Reliability Assessment of 33kV Kaduna Electricity Distribution Feeders, Northern Region, Nigeria

Y. Jibril and K.R. Ekundayo

Abstract—**The paper assesses the reliability performance of the 33kV Kaduna Electricity Distribution Feeders, Northern Region, Nigeria. The daily outages data of the feeders for the period of 16 months (January, 2011 to December, 2012) were collected and used to compute the monthly reliability indices for the feeders. Mogadishu and Rural Feeders recorded the highest failure rates in November 2011 when compared to other feeders, due to their frequent outage occurrence which brings about the highest loss of energy and monetary worth of loss to the PHCN management. The high forced outages recorded are indications of unreliable performance. Monthly reliability indices tables developed shows the Actual Energy Loss, Forced outage hour (FOH), failure rate, Mean time between failures (MTBF), Mean time to repair (MTTR), and the availability. These results were analysed, discussed, conclusions drawn and recommendations proposed to improve the reliability performance of the feeders studied.**

Index Terms — **Availability, Distribution system, Fault, Outage, Reliability**

I. Introduction

THE improvement in the operational performance of a nation's electric supply is vital for the economic and social developments. Efforts have been made over the years to improve the performance of nation's power sector (PHCN), since electricity is used for twenty four hours of the day, it has come to play an important role in all aspect of our industrial growth and as well as our economic growth and stability. Therefore the high rate of power demand requires a stable and continuous power supply to consumers, the study and analysis of outages of the 33kV distribution feeder network in a power system is necessary for improved performance. Reliability analysis techniques have been gradually accepted as standard tools for the planning, design, operation and maintenance of electric power system. The function of an electric power system is to provide electricity to its customers efficiently and with a reasonable assurance of continuity and quality *(Adegboye and Ekundayo, 2012).*

This paper assesses the operation of 33kV feeders' distribution network in Kaduna Town Mando, Northern region, Nigeria to contribution to the efforts already embarked upon by the nation's electric Power Sector toward integration of the performance of the national electric power transmission system utilities, to minimized its operational cost as well as improving the system reliability.

A modern power system is complex, highly integrated and very large. Fortunately, the system can be divided into appropriately subsystems or functional areas that can be analyzed separately *(Gupta and Tewari, 2009a, b; Kuo and Zuo, 2003; Lakhoua, 2009*). These functional areas are generation, transmission and distribution. Tree-faults is described as one of the major causes of faults in power systems. *(Lexu et al, and Uhunmwangho et al, (2009)* used a Load forest and analyse the existing injection and distribution substation based on engineering design to provide room for expansion and estimation of cost to carry out rehabilitation and replacement of defective equipment were some of the measures use to solve problems of broken poles, tie straps, cross arms, insulators and over loaded or leaking transformers in the electrical distribution system.

Shalini *et al, (2*005) developed an adaptive-fuzzy model to predict the failure rate of overhead distribution feeders based on factors such as tree density, tree trimming, lightning intensity and wind index. A gradient descent method was used to train the fuzzy model. They observed the root mean square error (RMSE) and absolute average error (AAE) to check performance of the model and discussed the variations of failure rate to various factors obtained from the sensitivity analysis used.

The Mitigation Techniques like electric or non electric methods could be used to improve the reliability in the system. Modern automation technologies can reduce contingency margins, improve utilization and economy of operation and even provide improved scheduling and effectiveness of maintenance and service. However, they must be applied well, with the technologies selected to be compatible with systems need and targeted effectively. On the other hand, non-electric method such as vegetation management, system improvements, crew placement and management, maintenance practices plays an important role in improving reliability in the system.

It was discovered that the peak frequent and delay forced outages during the rainy season, and the harmattan season. The causes are attributed to heavy winds, thunder strike, and other reasons are environmental disturbance such as vehicular accident, animal cause outages, and simultaneous use of weather sensitive devices.

