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Evaluation of Outages in Overhead and Underground Distribution Systems ofKaduna network; Northern Nigeria.

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Abstract: *Keeping a log of outages in 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 Kaduna 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. 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.*

Keywords -*Power distribution systems, power distribution reliability, Power system reliability analysis.*

I. Introduction

Continuous electric supply is essential for modern living. Any interruption in available of electricity causes major disruption in peoples 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 worth knowing that, the causes of incorrect behavior of protection and control systems, and that of circuit breakers are somewhat more complicated.

Utilities commonly used 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 operated, 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 experiences 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 phenomenon. In most cases, environmental factors, such as weather, vegetation, and animals causes a larger part of outages for the utilities.

In this paper an evaluation of outage data gathered in Kaduna the 33kV feeder's distribution system is presented. Kaduna Electricity Distribution Company, known as Kaduna Disco, is located in the North Central region of Nigeria. It has a franchise for distribution and marketing of electricity in the Kaduna Zone, which includes the Makera, Doka, BirninKebbi, Gusau, Sokoto and Zaria Districts. Kaduna Disco owns and maintains 37 numbers 33kV and 107 number of 11 kV circuits. It also operates 79 number 33/11 kV substations and 2,007 number11/0.415KVdistributionsubstations.

The systems of Kaduna include both urban and rural electrifications, both overhead and underground network system. Also, the data was recorded over a different period of time by this utility, 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. Section IV is conclusion.

II. Outage Evaluation Of Kaduna

The authorities monitored one or more feeders and thus some total of 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. Though, reliability data published during the period 1993 through 2003, has been found on the following distribution system components that are critical to the reliability of distribution system: O/H lines, U/G cables, circuit breakers, pole mounted transformers, power transformers, surge arresters and protection and control system, which are also applicable to Kaduna network and other similar utility.

Table 1 shows number of feeder outages and their corresponding percentages contribution recorded for these lines. In addition to lighting, 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 an outages. Out of 28 total numbers of feeders, Mando Feeders (6) records the highest number of outages because it served the main urban municipal city and some industrial areas.

A large number of outages are reported as known 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. Fig. 1 shows that outages were reported versus duration during the period under study, duration experienced was recorded as 7256.36hours, out of the stated figures, Mando feeders alone contributed 25.22% outage duration.

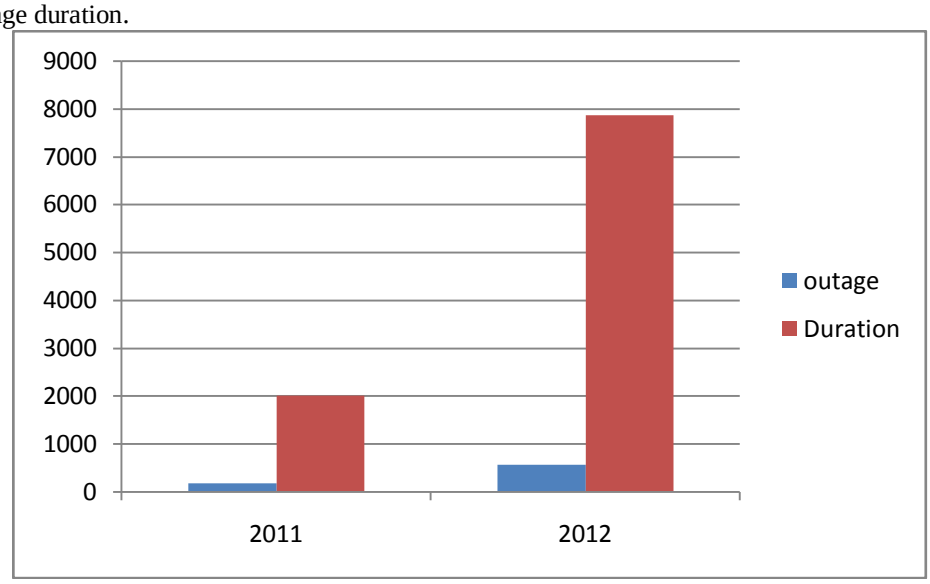

Figure 1 Outage and Duration in Kaduna by year (2011-2012).

Table 1: Tripping Outage and Duration Report on 33kV Feeder of Kaduna Power Holding Company of Nigeria, System Operations Kaduna RCC, 2011-2012.

