RELIABILITY ANALYSIS OF POWER SYSTEM NETWORK: A CASE STUDY OF TRANSMISSION COMPANY OF NIGERIA, BENIN CITY.

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Abstract – The Nigerian Power System Network is presently characterized by poor reliability with respect to customer's uncertainty with respect to how long the electric power supplied can last before they are put on load-shedding or otherwise. Data was collated from the daily operational log books of five feeders emanating from the Transmission Company of Nigeria, Benin City, Nigeria. The reliability indices have been calculated and the results interpreted using a spreadsheet. A mathematical model has also been developed for the network using the curve fitting tool in the MATLAB (2013) environment and a corresponding Simulink model was eventually developed from the mathematical model. The results show that the priority feeder has the highest reliability of 97.8% while the feeders characterized with obsolete equipment has the least reliability of 78.4% The results further shows a deviation from the world and ASAI Reliability and Availability standard an indication that the feeders needs to be optimized for a better productivity.

Keywords: Reliability, Failure Rate, feeders, Nigeria

1. **INTRODUCTION** - 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 to meet customer expectations [1]. The poor reliability of electrical power supply in Nigeria has made it one of the best markets for generators dealers across the world and the overall effect of this anomaly is an increase in pollution, increase in noise level etc. So long as this persists, the developmental level of the country will continue to depreciate because the developed countries are already looking towards green energy. An average citizen of the country presently rely on their standby generator more than that of the appropriate authorities when it comes to doing crucial work and this can also be extended to various industries and health sector who would rather run their generators to avoid downtime in order to avoid a huge cost implication and prevent loss of life. Reliability of any system is the probability that the system will continue to perform a given function at any point in time. Power System Reliability PSR is the ability of the system to providing sustainable power to the customers at all time as this is the best indices for the measurement for sustainability [2]. Over the years the Power System Network in Nigeria PSNN has been characterized by poor reliability due to incessant power outages, failures, load shedding, faults, ageing equipment in the network etc and this have caused many businesses in the country to relocate to countries with a much better reliability and it is in this wise that customers depends on stand-alone generator as their primary source of power while the power from the appropriate authority is been used as a stand-by source. According to [3], based on historical perspective more attention has been placed on reliability analysis of power generation than any other arm of the sector. If this is true how, how come the electrical power generation in Nigeria is still less than its demand? It is with this fact that [4] encourages work on the prediction and enhancement of reliability in a power system network. An increase in population, as well as economic activities and growth rate in the country, leads to a corresponding increase in reliable energy demand [5] but how well can the appropriate authorities continue to improving on the reliability of the system in order to meet up with the demands for the product is another question begging for answers. The PSNN has eventually become so unreliable that it has eventually become a tool with which the politicians used in their electoral campaign to score political points [6] but they tend not to achieve results at the end of the day because of their inexperience on how the sector works. Furthermore [7] asserts that the political process in Nigeria is somewhat affecting the reliability of the PSNN because politicians with no competence in the field of electrical engineering has often times been appointed to head the sector. According to the [8], the poor reliability of PSNN has frustrated and force investors outside the shores of Nigeria to countries where power is readily available. It is in this view that [9] ask what should be done in order to improve on the reliability of the PSNN given the resource endowment, the political, economic, technological, environmental constraints in Nigeria? Power System Reliability studies is paramount because it attracts cost benefit[10], helps in

identifying weak link in the system as well as identifying possible remedial actions that can be used to improve on the system's reliability. The collective advantage of this is that once the reliability of the PSNN is improved then there will be a corresponding improvement in the socio-economic activities of the country as various businesses will have a data to plan with. The major aim of PSNN is supposedly to be its ability to provide electric power at all times with a reduce cost and as reliable as possible but with the present poor generation of power in Nigeria it is paramount to start developing an idea on how the future of the PSNN in order to know the arm of the sector that requires investment, [11]. This will aid in reducing service interruption hence improving system reliability based on the environmental condition [12]. Furthermore, an improvement in the maintenance technique can also influence the reliability of the PSNN if properly coordinated with the right strategy [13] and also reduce the cost of energy not supplied [14].This paper, therefore, presents the reliability analysis of Transmission Company of Nigeria, Benin City as well as identifying the weak feeders and also prioritizing maintenance actions with respect to the such feeders.

