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Reliability assessment of transformer reliability in Benin City, Edo State and environ

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Abstract
A good understanding of system reliability is to enable system planners to seek better ways of improving the system network for better performance of transformers in a typical secondary distribution system having any type configuration whether radial or ring. In this work analytical technique was used in combination of the electrical transient analyzer software for the simulation of transformers used in these eight (Koko, Nekpenekpe, Ikpoba Dam, Etete, Guinness, G. R. A., Street I, Street II) feeders' stations from four numbers of transformers 132/33/11kV of 3 x 60 MVA and 1 x 30 MVA in Benin City, Edo State. The results of the analysis revealed that Koko Feeder Station is the most reliable in the network when compared to the other seven feeder stations from analysis of the system indices. An expected sensitivity analysis interrupting cost (ECOST) of any type of cessation that occurs has been included.

Keywords: feeder stations; expected sensitivity analysis interrupting cost; distribution transformers; analytical technique

1. Introduction

The significant feature of electrical power system arrangement is to make possible the necessities electrical energies to all end users at a prudently acceptable rate with agreeable level of reliability. Electricity supply entwine a very intricate and highly coordinated system. The relative importance of power system reliability will be noticed when electrical energy is interrupted, for which it decreases the fulfilment of use of electricity at home or causes the stoppage the operation of companies and results in colossal economic short fall [1, 2, 3]. System reliability is not the same as power quality. System reliability pertains to experienced and relatively short-lived interruptions. Power quality involves irregular voltage swings, odd waveforms, and harmonic effects. Interrupting network system for more than five minutes can be considered a reliability issue, while interruptions of less than five minutes calls for concern in power quality [4].

Electrical energy is a necessity for a growing economy; electricity perhaps is an underlying basic need of contemporary societies because of the accomplishments and convenient conditions associated with. This include improved electrical energy production that results in increased reliability available for all end users [5,6]. Distribution system initiates the fundamental circuit that is a repository to sub-station and end as the secondary service which enters the customers' meter. That power interruptions which are largely unavoidable can contribute to the unavailability of power and thus prevent power system from achieving the stet goals. Sometimes, it may be a sustained interruption that greatly affect both the utility company and its customers. Thus, it behooves on the power utility to determine the causes of failure and proffer solution to addressing the causes as this have negative effects on the customers and the nation gross domestic product (GDP). The system utility looks better ways of improving the reliability of a typical distribution stations irrespective of the configuration. Transformers performance in any network can contribute to the failures most stations do experience [7,8].

2. Reliability Formats

Three common index used are: The expected failure rate (f_r), the average outage time (ΔT) and the expected annual outage time (r). There seem to be two main approaches applied to reliability evaluation of distribution systems which have been discussed previously in many papers:

1. Simulation methods based on drawings from statistical distributions (Monte Carlo).
2. Analytical methods based on solutions of mathematical models.

The Monte Carlo techniques are time consuming due to the large number of drawings required in order to have accurate results. The fault contribution from each component is given by a statistical distribution of failure rates and outage times. One of the advantages of simulation methods is that no assumptions have to be made concerning the shape of the statistical distributions applied.

The analytical method is based on proposition concerning the statistical distributions of failure rates and repair times. The most common assessment techniques, using a set of approximate equations. The methods applied are less time-consuming than the simulation methods, but suffers from the problem of representing repair times adequately [9].

2.1 Reliability Interruption Indices [10]

The reliability index parameters are calculated:

$$f_r = \sum_{n=i}^{8} \lambda_r \qquad (outages/year) \tag{1}$$

$$\Delta T = \sum_{n=i}^{8} \lambda_T \qquad (hours/year) \tag{2}$$

$$r = \Delta T / f_r \qquad (hours/outage) \tag{3}$$

Where:

f_r = annual frequency outages/failure rate

ΔT =annual duration of outages

r = expected number of faults per year

System average interruption frequency index (SAIFI)

$$SAIFI = \frac{\sum \lambda_r N}{\sum N} = \frac{\text{total number of customers interruption}}{\text{Total number of customers served}} \quad (4)$$