		2011		2012		TOTAL		Percentage	
DISCO ZONE	station/service Area	OUTAGE	Duration	OUTAGE	Duration	OUTAGE	Duration	Outage	Duration
KADUNA	MANDO FEEDER (1)	22	19.34	105	233.32	127	252.66	6.46	3.48
KADUNA	MANDO FEEDER (2)	26	19	181	220.78	207	239.78	10.53	3.30
KADUNA	MANDO FEEDER (3)	3	10.72	57	92.08	60	102.8	3.05	1.42
KADUNA	MANDO FEEDER (4)	6	7.75	57	89.5	63	97.25	3.20	1.34
KADUNA	MANDO FEEDER (5)	27	22.32	425	671.3	452	693.62	22.99	9.56
KADUNA	MANDO FEEDER (6)	6	11.98	146	432.39	152	444.37	7.73	6.12
KADUNA	PAN	2	7.08	121	377.78	123	384.86	6.26	5.30
KADUNA	AREWA	3	0.71	76	162.42	79	164.13	4.02	2.26
KADUNA	RURAL	20	39.23	91	198.73	111	236.96	5.65	3.27
KADUNA	UNTL	4	5.41	21	131.42	25	134.83	1.27	1.86
KADUNA	MOGADISHU	6	9.95	155	352.25	161	362.2	8.19	4.99
KADUNA	NARAYI	0	0	6	25.47	6	25.47	0.31	0.35
KADUNA	ZARIA FEEDER 1	1	21.57	6	24.23	7	45.8	0.36	0.63
KADUNA	ZARIA FEEDER 2	10	95.93	9	174.38	19	270.51	0.97	3.73

KADUNA	ZARIA FEEDER 3	12	50.26	23	275.58	35	325.84	1.78	4.49
KADUNA	ZARIA FEEDER 4	0	0	3	36.62	3	36.62	0.15	0.51
KADUNA	ZARIA FEEDER 5	2	6.25	12	8.69	14	14.94	0.71	0.21
KADUNA	ZARIA FEEDER 6	5	9.32	11	86.06	16	95.38	0.82	1.31
KADUNA	TALATA MAFARA	2	1.38	24	88.17	26	89.55	1.32	1.23
KADUNA	TALATA MARADUN	2	27.51	69	390.03	71	417.54	3.61	5.75
KADUNA	TALATA BAKURA	6	22.84	74	325.62	80	378.46	4.07	5.22
KADUNA	GUSAU TSAFE	1	21.01	20	571.34	21	592.35	1.07	8.16
KADUNA	GUSAU NNPC	1	25.08	21	207.79	22	242.87	1.12	3.35
KADUNA	GUSAU K/NAMODA	0	0	35	461.19	35	461.19	1.78	6.36
KADUNA	GUSAU MAGAMI	3	52.66	48	1079.87	51	1132.53	2.59	15.61
KADUNA	GUSAU POWER HOUSE	0	0	1	14.05	1	14.05	0.05	0.19

III. Electric System Reliability Indices

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 System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), Customer Average Interruption Duration Index (CAIDI),and Average Service Availability Index (ASAI). The computations of these indices are briefly reviewed as follow:

SAIDI $=\sum(ri * Ni)/NT$ 1

Where,

r_i = Restoration time, hours.

N_i =Total number of customers interrupted.

N_T = Total number of customers served.

CAIDI $=\sum(ri * Ni)/\sum(Ni)$ 2

Where,

r_i = Restoration time, hours.

N_i =Total number of customers interrupted.

SAIFI $=\sum(Ni)/NT$ 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)

SAIFI= $SAIDI/_{CAIDI}$ 4

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

Where,

T= Time period 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 Kaduna distribution system is presented in table 2 based on the data collected, while figure 2 and figure 3 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 theother word, feeders represent customers.

Table 2:Electric System Reliability Indices of Kaduna Distribution Network, Kaduna RCC, 2011-2012

