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The Reliability Study of 11-Kv Distribution Feeders: A Case Study of Idi-Araba Phcn Injection Substation

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Abstract: *The frequent outages of power supply due to the occurrence of faults on the system constituents a major problem to electricity consumers in Nigeria. As it is being witnessed all around Nigeria, most commercial cities especially Lagos: Using 33-/11-kV Idi-Araba Injection substation, Mushin, Lagos as a case study, data containing number of faults on each feeders and their respective downtime were collected. This data collected were analysed mathematically to estimate the reliability of the injection substation for a period of five years. The results obtained from the analysis of the 11-kV feeders show that 2011 electricity supply was the most reliable with 81.18% of the system working without failure and 33-kV feeder shows a maximum reliability of 97.02% in 2007 working without failure. The percentage of the system working without failure for 11-kV over the period of five (5) years shows that the system was reliable with 63.61% out of 84.38% availability. Again, for the 33-kV feeder, the system was reliable with 93.39% reliability out of 99.01% availability.*
Keywords: *Reliability, Availability, MTTR, Failure rate, Feeders.*

I. Introduction

Electric energy occupies the top grade in the energy hierarchy. It finds innumerable uses in homes, industries, agriculture and even in transport. The fact that electricity can be transported practically instantaneously is almost pollution free at the consumer level and that its uses can be controlled very easily, make it very attractive as compared to other forms of energy. The per capita consumption of electricity in any country is an index of the standard of living of the people in that country. Nigeria's economy, like that of many other countries in the world, should witness rapid energy usage, but over the years, electricity supply in Nigeria had been epileptic due to problems ranging from poor funding, lack of good policy from government, lack of commitment on the part of PHCN staff, hence, making Nigeria the largest importer of generators in the world.

The electric power system networks are means by which the electric energy generated at the power stations are converted to the consumers. Almost two-thirds of the money invested by the utility company in supplying electric services to its consumer is spent in this division. The electric power network can be subdivided into two, namely; the transmission and distribution systems. The distribution system connects all the individual loads in a given locality to the transmission lines via switchgear equipment. The distribution system may be sub-divided into three, based on the voltage level as follows: primary distribution (33Kv), secondary distribution (11Kv) and tertiary distribution (415V three-phase or 230V single-phase). Hence, industries, individual, small and large consumers are serviced from the distribution network.

Therefore, there is the need to improve the reliability of distribution network, due to the increasing dependability of human existence on electricity.

II. Aim And Objectives

The main aim of this research is to perform a detailed mathematical analysis on Idi-Araba Injection Substation (33-/11-kV) to estimate the reliability of the primary and secondary distribution networks. The objectives of this research work are to determine the failure rate (λ), the mean time between failures (MTBF) and reliability of the network.

III. Index Of Reliability

Reliability is a probability expression that needs to be quantified to make it suitable for scientific analysis. This quantification is carried out by introducing performance parameters which indicate the degree of reliability and are called indices of reliability. Some of them are explained below.

(1) **Failure rate (λ):** This is the basic index of reliability. It is a measure of the frequency at which faults occurs.
(2) **Mean time between failure (MTBF):** This expresses the average time, which elapses between consecutive failures of a repairable system of equipment.

(3) **Mean time to repair (MTTR):** This is the average time that is needed to restore an equipment or item to operate effectively, once it fails. MTTR is a function of equipment design, the expertise of the personnel and the tools available. Hence, a low value of MTTR shows good maintainability.

(4) **Availability (A):** It is the probability that an equipment will be available to perform as required or that it will be in a state of operational effectiveness within a given period.

(5) Reliability $(R) = e^{-\lambda t}$

IV. Data Collection

For the purpose of this research study, the statistical summary of number of outages due to fault and preventive maintenance on 33-kV/11-kV of Idi-Araba injection substation in Mushin, Lagos was considered. For the 33-kV distribution system, two feeders were taken and the 11-kV for a period of seven years (2007-2012) as tabulated in tables 1.0 to 1.1 below.