System average interruption duration index (SAIDI)

$$SAIDI = \frac{\sum \Delta TN}{\sum N} = \frac{\text{sum of customers interruption duration}}{\text{Total number of customers}} \quad (5)$$

Customer average interruption duration index (CAIDI)

$$CAIDI = \frac{\sum \Delta TN}{\sum N} = \frac{\text{sum of customers interruption duration}}{\text{Total number of customers interruptions}} \quad (6)$$

These indices are not exactly predictable values, but expected or average values of underlying probability distributions and typify long-run average values. A precise step-by-step plan calculates reliability indices in terms of mean values and distributions for the number of outages and annual duration of outages. Indices are calculated both for the individual load points and for the whole system [10].

2.2 Assessment of Reliability

The eight feeder distribution stations under evaluation in this work are; Koko Feeder, Nekpenekpe Feeder, Ikpoba Dam Feeder, Etete Feeder, Guinness Feeder, G. R. A. Feeder, Street Feeder I and Street Feeder II stations. It has a total of 11, 917 customers connected to feeders indicated as load points.

Table 1: Load Points

Locations	Interruption Frequency Rate	No. of time Interruption occurs	No. in hours of Interruption	No. of Customers	Customer Types
Koko Feeder	794	4,513	3,990	2,189	Residential
Nekpenekpe Feeder	650	4,760	4,480	1,308	Res/Ind
Ikpoba Dam Feeder	790	3,951	4,995	920	Comm/Res
Etete Feeder	770	5,497	3,381	2,770	Residential
Guinness Feeder	758	4,970	3, 259	2,410	Comm/Res
G. R. A. Feeder	669	4,637	3,803	2,320	Residential
Street Feeder I	765	4,973	3,472	2,850	Residential
Street Feeder II	673	4,521	3,639	2,220	Residential

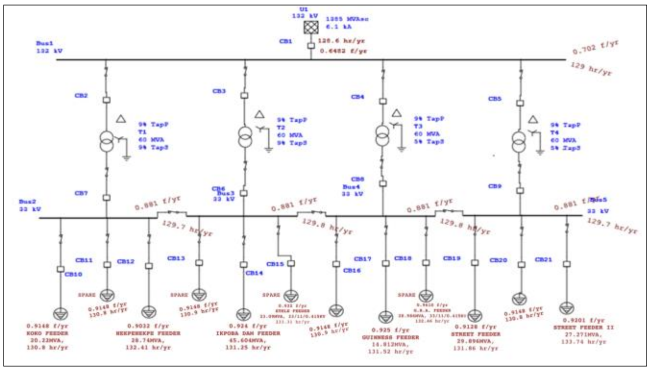

Fig 1: The ETAP simulation

Failure frequency, $F = 794$

Total Annual Downtime, $\sum T_{dx} = 3{,}413$

Time for Operation, $T = 365x24hrs = 8{,}760hrs$

Using Eqns. (1) to (5), we have;

Failure Rate of Load,

Analysis for Koko Feeder is as follows:

$$f_r = \sum_{n=1}^{8} \lambda_r = \frac{794}{8760} = 0.0906\, f / yr$$

Duration for outage annually,

$$\Delta T = \sum_{n=1}^{8} \lambda_T = \frac{4513}{8760} = 0.5152 hrs / yr$$

Duration for average outage,

$$r = \frac{\Delta T}{f_r} = \frac{0.5152}{0.0906} = 5.686 hrs$$

Table 2: Summary of Load Point Indices

Load Points	$f_r (f / hr)$	$r(hours)$	$\Delta T (hr / yr)$
Koko L_{p1}	0.9148	142.98	130.8
Nekpenekpe L_{p2}	0.9032	146.60	132.41
Ikpoba Dam L_{p3}	0.924	142.05	131.25
Etete L_{p4}	0.932	143.04	133.31
Guinness L_{p5}	0.925	142.18	131.52
G. R. A. L_{p6}	0.9410	149.77	132.46
Street I L_{p7}	0.9128	144.46	131.86
Street II L_{p8}	0.9201	145.35	133.74