2. METHODOLOGY

Data collated from the log book of the transmission station has been analyzed using the load point Indices to calculate the reliability, availability as well as the failure rate and the results obtained is graphically interpreted using the Microsoft Excel as well as the MATLAB(2013).

Mean Time Between Failures (MTBF): This is the average intervals between successive failures in a system.

Mean Time To Failure (MTTF): This is a function of the non-repairable equipment in the system hence; it is the average interval before the first failure in the system is noticed.

Mean Time to Repair (MTTR): This is the average time required to repair a system and bring it back to its operational state.

$$Failure\ Rate\ \lambda = \frac{FO}{TOH-DT} \quad (1)$$

$$MTTR = \frac{DT}{NO} \quad (2)$$

$$MTTF = \frac{1}{\lambda} \quad (3)$$

$$MTBF = MTTR + MTTF \quad (4)$$

$$AVAILABILITY = \frac{MTBF}{MTBF+MTTR} \quad (5)$$

$$RELIABILITY = \frac{TOH-DT}{TOH} \quad (6)$$

Where FO = feeders outage, TOH=Total Operating Hours, DT = Downtime, NO = Number of Outage.

The reliability indices have been calculated using the equations [1-6]. The curve fitting tool in the matrix laboratory MATLAB (2013) is used in deriving the mathematical model for the reliability of the network. The mathematical model derived is used to develop a Simulink model for the reliability of the network using the Simulink library in the MATLAB (2013) environment.

The mathematical model for the reliability of the network is given as:

$$F(x,y) = a + b\sin(m\pi xy) + ce^{-}(wy)^2 \quad (7)$$

Where

a = 0.8554

b = 0.08113

c = 0.7537

m = 0.3804

w = 0.5678

$$F(x,y) = 0.855 + 0.8113\sin 68.472xy + 7537\, e^{-}0.3223y^2 \quad (8)$$

3. RESULTS

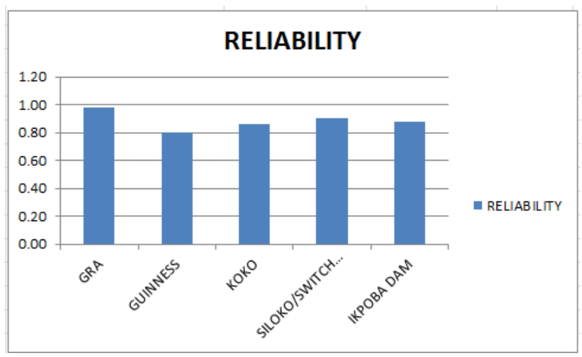

Figure 1: Feeders Reliability for 2011

Figure 2: Feeders Availability for 2011

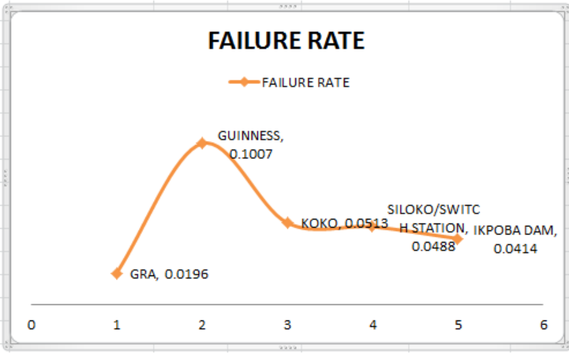

Figure 3: Feeders Failure Rate for 2011

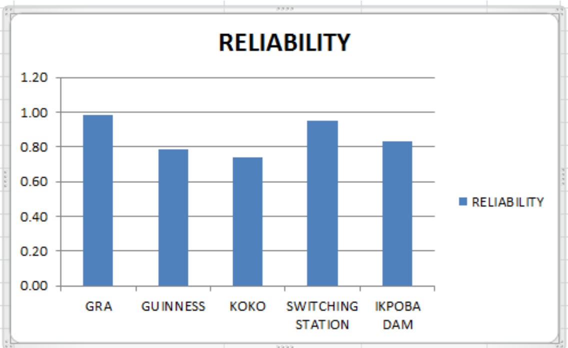

Figure 4: Feeders Reliability for 2012

Figure 5: Feeders Availability for 2012

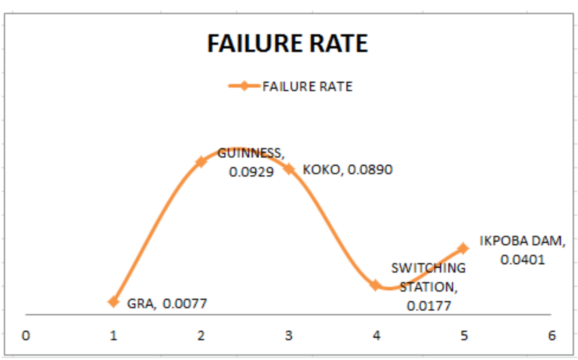

Figure 6: Feeders Failure Rate for 2012

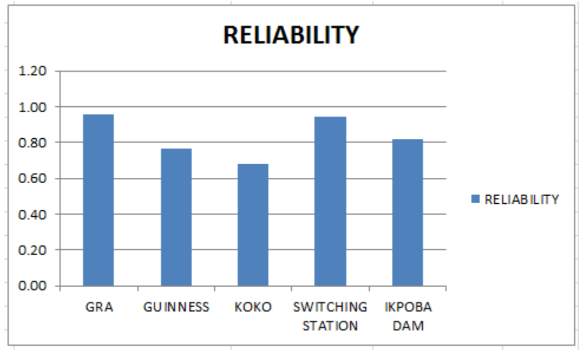

Figure 7: Feeders Reliability for 2013

Figure 8: Feeders Availability for 2013

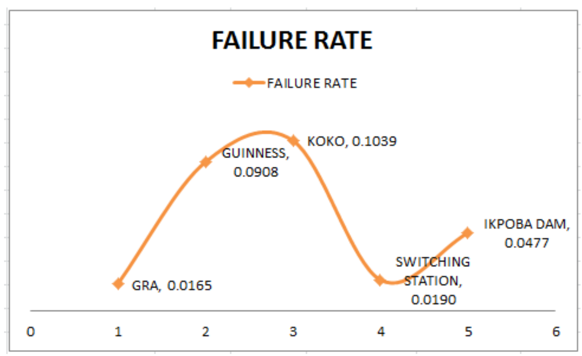

Figure 9: Feeders Failure Rate for 2013

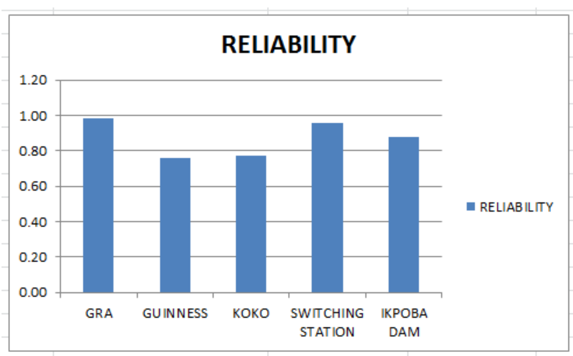

Figure 10: Feeders Reliability for 2014

Figure 11: Feeders Availability for 2014

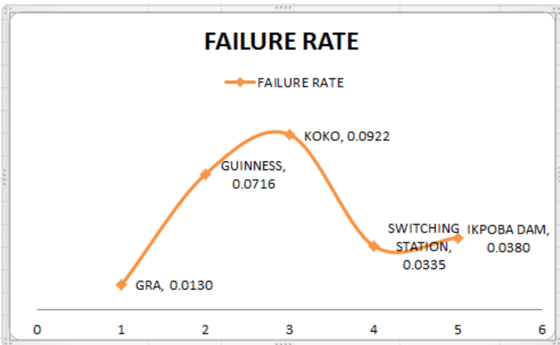

Figure 12: Feeders Failure Rate for 2014

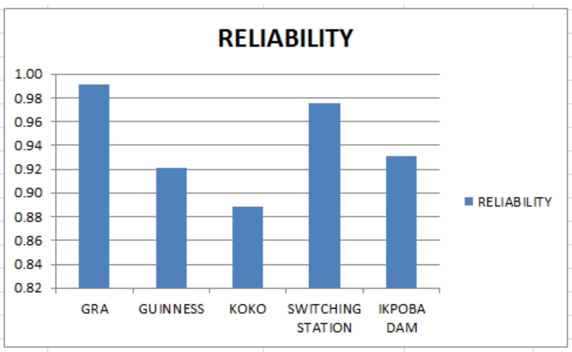

Figure 13: Feeders Reliability for 2015

Figure 14: Feeders Availability for 2015

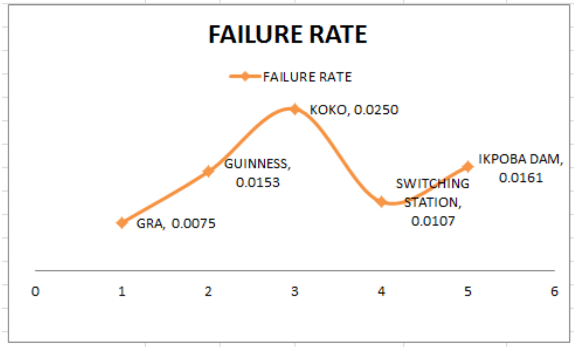

Figure 15: Feeders Availability for 2015

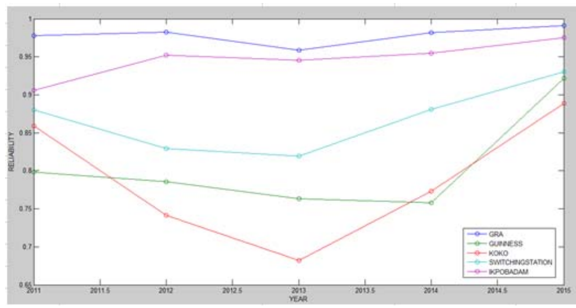

Figure 16: Feeders Reliability for 2011-2015

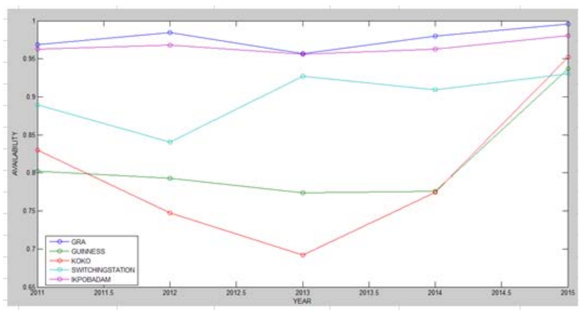

Figure 17: Feeders Availability for 2011-2015

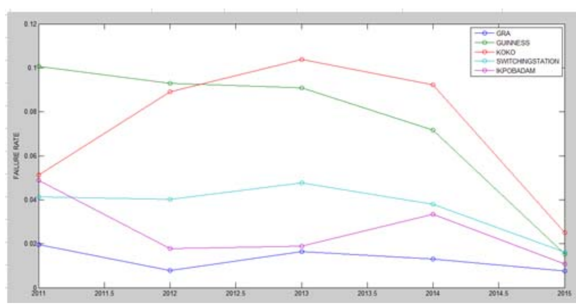

Figure 18: Feeders Failure Rate for 2011- 2015

4. DISCUSSION OF RESULTS

