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Reliability Assessment of Power Distribution of Abakpa Network Sub-Station of Kaduna Disco

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Abstract

For all in the business of distribution system, reliability is of paramount importance. The goal of distribution system reliability assessment is to predict the availability of power at each customer's service entrance. The extensive use of electricity has led to a high susceptibility of power failures. The aim of this paper is to assess and quantify the reliability performance of Abakpa distribution sub-station of Kaduna Disco, 2010 to 2012 and to propose distribution network system design approach as to achieve high degree of reliability. The paper further present the reliability indices used to measure distribution system reliability and discuss some of the factors that influence the indices.

Keywords: *Distribution System, Reliability, Availability, Quality, Reliability Indices*

Background to the Study

Distribution reliability is the ability of the distribution system to perform its function understated conditions for a stated period of time without failure[1]. Distribution reliability is becoming significantly important in the current competitive climate because the distribution system feeds the customer directly. The distribution system is the face of the utility to the customer. Its assessment is to determine the system reliability and customer satisfaction. Rigorous analytical treatment of distribution reliability requires well defined units of measurement, referred to as metrics. Many utilities across the world today use reliability indices to track the performance of the utility or a region or a circuit. Regulators require most investor owned utilities (IOU) to report their reliability indices [2]. The regulatory trend is moving to performance based rates where performance is penalized or rewarded based as quantified by reliability indices. Most of the utilities or DISCO also pays bonuses to managers or others based in part on reliability achievements. Even some of the commercial and industrial customer asks utilities for their reliability indices when planning to find a location for their establishments. This paper presents a

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brief review of reliability assessment and evaluates the reliability performance of Abakpa distribution network for the period, 2010 to 2012. The paper therefore is structure into the following sections; section two review the subject matter, reliability; section three discusses the related term availability; section four highlight reliability analysis, this further analyses the data collected and presents the assessment results of the distribution network; section five further discuss the factors that influence reliability indices, and section six draw the summary and conclusion.

Power Quality, Reliability and Availability

Power quality is an ambiguous term that means many things to many people. The power Quality is affected when a voltage waveform is distorted by transients or harmonics, changes its amplitudes or deviates in frequency[3].Customer interruptions are power quality concern since it reduces voltage to zero. Reliability is primarily concerned with customer interruptions and is therefore a subset of power quality. Availability is defined as the percentage of time a voltage source is uninterrupted. Power quality deals with any deviation from a perfect sinusoidal voltage source. Reliability deals with interruptions. Availability deals with the probability of being in a interrupted state.

Power Quality

Perfect power quality is characterized by a perfect sinusoidal voltage source without wave form distortion, variation in amplitude or variation in frequency. Power quality concerns are becoming more frequent with the proliferation of sensitive electronic equipment and automated process. Power quality problems are basically divided into many categories such as interruptions, sags, swells, transients, noise, flicker, harmonic distortion and frequency variations.

Reliability

Distribution reliability primarily relates to equipment outages and customer interruptions. In normal operating conditions, if all equipment (except stand by) are energized, all the customers on those equipment are also energized. Schedule and unscheduled events disrupt normal operating conditions and can lead to outages and interruptions. The unscheduled events are caused either due to human error or due to equipment failures. The schedule events are meant for periodic/preventive maintenance of the equipment and shall be notified in advance to the customers when due. Several indicators are used toevaluate reliability in the transmission and distribution system [3] and [4]. The Regulation can aim to compensate customers for very long interruptions, keep restoration times under control and create incentives to reduce the total number outage and duration of interruptions.

Availability

Availability is the probability of something being energized and Unavailability is the probability of not being energized. Reliability and availability associated with one another. Although, these definition appear to be very similar to the reliability function R(t), the two have different meanings. While reliability places emphasis on failure free operation up to time t, the availability is concerned with the status of the equipment at time t. It is most basic aspect of reliability and is typically measure in percent or per unit. Unavailability can be computed directly from interruption duration information. If a customer experiences 29 hours of interrupted power in a year, availability is equal to 8760-29 = 99.67% , while unavailability is equal to 100-99.67 = 0.33%. With the growth of ultrasensitive loads, it has become common to describe high levels of reliability. Although it is not possible to achieve 100% reliability aims should be targeted at least in achieving 99.9%.