Min Gui Pahwa *et al, (2009)* presents a methodology for yearend analysis of animal-caused outages. They used

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models to estimate weekly animal-caused outages in overhead distribution systems using combination of wavelet transform techniques and neural networks. Results obtained for four districts in Kansas of different sizes are compared with observed outages to evaluate performance of three different models for estimating these outages. Adegboye B.A and E. Dawal (2011) carried out a study and analysis of outages on the 33kV primary distribution feeders in Zaria. It was found out that outage rates were higher in the rainy seasons than in the dry seasons due to failures associated with damages on the transmission line equipment during heavy rain falls. Similar observations were made when the study was extended to the 11kV primary distribution feeders.

II. The Kaduna Electricity Distribution Network

The 330/132/33KV transmission sub-station at the Mando transmission centre of the Power Holding Company of Nigeria (PHCN) in Kaduna is fed by 330kV double circuit transmission lines from Shiroro Hydro-power generation station in Niger State. It controls High voltage at 330kV, 132kV, 33kV, 11kV. The RCC Mando Transmission Station (T/S) is separated into two parts, namely, the primary subsystem and the secondary subsystem. The Kaduna Town distribution system is one of the three outgoing secondary of 132KV/33kV Transmission network from Kaduna RCC Transmission Station, Mando switchyard. The primary distribution subsystem consists generally of a 330/132kV transmission line carrying the three-phase voltage form the switchyard within Mando T/S to the substation located near the area served.

And the secondary subsystem: 132kV line 1 at 132/33kV and 132kV line 2 at 132/11kV feeders. The Kaduna Town distribution network consists of 132/33kV and 132/11kV substation having 1 x 60MVA - 132/33kV transformer, 3 x 30MVA - 132/33kV transformers, and 1 x 15MVA 132/11kV transformer. On the 132kV line 1 are five feeders and a bus section which supply the following major areas 33kV Arewa feeder: NORTEX, Kakuri, Barnawa, and Nasarawa; 33kV Rural feeder: Gwagwada, Kachia, Angwan- Fama, SPARE, Narayi and Angwan-Boro; 33kV PAN feeder: Gonin-Gora, NOCACO, Arewa Bottlers, and Coca-Cola; 33kV Mogadishu feeder: Leventis, Polytechnic, Tudun-wada and Government house; and 33kV UNTL Company feeder. Then the 132kV Line 2 supply power to Constitution road, Junction road and Teaching Hospital.

Outage and its Classification: An outage describes the state of a component when it is not available to perform its intended function due to some event directly associated with that component *(Endreyi, 1978).* Outages are generally classified as forced or scheduled depending on whether it results from tripping of the feeder or it is deliberately taken out of service.

Transient or Temporary Forced Outage: These are outages for which the causes are not permanent. An example is a branch of tree touching the line as a result of breeze (windy air). The outage could be for less than 80 minutes. For such outages, the circuit breakers remain closed when relays are reset and lines reclosed.

Permanent Outage: This is an outage which lasts for more than 80 minutes before restoration. For such outages the circuit breakers are open during the period of outage.

It should be noted that if a circuit is interrupted more than once in a single day, mostly during peak load periods, only the interruption with the longest outage time is used for classification. This research work is concerned with the outages on the 33kV feeders of the Kaduna Town distribution system. The outage data collected from the Kaduna Electricity Distribution Company, PHCN Transmission Station, Mando, Nigeria comprises of information on each daily failure event between January 2011 and July 2012.

III. Methodology

In other assess the performance of system, the various reliability indices were computed using:

i. $\text{Availability A} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$ (1.0)

ii. $\text{Failur Rate } (\lambda) = \frac{1}{\text{MTTF}}$ (2.0)

iii. Mean Time to failure (or Mean Up Time)
$\text{MTTF} = \frac{\text{SH}}{\text{NF}}$ (3.0)

iv. Mean Tine to Repair (or Mean Down Time)
$\text{MTTR} = \frac{\text{FOR}}{\text{NF}}$ (4.0)

v. Mean Time Between Failure (MTBF)
$\text{MTTF} + \text{MTTR}$ (5.0)

vi. $\text{Service Hours(SH)} = \text{H} - \text{OH}$ (6.0)

vii. $\text{Repair rate}(\mu) = \frac{1}{\text{MTTR}}$ (7.0)

viii. $\text{Uavailability } (\bar{\text{A}}) = \frac{\lambda}{\lambda + \mu}$ (8.0)

ix. $\text{Operation Hours (OH)} = \text{FOR} + \text{SH}$ (9.0)

x. $\text{Hours (H)} = \text{Number of days} \times 24 \text{ hours}$ (10.0)