The reliability indices has been determined and the results interpreted graphically using the spreadsheet and MATLAB 2013. From the resultssummary in Table 6, it was discovered that the within the period of investigation, the GRA feeder is the most reliable of all the feeders with 97.8% while the KOKO feeder is the weakest of all the feeder wit a reliability of 78.4%. The reason why the GRA feeder is more reliable than other feeders may be attributed to the fact that it is a priority feeder that feeds the Government Residential Areas hence, as can be seen from fig 18 it experiences a decreasing failure rate initially and later a failure rate that is almost constant as this is an indication that only random external event could lead to failure in the feeder though, more work still need to be done in order to improve on the reliability of the feeder for it to meet the reliability world standard of 99%[13] and also the availability ASAI standard of 0.99989 [15]. Furthermore, Koko feeder experiences a massive increasing FR initially and this is a pointer to the fact that the failures may have arises as a result of aging equipment in the feeder, however, a slow decreasing FR was later observed in the feeder. The Guinness feeder to experiences a decreasing FR and this may not be unconnected to the fact that it is an industrial feeder and as such needed proper maintenance for good service reliability to the industries because they consume more power and are also ready to pay for the power consumed. Ikpoba Dam feeder experiences a constant FR at some interval of time but as parts begins to fail, the FR increases with time and when defective item are weeded out early enough from the system, a decreasing FR is observed. The Siloko feeder now known as Switching Station experiences a FR that took the shape of a bathtub curve.