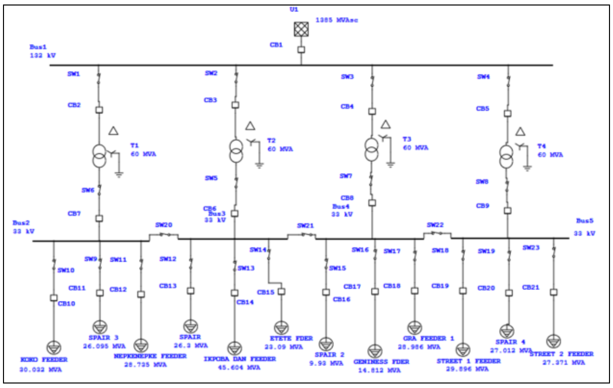

Fig 2: Benin City Town and Environ Distribution Network

Table 3: Power Outages schedules and Actions taken

Description	Action taken	Duration of Interruption in minutes	Affected areas	No. of customers affected
Transformer tripped at 11kV substation at Koko Feeder	Fault was due to bushing HT terminal red phase which snapped; temporary power supplied through 11 kV sub-station at Benin-Sapele Road.	794	Part of Koko, Ugbenu, Obayantor and Okah areas.	1,005
60MVA transformer T21 flashover that affected the Etete Feeder.	11kV sub-station at Etete Feeder was affected in Benin City; temporary power supply given through sub-station.	770	Part of main power station controlled by 60 MVA transfor-mer T21.	530
Faulty underground cable in between 11 kV substation at Guinness Feeder	Temporary power supplied through 500 kVA transformer	758	Customers in the suburb areas.	105
Transient fault – animal contact, lightning strikes and momentary tree contact at G. R. A. Feeder	G. R. A. Feeder 11 kV S/S tripped; Survey of the overhead; protection relay operated with total load fault was cleared;	260	G. R. A. area in Benin, Aerod-rome and civil service comm-ission (CSC) office area were affected	1,480
Ikpoba Dam Feeder 11 kV S/S bad weather, lightning caused tripping.	Ikpoba Dam Feeder 11 kV S/S tripped; Survey of the overhead; protection relay operated with total load fault was cleared.	560	At Ikpoba Dam, at the fault time, all the process at the dam was affected.	102
Nekpenekpe Feeder 11 kV S/S Overhead line overloaded.	Nekpenekpe Feeder 11 kV S/S Blue Phase to Ground was noticed and the feeder reenerg- ized after load shedding and became successful.	770	The residents in Nekpenekpe area was affected due to serious neglect by utility authority.	1,520
Street Feeder I Lightning thunderstorm.	The feeder tripped with phase to earth fault; reenerg-izing feeder was successful with initial load of 25 kW.	308	The residents in Street Feeder I area was affected resulting from the heavy downpour from the after the thunderstorm.	1,320
Street Feeder II faulty transformer winding.	Street Feeder II Feeder 11 kV S/S was affected by transformer winding fault.	480	The residents in Street Feeder II area was affected resulting from faulty winding transformer.	1,240

Table 4: Review for Feeder the Eight Feeder Stations

Locations	SAIFI (2016)	SAIDI (2016)	CAIDI (2016)	ASAI (2016) (%)	SAIFI (2017)	SAIDI (2017)	CAIDI (2017)	ASAI (2017) (%)
Koko Feeder	0.923	132.26	143.22	91.51	0.964	132.24	143.33	91.52
Nekpenekpe Feeder	0.932	131.02	140.81	92.07	0.944	131.02	140.7	92.07
Ikpoba Dam Feeder	0.915	130.98	141.06	92.07	0.914	131.01	141.06	91.81
Etete Feeder	0.899	134.09	144.07	90.98	0.900	134.10	144.06	91.02
Guinness Feeder	0.920	131.46	141.75	91.23	0.958	131.32	141.55	91.63
G. R. A. Feeder	0.922	132.98	142.82	94.09	0.925	132.82	142.68	94.76
Street Feeder I	0.898	131.38	140.35	90.16	0.876	131.11	140.43	91.05
Street Feeder II	0.917	132.83	142.50	91.84	0.925	132.69	142.66	91.76

3. Results and Discussion

Below is the simulated result of the Koko, Nekpenekpe, Ikpoba Dam, Etete, Guinness, G. R. A., Street I and Street II feeder stations as shown in Figures 3-10; Table 5 is the expected sensitivity analysis interrupting cost (ECOST).