Table 1.0: 11kV feeder data

11-kV Feeder by Feeder Outages		Years					
		2007	2008	2009	2010	2011	Total
Babalola	Number of Outages	50	67	31	37	26	**211**
	Down Time (Hours)	394.57	450.18	393.22	344.23	200.11	**1782**
LUTH	Number of Outages	9	11	12	12	6	**50**
	Down Time (Hours)	86.19	161.34	117.42	74.18	28.01	**467.1**
Idi-Araba	Number of Outages	76	62	17	21	16	**192**
	Down Time (Hours)	467.64	342.08	429.3	390.01	185.16	**1814**
Daniyan	Number of Outages	95	63	71	33	23	**285**
	Down Time (Hours)	472.33	274.37	505.17	446.01	173.23	**1871**

Table 1.1: 33kV feeder data

33-kV Feeder by Feeder Outages		Years					
		2007	2008	2009	2010	2011	Total
Akangba	Number of Outages	6	15	10	15	7	**53**
	Down Time (Hours)	10.58	41.01	19.35	60.43	23.37	**154.7**
Isolo	Number of Outages	5	20	12	21	13	**71**
	Down Time (Hours)	16.55	97.21	77.02	45.09	42.02	**277.9**

V. Methodology

In other to access the performance of the feeders, the various reliability indices were computed using:

(i) Failure rate $(\lambda) = \dfrac{Cumulative\ fault\ frequency\ for\ each\ year}{Period\ of\ occurence\ for\ each\ year}$

Or -

(1)

$$\lambda = \frac{Number\ of\ time\ that\ failure\ occur}{Number\ of\ unit-hour\ of\ operation}$$

(ii) Mean time between failure $(MTBF) = \dfrac{Total\ system\ operating\ hours}{Number\ of\ failure}$ -

(2)

(iii) Mean time to repair $(MTTR) = \dfrac{Total\ system\ downtime}{Number\ of\ \ failure}$ -
(3)

(iv) Availability (A) = $\dfrac{MTBF - MTTR}{MTBF}$ -
(4)

(v) Reliability $(R) = e^{-\lambda t}$ -
(5)

Where λ = Failure rate
R = Reliability
t = time (1day)

VI. Data Analysis And Result

The focus here is to determine the failure rate, operating time, availability and reliability of the substation for each year (2007 to 2011) using Matlab program below. A reliability study of 33-kV/11-kV feeder network of Power Holding Company of Nigeria (PHCN), Idi-Araba Injection substation was carried out in this research. Number of outage and down time losses data were collected from PHCN and analysed using Mat-Lab program to calculate the reliabilities of each feeders for one day for each of the years.

Table 1.2: Summary of the 11-kV Feeder's Failure rates over five years

Feeder	2007	2008	2009	2010	2011
Babalola	0.005977	0.008063	0.003705	0.004397	0.003037
Luth	0.001038	0.001267	0.001389	0.001382	0.000687
Idi-Araba	0.009165	0.007365	0.002041	0.002509	0.001866
Daniyan	0.01146	0.003705	0.008601	0.003970	0.002678

Figure 1.1: Bar chart for 11-kV feeders failure rate over five years

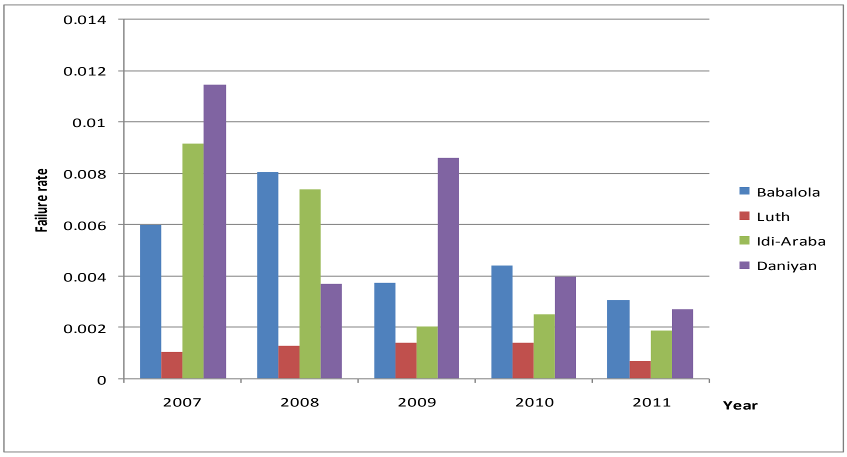


Table 1.3: Summary of the 11-kV feeder Reliability

Feeder	2007	2008	2009	2010	2011
Babalola	86.64%	82. 41%	91.49%	89.99%	92.97%
Luth	97.54%	97.00%	96.72%	96.74%	98.36%
Idi-Araba	80.26%	83.80%	95.22%	94.16%	95.62
Daniyan	75.95%	83.21%	81.35%	90.91%	93.77%