Where; NF is the number of times a unit experiences forced outage; OH, is the time in hours during which a unit or major equipment was not available for use; FOH is the time in hours during which a unit or major equipment was unavailable or experience forced outage during Operation due to fault; SOH, is time in hours during which a unit or major equipment was deliberately taken out of service. SH, is total number of hour the unit was actually operated with breakers closed to the station; H, is total Period:
(usually one year = 8760hour) and λ is failure rate.

IV. Discussion of Results

Reliability assessment was made based on the extraction of the data from the daily tripping report of five (5) 33kV feeders supplying Kaduna Town. The monthly reliability indices generated from the data collected at the station between January 2011 to July 2012 was computed using reliability equations above. The outage data for February 2011 and September, 2012 were not available at the station at the time of research. However, Arewa and U.N.T.L feeders have no records outages for the Months (April and October, 2011) with no energy loss, hence these feeder are

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fully available, functional and reliable during the period.

From the data, it can be shown that the closer the value of MTTF is to MTBF, the longer the service hours and the shorter the outage duration. Therefore by minimizing the value of MTTR, the service hour can be increased thereby increasing the overall system performance. This simply means that the feeder with shortest MTTR and longest MTTF has the highest availability and is the most reliable as shown in Fig. 4. From Fig. 1 and Fig. 3, it was observed that 33kV Mongadishu feeder, and Rural feeder have the highest failure rate due to their frequent outages occurrences. These indicate that the outage of those feeders brings about the highest loss of energy, as well as the highest monetary worth of loss to the PHCN management compared to the other feeders.

On the other hand 33kV Arewa feeder, PAN feeder and U.N.T.L feeder respectively have the least outages occurrence. This implies that a customer served by these feeders experience least interruption of power supply for that period of study and justifies the highest amount of preventives maintenance as shown in Fig. 2 below:

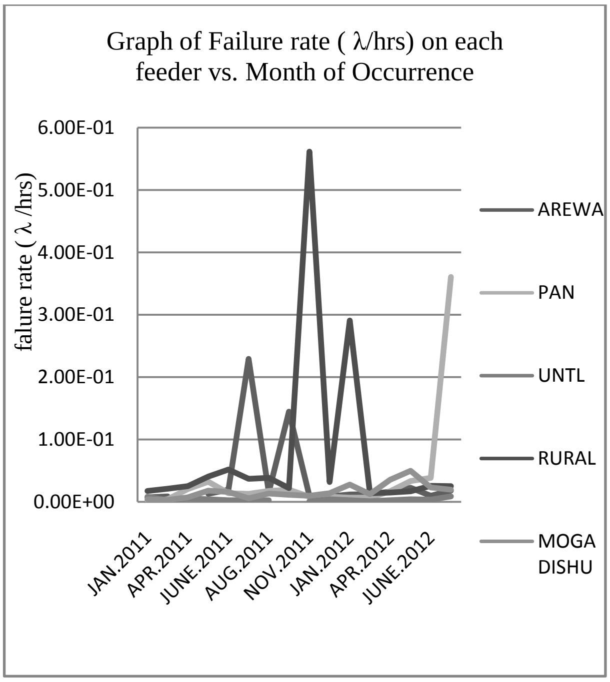

Fig 1: Failure rates against the monthly records of outages occurrence

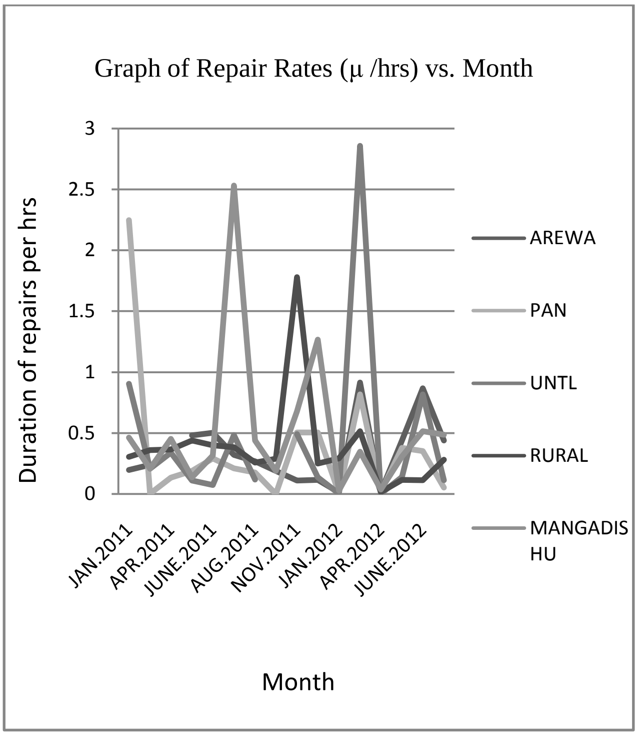

Fig 2: Graph of Repair rates against the monthly outages Occurrence

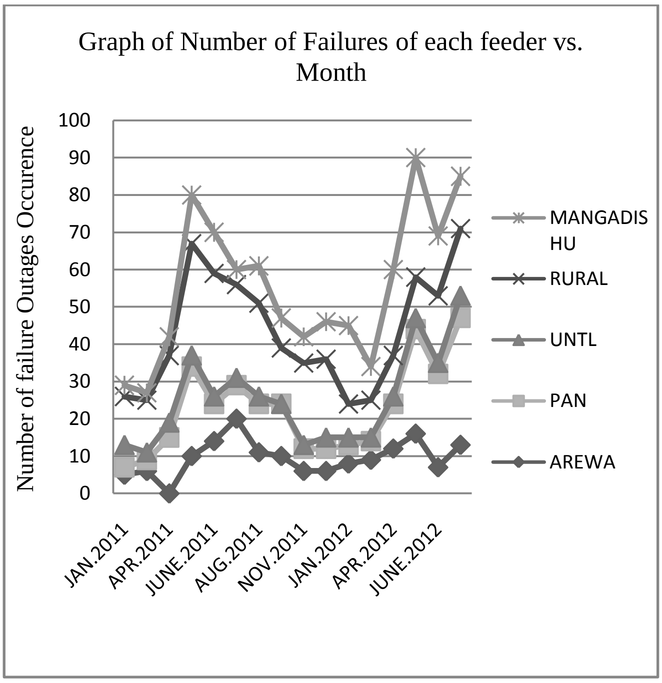

Fig 3: Graph of number of failures of each feeder against Month

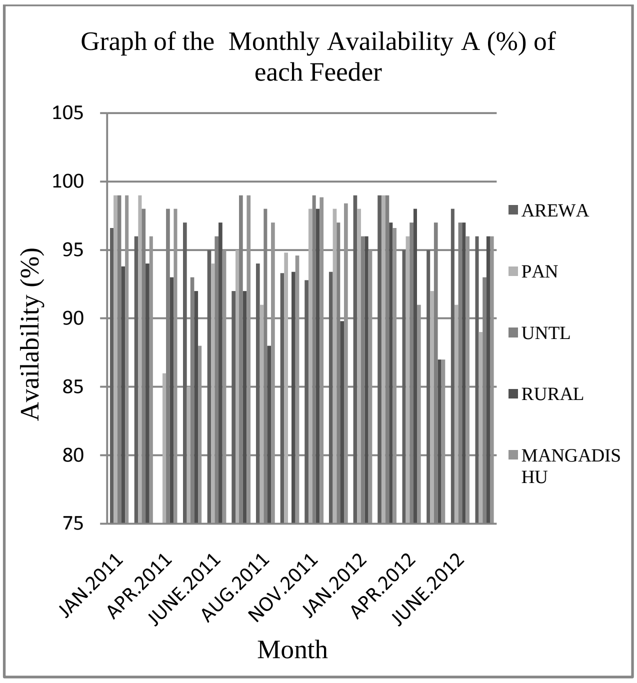

Fig 4: Graph of Monthly Availability A (%) of each feeders

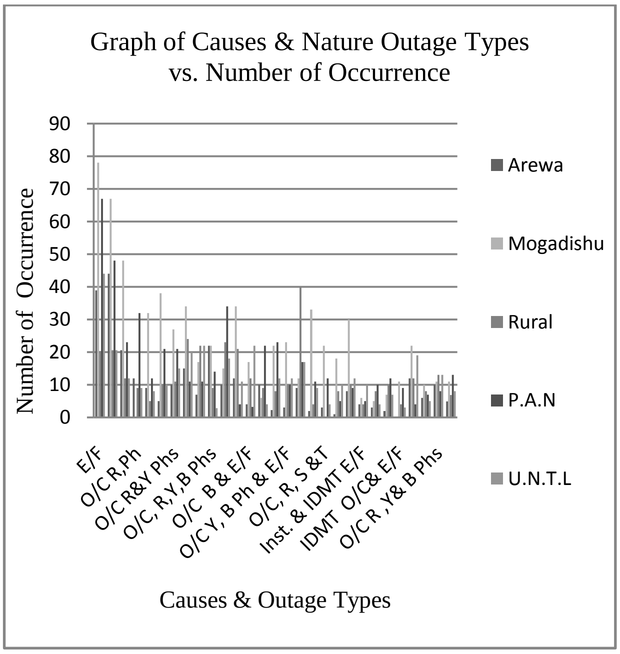

Fig 5: Graph Causes & nature of Outages Types vs. No of Occurrences

Mogadishu feeder, Rural feeder and P.A.N feeder are considered to be the problematic feeders in terms of frequent forced outages. The enormous forced outages could be attributed to damages to the overhead lines due to heavy winds, thunder strikes, storm and other disturbances associated with rain. Such damages include breaking of the 33kV cross arm; shattering of the lightning arrestor; cracking or shattering of insulators; Explosion of the ring mains units; Bending or falling of trees. This brings about over-current, which results to relay operation to trip the circuit breaker, thereby causing interruption of power supply ramped between April – July 2011, and March – May, 2012 as shown on Fig. 3. Table 1.0, shows the summary of the average availability value of the five feeders for the whole duration (16 Months) in tabulated below:

TABLE I
AVERAGE AVAILABILITY OF THE FEEDERS

Summary of Cumulative Average of the Availability of the Feeders	
Name of Feeder	Availability, A (%)
Arewa	95.47
P.A.N	94.05
U.N.T.L	97.07
Rural	93.88
Mogadishu	95.24

The U.N.T.L feeder has the highest overall availability of 97.07% and Rural feeder has the lowest value of availability of 93.88%. However, feeder with the highest value has not met the 0.99989 expected values in recent time as suggested by IEEE standard of ASAI, though all the five feeders have the acceptable level of reliability.