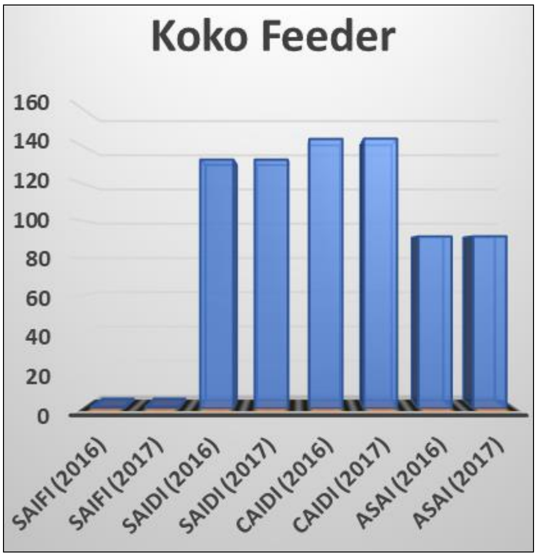

Fig 3: Koko Feeder

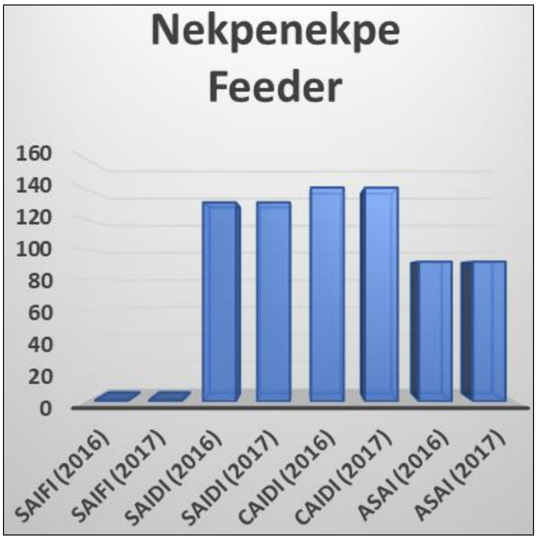

Fig 4: Nekpenekpe Feeder

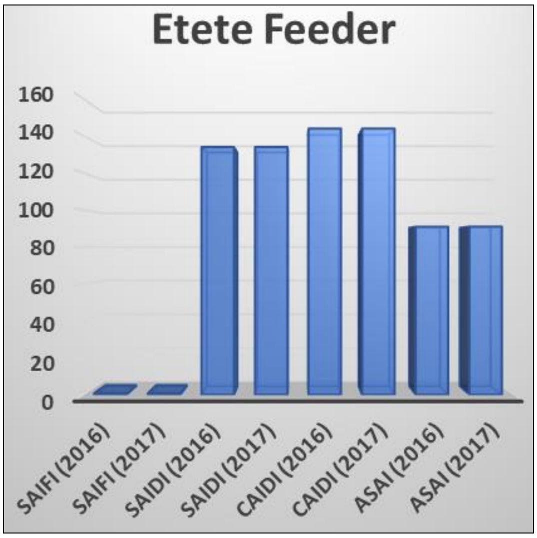

Fig 6: Etete Feeder

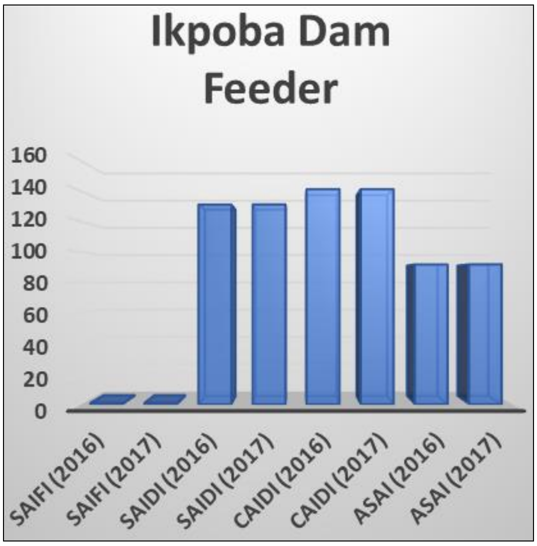

Fig 5: Ikpoda Dam Feeder

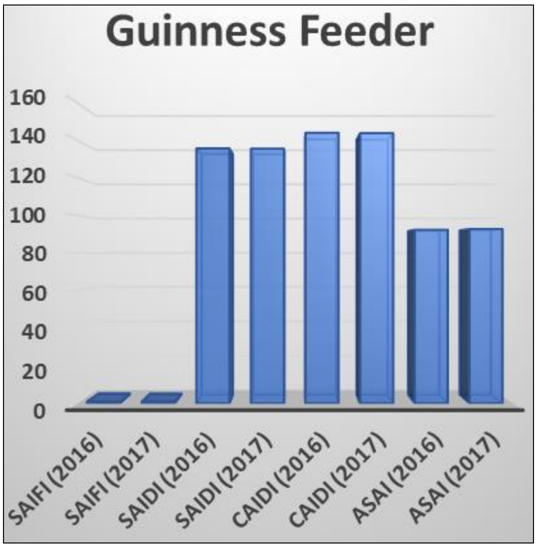

Fig 7: Guinness Feeder

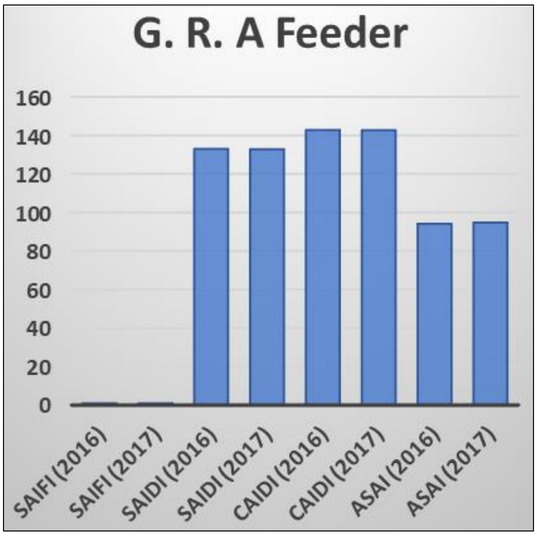

Fig 8: G. R. A. Feeder

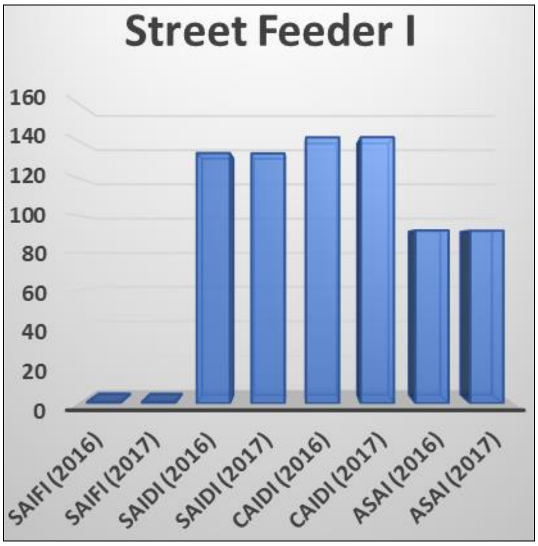

Fig 9: Street Feeder I

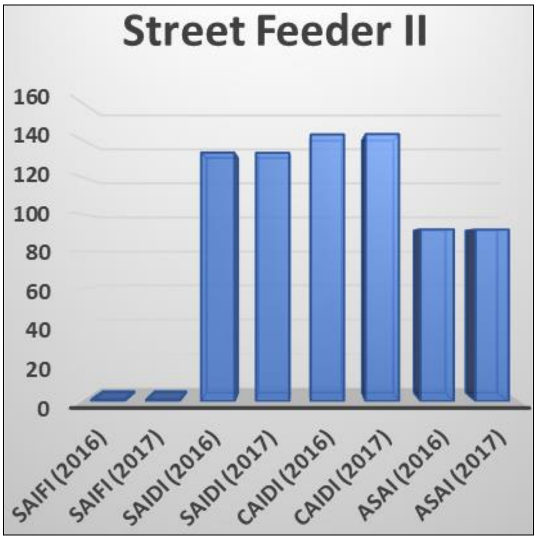

Fig 10: Street Feeder II

Table 5: Expected Sensitivity Analysis Interrupting Cost (ECOST)

	Interruption	
Sector Name	**Duration**	**Cost**
	(minutes)	**$/kW**
Agriculture	1.00	0.06
	20.00	0.34
	60.00	0.65
	240.00	2.06
	480.00	4.12
Commercial	1.00	0.38
	20.00	2.97
	60.00	8.55
	240.00	31.32
	480.00	83.01
Govt. & Inst.	1.00	0.04
	20.00	0.37
	60.00	1.49
	240.00	6.56
	480.00	26.04
Industrial	1.00	1.63
	20.00	3.87
	60.00	9.09
	240.00	25.16
	480.00	55.81
Office & Bldg	1.00	4.78
	20.00	9.88
	60.00	21.06
	240.00	68.83
	480.00	119.20
Residential	1.00	0.00
	20.00	0.09
	60.00	0.48
	240.00	4.91
	480.00	15.69

4. Conclusion