Figure 1.2: Bar chart for 11-kV feeders' reliability over five years

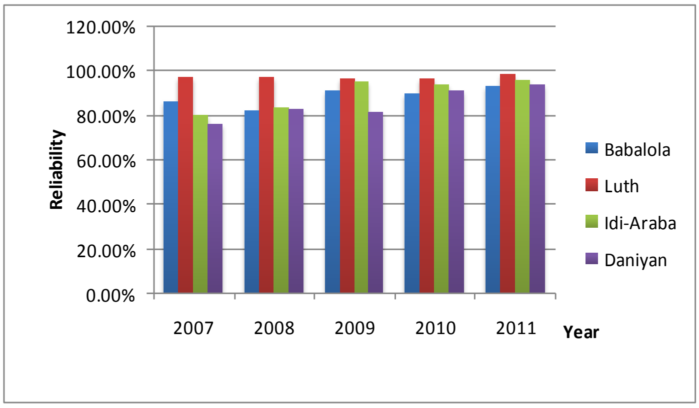


Table 1.4 Summary of the 11-kV feeder MTTR (Hours) over five years

Feeder	2007	2008	2009	2010	2011
Babalola	7.89	6.71	12.67	9.30	7.70
Luth	9.58	7.31	9.79	6.18	4.67
Idi-Araba	6.15	5.51	25.23	18.56	11.55
Daniyan	4.97	4.22	7.11	13.53	7.52

Figure 1.3: Bar chart for 11-kV feeders MTTR over five years

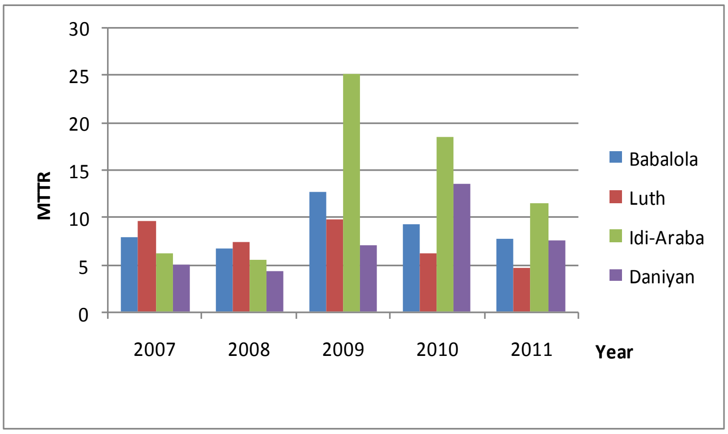


Table 1.5: Summary of the 11-kV feeder Availability over five years

Feeder	2007	2008	2009	2010	2011
Babalola	95.50%	94.86%	95.52%	96.07%	97.72%
Luth	99.02%	99.08%	98.66%	99.15%	99.68%
Idi-Araba	94.66%	96.10%	95.10%	95.55%	97.89%
Daniyan	94.61%	96.87%	94.24%	94.90%	98.03%