DISCO ZONE	station/service Area	OUTAGE	Duration	SAIDI	SAIFI	CAIDI	ASAI
KADUNA	MANDO FEEDER 1	127	252.66	9.72	4.89	1.99	99.89
KADUNA	MANDO FEEDER 2	207	239.78	9.22	7.96	1.16	99.89
KADUNA	MANDO FEEDER 3	60	102.8	3.95	2.31	1.71	99.96
KADUNA	MANDO FEEDER 4	63	97.25	3.74	2.42	1.54	99.96
KADUNA	MANDO FEEDER 5	452	693.62	26.68	17.39	1.54	99.7
KADUNA	MANDO FEEDER 6	152	444.37	17.09	5.85	2.92	99.81
KADUNA	PAN	123	384.86	14.8	4.73	3.13	99.83
KADUNA	AREWA	79	164.13	6.31	3.04	2.08	99.92
KADUNA	RURAL	111	236.96	9.11	4.27	2.14	99.9
KADUNA	UNTL	25	134.83	5.19	0.96	5.39	99.94
KADUNA	MOGADISHU	161	362.2	13.93	6.19	2.25	99.84
KADUNA	NARAYI	6	25.47	0.98	0.23	4.25	99.99
KADUNA	ZARIA FEEDER 1	7	45.8	1.76	0.26	6.54	99.98
KADUNA	ZARIA FEEDER 2	19	270.31	10.4	0.73	14.22	99.88
KADUNA	ZARIA FEEDER 3	35	325.84	12.53	1.35	9.31	99.85
KADUNA	ZARIA FEEDER 4	3	36.62	1.41	0.12	12.21	99.98
KADUNA	ZARIA FEEDER 5	14	14.94	0.57	0.53	1.07	99.99
KADUNA	ZARIA FEEDER 6	16	95.38	3.67	0.62	5.96	99.96
KADUNA	TALATA MAFARA	26	89.55	3.44	1	3.44	99.96
KADUNA	TALATA MARADUN	71	417.54	16.06	2.73	5.88	99.81
KADUNA	TALATA BAKURA	80	378.46	14.56	3.08	4.73	99.83
KADUNA	GUSAU TSAFE	21	592.35	22.78	0.81	28.21	99.73
KADUNA	GUSAU NNPC	22	242.87	9.34	0.85	11.03	99.89
KADUNA	GUSAU K/NAMODA	35	461.19	17.73	1.35	13.18	99.79
KADUNA	GUSAU MAGAMI	51	1132.53	43.56	1.96	22.21	99.5
KADUNA	GUSAU POWER HOUSE	1	14.05	0.54	0.04	14.05	99.99

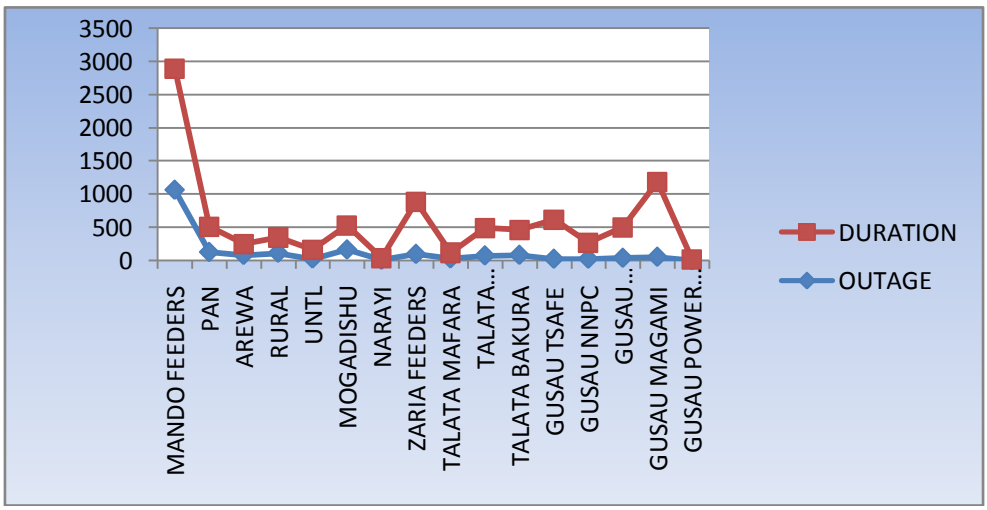

Figure 2. Outage and Duration versus Feeders

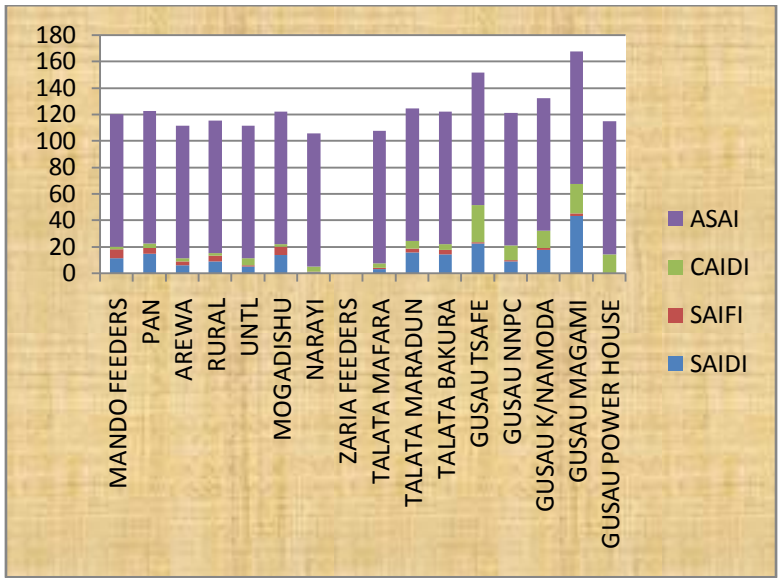

Figure 3. Kaduna Distribution Network Reliability Indices.

IV. Conclusions

Analysis of outages evaluated in the electric distribution system on utilities in Kaduna 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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