The Feeder stations system being considered results from the outage power obtained from the eight feeder stations starting with Koko Feeder, Nekpenekpe Feeder, Ikpoba Dam Feeder, Etete Feeder, Guinness Feeder, G. R. A. Feeder, Street Feeder I and Street Feeder II stations; these are depicted in Figures 3-10. From the analysis of these feeder station, Koko feeder was adjudged more stable when compare with other feeder station; while Street feeder I was noticed to be at the least in the performance analysis, the reason for low performance could be power outages identified in feeder stations includes weather – related causes lightning and thunderstorms, faulty equipment, and animal contacts which may be applicable to other feeder stations. Power restoration needs are carried out as soon faults are noticed in any of the feeder stations, besides sample analysis was necessary to evaluate the various indices as may be applicable. Table 5 shows the expected sensitivity analysis interrupting cost (ECOST) for the four transformers used in the analysis.

References

1. IEEE Standard 1366, Electric Power Distribution Reliability Indices, 2012.

2. IEEE. "IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces." February, 2018.
3. Harikrishna KV, Ashok V, Chandrasekhar P. "Performance Assessment in Power Distribution System based on Reliability Indices" at International Conference on Power System Engineering (ICPSE) 14& 15 Feb, 2013. Malaysia.
4. Lowry MN, Tim W, Lisa S. Performance-Based Regulation in a High Distributed Energy Resources Future. Report No. 3, LBNL-1004130. Lawrence Berkeley National Laboratory (LBNL). January, 2016.
5. IEEE. Electric Power Grid Modernization Trends, Challenges, and Opportunities, 2017.
6. Michael JS, Josh S, Marshall B. Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States (San Francisco, CA: Lawrence Berkeley National Laboratory, 2015. http://emp.lbl. gov/sites/all/files/lbnl-6941e.pdf.
7. Richard JC. Weather-Related Power Outages and Electric System Resiliency (Washington, DC: Congressional Research Service, 2012. https://fas.org/sgp/crs/misc/R42696.pdf.
8. Grid Modernization Laboratory Consortium. State Engagement in Electric Distribution System Planning. U.S. Department of Energy, 2017.
9. Billinton R and Allan R, Reliability evaluation of power systems. Springer Science & Business Media, 2013.

9. Mehkri S, Perez D, Najarro P, Tsapekos M, Bopanna KN. Effect of Lutein (Lute-gen®) on proliferation rate and telomere length in vitro and possible mechanism of action. Int J Biol Res. 2019;4(4):84-91.