V. Conclusion

The outages on the 33kV feeders of the Kaduna Electricity distribution network have been studied for 16 Months based on daily outage data collected from the PHCN transmission sub-station in RCC Mando, Kaduna.

Based on the result obtained from the data analysis represented with the graphs, it can be seen that Mogadishu feeder experienced the highest number of failures even though it is not the least available which means that outages are due to temporary outages or transient fault and the duration is usually short. Therefore the feeder should be look upon to, so that any weak equipment should be replaced, wooden poles should be replaced with concrete poles.

Rural feeder and PAN feeder also has a very high number of failures in the month of April, May, and July due to over current and earth fault. To prevent such, measure such as cutting down of braches of tree near the overhead lines should be employed. Failures on U.N.T.L feeder is due to sudden switching of heavy equipment used by the company. In conclusion the record of the availabilities of all feeders recorded from the result of the analysis of the data is lower than the IEEE standard of the ASAI which is 0.99989.

VI. Recommendations

1) More investment in human and financial resources is needed to maintain the above conditions. If an efficient and reliable supply is made with an effective billing system, the revenue generated could be easily channelled towards achieving these conditions.

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2) Feeders should be constructed in pairs so that in the event of a failure of one, the standby can be switched on to at various substations;

3) The number of distribution substation should be increased to reduce the incidence of overloading the transformer.

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