013) have been found on the following distribution system components that are critical to the reliability of distribution system: Overhead lines, under ground cables, circuit breakers, pole mounted transformers, power transformers, surge arresters and protection and control system, which are also applicable to Kano network just as other similar networks.

Table 1 shows the number of feeder outages and their corresponding percentages recorded for these lines. In addition to lightning, earth faults, unknown and operation and maintenance were recorded as the main causes of outages. Environmental factors, which include lightning, wind, trees, birds, animas, fire and storm caused outages. Out of 47 total numbers of feeders, Kumoboso Feeders (6) recorded the highest number of outages, 43% of all the outages.

A large number of outages are reported as unknown or other causes. This typically happens due to inexperience of linemen. As they get more experienced, they are able to identify the causes more effectively with fewer unknowns. Figure 1 show that outages were reported versus duration during the period under study, duration experienced was recorded as 8214.53hours, out of the stated figures, Kumoboso feeders alone contributed 43.28% outage duration.

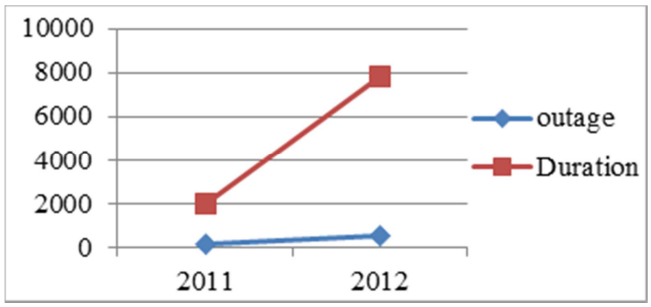

Fig. 1. *Outage and Duration in Kano by year (2011-2012)*

3. Electric System Reliability Indices

The Institute of Electrical and Electronic Engineers (IEEE) defines the generally accepted reliability indices it's standard number P1366 [6].

This paper present the reliability indices used to measure distribution system reliability, how to calculate the indices, and discusses some of the factors that influence the indices. The most common distribution indices used in this report include [6]: System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), Customer Average Interruption.

Table 1. *Outrage Event on 33kV of Kano PHCN Distribution Network (2011-2012)*

DISCO	STATIONS/SERVICE AREA	2011		2012		TOTAL		PERCENTAGE	
		Outage	Duration	Outage	Duration	Outage	Duration	Outage	Duration
KANO	KUMBOTSO SHARADA	47	211.54	180	272.16	227	483.7	12.81	5.6
KANO	KUMBOTSO BAGAUDA	12	196.45	124	1655.56	136	1852.01	7.67	21.46
KANO	KUMBOTSO MADOBI	28	172.4	54	478.65	82	651.05	4.62	7.54
KANO	KUMBSO. WATER WORK	22	5.06	113	443.13	135	448.19	7.62	5.19
KANO	KUMBOTSO ANGEL	1	0.07	17	34.91	18	34.26	1.02	0.4
KANO	KUMBOTSO SPANISH	10	2.12	66	83.44	76	85.56	4.29	0.99