Reliability Analysis

Reliability analysis of electrical distribution system is considered 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 [5].There are two main approaches applied for reliability evaluation of distribution system, Namely: Simulation method based on drawings from statistical distributions (Monte Carlo) is time consuming in-order to obtain accurate results; and Analytical methods based on solutions of mathematical models. The analytical approach is based on assumptions concerning based on statistical distributions of failure rates and repair times. The usual method of evaluating the reliability indexes is an analytical approach based on failure modes assessment and the use of equations for both series and parallel networks. The common indices used for evaluation of Abakpa distribution substation are the expected failure rate (λ), the average outage time(r), and the expected annual outage times (U) which are adequate to the simple radial system.

Discussion of Result

The investigation involved the personal interview and consultation with both the PHCN staff and customers. The procedure adapted in this research work for assessing the reliability of the distribution network of Abakpa sub – stations are as follows:

1. Filed data collection from the operations logbooks and data processing via available information packages.
2. Application of frequency and duration method to compute the distribution network outage rates, failure rates, repairs rate, MTBF etc.
3. Statistical survey of yearly faults recorded as against the nature/causes of faults.

For the purpose of this study, the statically summary of the fault frequency on 132kv/33kV/11kV transmission station in Kaduna city network was considered. Fault data logbook, 2010 – 2012 was used as sample case. Here, the yearly faults data from the logbook as documented by the Abakpa sub – station were used as database. Due to large data involved, load outages and downtime results were summed up on yearly basis to cover the period of 3years as shown in table 1, and the corresponding downtime in hours is shown in table 2 respectively.

Table 1: Statistical summary of fault frequency on 132/33kv (2010 - 2012)

	2010		**2011**		**2012**		
Nature/causes of fault	**Faulty freq.**	**Comm. faulty freq.**	**Faulty freq.**	**Comm. faulty freq.**	**Faulty freq.**	**Comm. faulty freq.**	**Total**
Earth leakage fault	938	938	805	805	132	132	1875
Switch gear fault related	10	948	95	900	49	181	154
Fault tripping unit	151	1099	37	937	402	583	590
Faulty transformer	19	1118	30	967	38	621	87
Tree falling on line	171	1289	52	1019	79	700	302
Failure on line due to jumpers	551	1840	422	1441	58	758	1031
Pole and pin installation damage	28	1868	79	1520	34	792	141
Cable injured and spoiled by digger	5	1873	20	1540	47	837	72
Reactor fault	40	1913	83	1623	65	904	188
Faulty circuit inverter	219	2132	95	1718	112	101	426
Gang isolators	33	2165	72	1790	66	1082	171
Over current	846	3011	176	1966	45	1127	1067

	2010		2011		2012		
Nature/causes of fault	**Down time**	**Cumulative Down time**	**Down time**	**Cumulative Down time**	**Down time**	**Cumulative Down time**	**Total**
Earth leakage fault	231.3	231.3	1467	1467	467.45	467.45	2165.7
Switch gear related fault	69.54	300.84	2696.7	4163.7	96.55	564	2862.79
Fault tripping unit	138.06	438.9	874	5037.7	874	1438	1886.06
Faulty transformer	54.02	492.92	256.44	5294.14	25	1463	335.46
Tree falling on line	218.91	711.83	955	6249.14	550	2013	1723.91
Failure on line due to jumpers	720.3	1432.13	428	6731.14	82	2095	1284.3
Pole and pin insulator damage	176.82	1608.95	379.3	7110.44	79.3	2174.3	634.42
Cable injured and spoiled by digger	45.61	1654.56	100.8	7211.24	75.8	2250.1	222.21
Reactor faults	168.95	1823.51	118.72	7329.96	68.72	2318.82	356.39
Faulty circuit breaker	274.02	2097.53	269.5	7569.46	369.5	2688.32	913.02
Gang isolators	261.13	2358.66	239.5	7808.96	108.5	2796.82	609.13
Over current	226.36	2585.02	545	8353.96	67	2863.82	838.36

Cumulative fault frequency, period of occurrence and total downtime are the parameters needed to be used in reliability indices calculation and are shown in table 1 and 2 respectively for the period of 2010 – 2012.