Table 1: Reliability Indices for 2011

FEBRUARY-DECEMBER, 2011							
FEEDER	OUTAGE	DOWNTIME	MTBF	MTTR	AVAILABILITY	RELIABILITY	FAILURE RATE
GRA	154	174.8	1667.150	22.655	0.9864	0.9782	0.0196
GUINNESS	644	1618.6	140.303	27.748	0.8022	0.7981	0.1007
KOKO	353	1129.3	173.417	24.731	0.8574	0.8591	0.0513
SILOKO/SWITCH STATION	354	755.7	576.190	21.612	0.9625	0.9057	0.0488
IKPOBA DAM	292	960.9	352.766	39.046	0.8893	0.8801	0.0414

Table 2: Reliability Indices 2012

JANUARY - DECEMBER, 2012							
FEEDER	OUTAGE	DOWNTIME	MTBF	MTTR	AVAILABILITY	RELIABILITY	FAILURE RATE
GRA	66	153.7	2364.674	36.684	0.9845	0.9825	0.0077
GUINNESS	639	1878.6	176.673	36.605	0.7928	0.7855	0.0929
KOKO	578	2264.8	196.646	49.727	0.7471	0.7415	0.0890
SWITCHING STATI	148	417.8	1128.186	36.180	0.9679	0.9523	0.0177
IKPOBA DAM	291	1498	490.761	78.361	0.8403	0.8290	0.0401

Table 3: Reliability Indices 2013

JANUARY - DECEMBER, 2013							
FEEDER	OUTAGE	DOWNTIME	MTBF	MTTR	AVAILABILITY	RELIABILITY	FAILURE RATE
GRA	139	360.5	831.524	36.735	0.9558	0.9588	0.0165
GUINNESS	607	2074.1	181.854	41.179	0.7736	0.7632	0.0908
KOKO	621	2784.5	174.247	53.633	0.6922	0.6821	0.1039
SWITCHING ST	157	476.3	1184.092	51.873	0.9562	0.9456	0.0190
IKPOBA DAM	342	1583.4	319.930	55.313	0.8271	0.8192	0.0477

Table 4: Reliability Indices 2014

JANUARY - DECEMBER, 2014							
FEEDER	OUTAGE	DOWNTIME	MTBF	MTTR	AVAILABILITY	RELIABILITY	FAILURE RATE
GRA	112	159.1	937.229	18.170	0.9806	0.9818	0.0130
GUINNESS	475	2122.2	242.107	54.339	0.7756	0.7577	0.0716
KOKO	625	1984.9	170.926	38.531	0.7746	0.7734	0.0922
SWITCHING STA	280	398	514.290	19.227	0.9626	0.9546	0.0335
IKPOBA DAM	293	1045.8	575.733	52.288	0.9092	0.8806	0.0380