DISCO	STATIONS/SERVICE AREA	2011		2012		TOTAL		PERCENTAGE	
		Outage	Duration	Outage	Duration	Outage	Duration	Outage	Duration
KANO	DAKATA CLUB	5	25.67	54	120.14	59	145.81	3.33	1.69
KANO	DAKATA IDH	2	4.1	24	188.22	26	192.32	1.47	2.23
KANO	DAKATA GAZEWA	2	37.73	18	113.48	20	151.21	1.13	1.75
KANO	DAKATA GASKIYA	0	0	47	180.49	47	180.49	2.65	2.09
KANO	DAKATA ZARIA ROAD	7	9.79	178	399.9	185	409.69	10.44	4.75
KANO	DAKATA BRISCOE	0	0	9	29.4	9	29.4	0.51	0.34
KANO	DAN AGUNDI CLUB	2	3.3	20	67.1	22	70.4	1.24	0.82
KANO	DAN AGUNDI BUK	4	5	83	241.93	87	246.93	4.41	2.86
KANO	DAN AGUNDI KURMA	3	26.98	143	298.96	146	325.94	8.24	3.78
KANO	DAN AGUNDI ZARIA RD.	1	2.82	4	84.2	5	87.02	0.28	1.01
KANO	DAN AGUNDI CBN	3	22.63	52	173.13	55	195.76	3.1	2.27
KANO	DUTSE SUMAILA	0	0	7	26.08	7	26.08	0.4	0.3
KANO	DUTSE BRINI KUDU	0	0	11	69.64	11	69.64	0.62	0.81
KANO	DUTSE JAHUN	0	0	20	55.05	20	55.05	1.13	0.64
KANO	KANKIA-KANKIA	2	13.6	17	124.28	19	137.88	1.07	1.6
KANO	KANKIA MUSAWA	2	4.15	34	545.49	36	549.64	2.03	6.37
KANO	KANKIA KAZAURE	2	5.23	21	194.09	23	203.32	1.3	2.36
KANO	HADEJA NGURU	0	0	4	0.54	4	0.54	0.23	0.01
KANO	HADEJA GUMEL	0	0	3	0.71	3	0.71	0.17	0.01
KANO	HADEJA KAFIN HAUSA	0	0	2	3.3	2	3.3	0.11	0.04
KANO	KWANAR- KWANAR	0	0	13	15.61	13	15.61	0.73	0.18
KANO	KWANAR DAN GORA	0	0	16	123.86	16	123.86	0.9	1.43
KANO	AZARE/JAMARE	0	0	10	55.44	10	55.44	0.56	0.64
KANO	FUNTUA MALUNFASHI	5	53.74	138	665.36	143	719.1	8.07	8.33
KANO	FUNTUA DANDUME	4	26.98	71	574.95	75	601.93	4.23	6.97
KANO	FUNTUA TEXTILE	0	0	2	32.75	2	32.75	0.11	0.38
KANO	KATSINA POLY	7	85.5	21	164.66	28	250.16	1.58	2.9
KANO	KATSINA DAURA	6	52.94	15	120.55	21	173.49	1.19	2
KANO	KATSINA GRA	0	0	2	13.75	2	13.75	0.11	0.16
KANO	KATSINA AJIWA	0	0	2	12.85	2	12.85	0.11	0.15
		177	967.8	1595	7663.76	1772	8631.56	100	100

Duration Index (CAIDI) and Average Service Availability Index (ASAI).

The computation of these indices is briefly review as follow[6]:

$$\text{SAIDI}=\sum(ri * Ni)/NT \quad (1)$$

Where,

r_i = Restoration time, hours.

N_i=Total number of customers interrupted.

N_T = Total number of customers served.

$$\text{CAIDI}=\sum(ri * Ni)/\sum(Ni) \quad (2)$$

Where,

r_i = Restoration time, hours.

N_i=Total number of customers interrupted.

$$\text{SAIFI}=\sum(Ni)/NT \quad (3)$$

Where,

N_i=Total number of customers interrupted.

N_T = Total number of customers served.

SAIFI can also be found by dividing the SAIDI value by the CAIDI value, (ie)

$$\text{SAIFI}=SAIDI/_{CAIDI} \quad (4)$$

$$\text{ASAI}=[\ 1-(\sum(ri * Ni)/\ (NT * T))] * 100 \quad (5)$$

Where,

T= Timeperiod under study, hours.

r_i = Restoration time, hours.

N_i=Total number of customers interrupted.

N_T = Total number of customers served.

From the review above, eqns(1-5)the electric system reliability indices of Kano distribution system is computed and presented in table 2 based on the data collected, while figure 1 and figure 2 shows the corresponding pictorial view of the analysis. The total number of feeders here in this paper represented the total number of customers served, in the other word, feeders represent customers.