From these tables (i.e. tables 1 and 2), the following equations can be used to compute reliability indices for the components, for the nature or causes of failure for each year for these period of study.

$$FailureRate(\lambda) = \frac{averagenumberoffailure/outage}{periodofoccurenceinhours} (1)$$

$$MeanTimeToFailure(MTTF) = \frac{1}{\lambda} (2)$$

$$MeanTimeToRepair(MTTR) = \frac{totalmeantime}{avearagenumbereoffrequency} (3)$$

$$MeanTimeBetweenFailure(MTBF) = MTTF + MTTR (4)$$

$$AvailabilityA(t) = \frac{MTBF - MTTR}{MTBF} X100 \qquad (5)$$

$$Reliability, R(t) = e^{-\lambda t} = e^{-t/m} (6)$$

Table 3. Reliability indices of Abakpa sub-station equipment components faults (2010 - 2012)

Nature/causes of fault	Failure rate(%/10^3hr)	MTTF(HR)	MTTR(HR)	Availability%	Reliability%
Earth leakage fault	7.135	14.02	1.15	91.71	85.7
Switch gear related fault	0.586	170.65	18.59	89.11	98.3
Fault tripping unit	2.245	44.54	3.20	92.81	95.9
Faulty transformers	0.331	302.11	3.86	98.7	99.9i
Tree falling on line	1.149	87.03	5.71	93.4	98.0
Failure on line due to jumpers	3.923	25.49	1.25	95.1	95.1
Pole and pin insulator damage	0.537	186.22	4.51	97.6	99.7
Cable injured and spoiled by digger	0.274	364.96	3.09	99.2	99.9
Reactor faults	0.731	136.79	1.89	98.6	99.7
Faulty circuit breaker	1.621	61.69	2.14	96.5	98.5
Gang isolators	0.651	153.61	3.56	97.7	99.6
Over current	4.060	24.63	0.79	96.8	96.7

Table 4: Calculated value for the Reliability Indices for the year 2010-2012

Years	Failure rate (%/10^3hr)	MTTF(hr)	MTTR(hr)	MTBF(hr)	Availability%	Reliability
2010	34.37	2.9095	0.8585	3.768	77.2	41.13
2011	22.44	4.4563	4.2492	8.7055	51.2	15.34
2012	12.87	7.7700	2.5411	10.3111	75.4	69.91

Using equations 1 – 6, we shall obtain the values of reliability indices as shown in tables 3 and 4 respectively. The mathematical modeling analysis of the system proved that faulty transformers and cable damaged by digger of the components and year 2012 of the supply was reliable with 99.9% and 69.9% of the system working without failure, and earth leakage component and year 2011 has the least supply of 85.7% and 15.3% respectively. In general, the cumulative outage downtime (8353.96hrs) experienced in 2011 were very high and these rendered the system to have the least supply of 15.3% of working without failure. Tables 3 and 4 showed the justification of the Abakpa Distribution Sub-station.

Factors Affecting Reliability Performance

Reliability performance varies dramatically from one system to another and this is not necessarily an indication that one system has poor performance. Many factors influence the expected reliability at a particular location or for an entire system. Studies have shown that reliability is greatly affected by lighting, circuit length, circuit density, and system voltage. There is an almost direct correlation between lighting and reliability (the more lighting flashes, the lower the reliability), as well as circuit length, longer circuit have more interruptions. Utilities with higher system voltages tend to have more outages, but this may be related to the length of the circuit more than the voltage. One of the major factors to be into consideration is the circuit configuration. Circuit configuration also has an impact on system reliability. Simple overhead radial systems have the worst reliability. Other factors include geographical locations (forest, mountainous terrain etc), vegetations, animals, birds, squirrels and pests causing ground faults which affect reliability levels. Hence, it is obvious to expect a different level of reliability at various locations.

Conclusion

Understanding how to correctly apply the IEEE standard reliability indices is the first step in measuring the reliability of an electric distribution system. Indices are developed as a powerful tool for reliability assessment of the existing distribution systems. Indices can be use for the assessment of distribution configuration reliability associated with looped networks, complex protection, and restoration elements. The modern technology and with the consistence employment of reliability metric/ indices are the most practical solution to improve power network reliability. The parameters presented in this paper showed the justification of the network system.

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