Table 5: Reliability Indices 2015

JANUARY -OCTOBER, 2015							
FEEDER	OUTAGE	DOWNTIME	MTBF	MTTR	AVAILABILITY	RELIABILITY	FAILURE RATE
GRA	54	63.7	2880.400	11.308	0.9961	0.9913	0.0075
GUINNESS	103	573	1060.565	66.748	0.9371	0.9215	0.0153
KOKO	162	812	1248.365	60.045	0.9519	0.8887	0.0250
SWITCHING STA	76	179	3763.436	73.065	0.9806	0.9755	0.0107
IKPOBA DAM	109	506.7	3018.882	107.289	0.9645	0.9306	0.0161

Table 6: Reliability Indices 2011- 2015

RELIABILITY FOR 2011-2015							
FEEDER	OUTAGES	DOWNTIME	MTBF	MTTR	AVAILABILITY	RELIABILITY	FAILURE RATE
GRA	525	911.8000	8937.0440	131.4592	0.9853	0.9781	0.0129
GUINNESS	2468	8266.5000	1801.5020	226.6192	0.8742	0.8012	0.0741
KOKO	2339	8975.5000	1963.6011	231.4747	0.8821	0.7842	0.0717
IKPOBA DAM	1327	5594.8000	4758.0713	332.2973	0.9302	0.8655	0.0369
SWITCHING STATION	1015	2226.8000	7166.1929	201.9567	0.9718	0.9465	0.0258

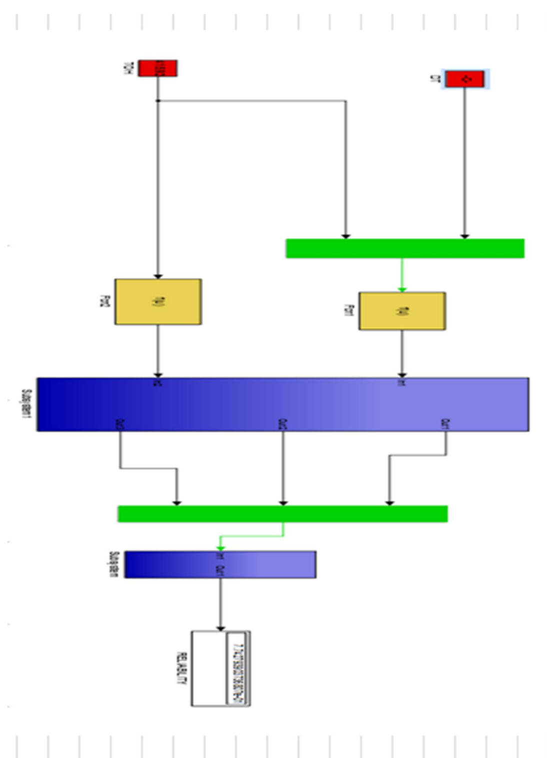

Figure 19 Simulink Model for Feeders Reliability

5. CONCLUSION

This paper has carried out a critical study on the reliability of the network under investigation and the feeder tripping profile has been interpreted graphically. A mathematical model for the reliability of the network has been derived and used to develop a Simulink model for the network.The first part of the paper gives a brief introduction of the topic while the second part gives the methodology, the third and fourth part gives the result as well as the interpretation while the fifth and sixth part of the study gives the conclusion and recommendation respectively.

6. RECOMMENDATIONS

1. Customers are encouraged to pay their utility bills on time so that funds will be available to carry out maintenance action on the system.
2. Koko feeder needs a total overhaul if the reliability must be improved on.
3. The method presently adopted by the appropriate authority in the maintenance of especially the GRA feeder should also be applicable to all other feeders in the station.

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BIOGRAPHIES

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