Table 2. *Electric Reliability Indices of Kano Distribution Network (2011-2012)*

DISCO	STATIONS/SERVICE AREA	OUTAGE	DURATION	SAIDI	SAIFI	CAIDI	ASAI
KANO	KUMBOTSO SHARADA	227	483.7	12.99	5.97	2.18	99.85
KANO	KUMBOTSO BAGAUDA	136	1852.01	48.74	3.58	13.62	99.44
KANO	KUMBOTSO MADOBI	82	651.05	17.13	2.16	7.94	99.80
KANO	KUMBSO. WATER WORK	135	448.19	11.80	3.58	3.30	99.87
KANO	KUMBOTSO ANGEL	18	34.26	0.90	0.47	1.90	99.98
KANO	KUMBOTSO SPANISH	76	85.56	2.25	2.00	1.13	99.97
KANO	DAKATA CLUB	59	145.81	3.84	1.55	2.47	99.96
KANO	DAKATA IDH	26	192.32	5.17	0.68	7.40	99.94
KANO	DAKATA GAZEWA	20	151.21	3.98	0.53	7.56	99.95
KANO	DAKATA GASKIYA	47	180.49	4.75	1.24	3.84	99.95
KANO	DAKATA ZARIA ROAD	185	409.69	10.78	4.87	2.22	99.88
KANO	DAKATA BRISCOE	9	29.4	0.77	0.24	3.27	99.99
KANO	DAN AGUNDI CLUB	22	70.4	1.85	0.58	3.20	99.98
KANO	DAN AGUNDI BUK	87	246.93	6.50	2.29	2.84	99.93
KANO	DAN AGUNDI KURMA	146	325.94	8..58	3.84	2.23	99.90
KANO	DAN AGUNDI ZARIA RD.	5	87.02	2.29	0.13	17.40	99.97
KANO	DAN AGUNDI CBN	55	195.76	5.15	1.45	3.56	99.94
KANO	DUTSE SUMAILA	7	26.08	0.69	0.18	3.73	99.99
KANO	DUTSE BRINI KUDU	11	69.64	1.83	0.29	6.33	99.98
KANO	DUTSE JAHUN	20	55.05	1.45	0.53	2.75	99.98
KANO	KANKIA-KANKIA	19	137.88	3.63	0.50	7.26	99.96
KANO	KANKIA MUSAWA	36	549.64	14.46	0.95	15.27	99.83
KANO	KANKIA KAZAURE	23	203.32	5.35	0.61	8.84	99.94
KANO	HADEJA NGURU	4	0.54	0.014	0.11	0.14	99.99
KANO	HADEJA GUMEL	3	0.71	0.019	0.08	0.24	99.99
KANO	HADEJA KAFIN HAUSA	2	3.3	0.09	0.05	1.65	99.99
KANO	KWANAR- KWANAR	13	15.61	0.41	0.34	1.20	99.99
KANO	KWANAR DAN GORA	16	123.86	3.26	0.42	7.74	99.96
KANO	AZARE/JAMARE	10	55.44	1.46	0.26	5.54	99.98
KANO	FUNTUA MALUNFASHI	143	719.1	17.51	3.63	4.82	99.80
KANO	FUNTUA DANDUME	75	601.93	15.12	1.87	8.09	99.82
KANO	FUNTUA TEXTILE	2	32.75	0.86	0.05	16.38	99.99
KANO	KATSINA POLY	28	250.16	6.58	0.74	8.93	99.92
KANO	KATSINA DAURA	21	173.49	4.57	0.55	8.26	99.95
KANO	KATSINA GRA	2	13.75	0.36	0.05	6.88	99.99
KANO	KATSINA AJIWA	2	12.85	0.34	0.05	6.43	99.99

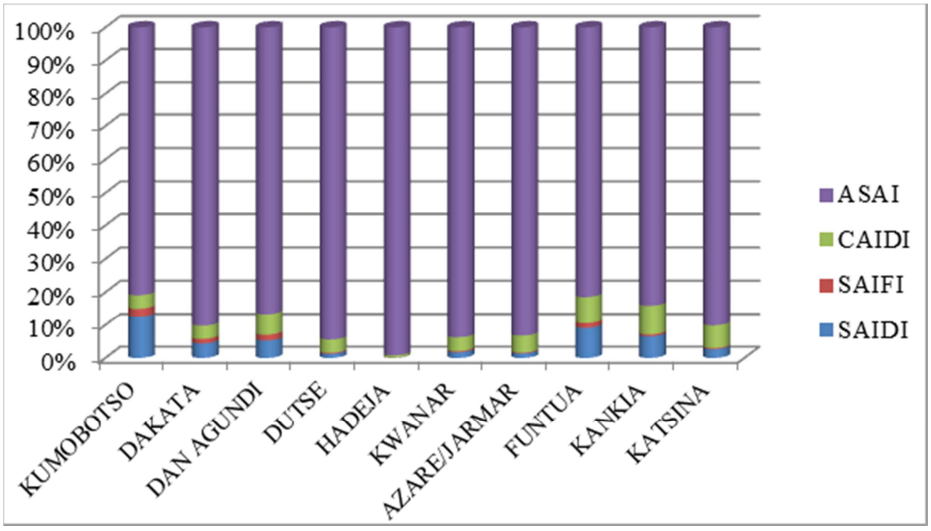

Fig. 2. *Kano Distribution Network Reliability Indices*

4. Conclusions

Analysis of outages evaluated in the electric distribution system on utilities in Kano was presented in this paper. The causes of this failures which are due to variety of factors such as; weather conditions (storm, lighting, outdoor temperature and air humidity), contamination, vegetation, animals, human, excessive ambient temperature, moisture, excessive load, lack of maintenance, ageing, wear-out and design (circuit length, voltage system and circuit configuration). These factors make the component failure rates vary with time and location. Therefore, it is sometimes not accurate enough to assign identical average failure rate value to all components of a particular type and location. The main conclusion that can be drawn from this study is that the environmental factors are mostly responsible for over 50% of the outage in systems and the reliability indices is within the standard performances.

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