Figure 1.4: Bar chart for 11-kV feeders Availability over five years

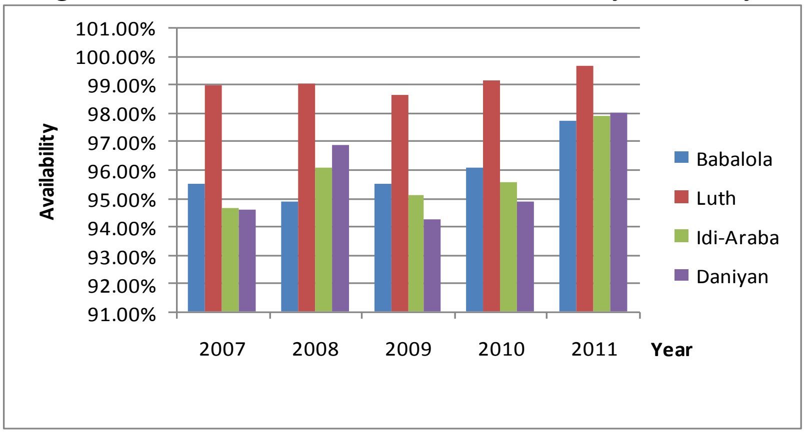


Table 1.6: Summary of the 33-kV feeder Failure Rate over five years

Feeder	2007	2008	2009	2010	2011
Akangba	0.000686	0.00172	0.00114	0.00172	0.000801
Isolo	0.000572	0.00231	0.00138	0.00241	0.00149

Figure 1.5: Bar chart for 33-kV feeders failure rate over five years

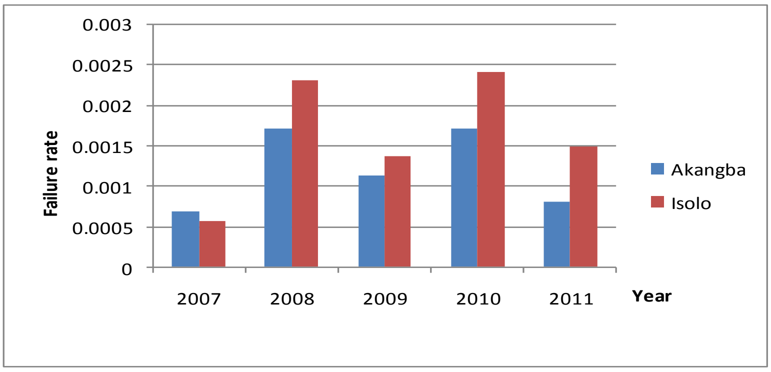


Table 1.7: Summary of the 33-kV feeder Reliability over five years

Feeder	2007	2008	2009	2010	2011
Akangba	98.37%	95.96%	97.29%	95.94%	98.10%
Isolo	98.64%	94.61%	96.74%	94.38%	96.48%

Figure 1.6: Bar chart for 33-kV feeders' reliability over five years

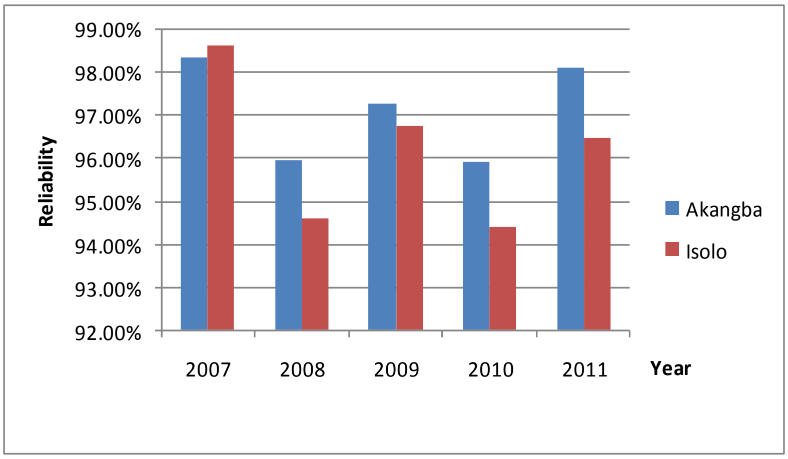


Table 1.8: Summary of the 33-kV feeder MTTR (Hours) over five years

Feeder	2007	2008	2009	2010	2011
Akangba	1.76	2.74	1.89	4.03	3.34
Isolo	3.31	4.84	6.39	2.12	3.20

Figure 1.7: Bar chart for 33-kV feeders MTTR over five years

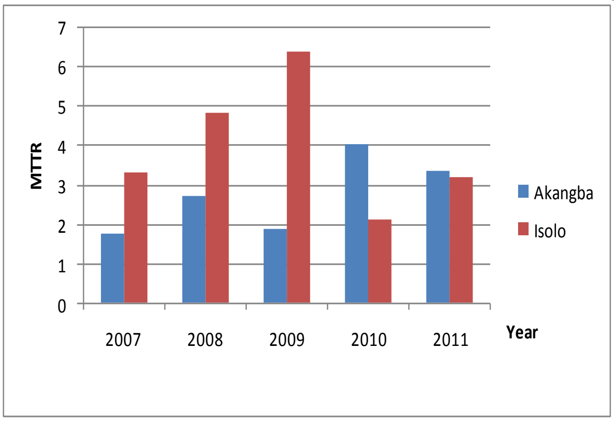


Table 1.9: Summary of the 33-kV feeder Availability over five years

Feeder	2007	2008	2009	2010	2011
Akangba	99.88	99.53	99.78	99.31	99.73
Isolo	99.81	98.89	99.12	99.49	99.52

Figure 1.8: Bar chart for 33-kV feeders Availability over five years

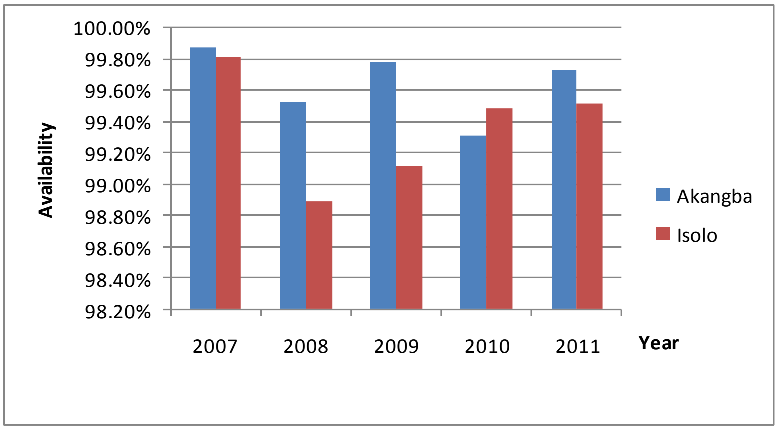


Table 1.10: Five years feeders by feeder 11-kV down time in hours

Year	Feeders				Total
	Babalola	**Luth**	**Idi-Araba**	**Daniyan**	
2007	394.57	86.19	467.64	472.33	1420.73
2008	450.18	80.48	342.08	274.37	1147.11
2009	393.22	117.42	429.30	505.17	1445.11
2010	344.23	74.18	380.10	446.61	1255.12
2011	200.11	28.01	184.76	172.85	585.73
Grand total	**1782.31**	**386.28**	**1813.88**	**1871.33**	**5853.8**

Table 1.11: Five years feeders by feeder 11-kV outages due to fault

Year	Feeders				Total
	Babalola	**Luth**	**Idi-Araba**	**Daniyan**	
2007	50	9	76	95	230
2008	67	11	62	63	203
2009	31	12	17	71	131
2010	37	12	21	33	103
2011	26	6	16	23	71
Grand total	**211**	**50**	**192**	**285**	**738**

Table 1.12: Calculated value of 11-kV reliability indices for the year 2007 -2011

Year	Failure Rate (hr)	MTTR (hr)	MTBF (hr)	Availability (%)	Reliability (%)
2007	0.03134	6.177	31.908	80.64	47.13
2008	0.02667	5.651	37.495	84.93	51.73
2009	0.01791	11.031	55.835	80.24	65.06
2010	0.01372	12.186	72.886	83.28	71.94
2011	0.008686	8.250	115.128	92.83	81.18
For a period of 5 years	**0.01967**	**8.659**	**62.6504**	**84.384**	**63.61**

Figure 1.9: Bar chart for 11-kV feeders Reliability indices over five years

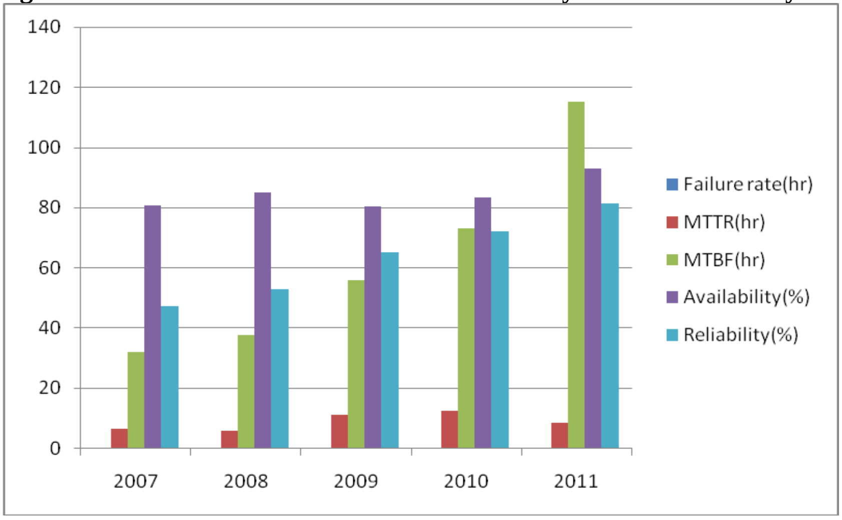


Table 1.13: Five years feeders by feeder 33-kV down time in hours

Years	Feeders		Total
	Akangba	**Isolo**	
2007	10.58	16.55	27.13
2008	41.10	96.81	137.91
2009	18.85	76.62	95.47
2010	60.43	144.49	104.92
2011	23.37	41.62	64.99
Grand total	**154.33**	**276.09**	**430.42**

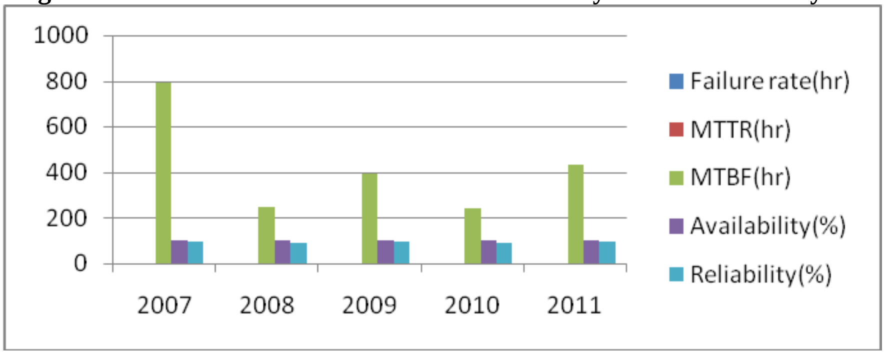
Table 1.14: Five years feeders by feeder 33-kV outage due to fault

Years	Feeders		Total
	Akangba	**Isolo**	
2007	6	5	11
2008	15	20	35
2009	10	12	22
2010	15	21	36
2011	7	13	20
Grand total	**53**	**71**	**124**

Table 1.15: Calculated value of 33-kV reliability indices for the year 2007-2011

Year	Failure Rate λ (hr)	MTTR (hr)	MTBF (hr)	Availability (%)	Reliability (%)
2007	0.001260	2.47	793.65	99.69	97.02
2008	**0.004059**	**3.94**	246.37	98.40	90.72
2009	0.002539	4.34	393.86	98.90	94.09
2010	0.004159	2.91	240.44	98.79	90.50
2011	0.002300	3.25	434.78	99.25	94.63
For a period of 5 years	**0.00286**	**3.382**	**421.82**	**99.01**	**93.39**

Figure 1.10: Bar chart for 33-kV feeders Reliability indices over five years



VII. Conclusion

Quality electricity supply to consumers is desirable for progress and advancement of the living standard of any people thus the need for system reliability. To facilitate this, accurate monitoring of power system is necessary to help the operator detect dangerous conditions that might damage or cause loss of service. Conclusion can be made from the analysis carried out on the outage data due to faults that were obtained at the Idi-Araba distribution substation between 2007 and 2011. The result shows that the frequency of faults is extremely low for all the months on the 33-kV lines. This trend makes the reliability to be very high which is good for the system. In conclusion, reliability of power being available at the substation is very poor because the power generated is smaller when compared to the power demand. Further research in this and related field is encouraged.

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