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Pre-Privitisation Network Reliability Assessment in Electric Power Distribution Feeders in Akure, Nigeria

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Abstract-The reliability Studies of Akure Feeders in Ondo State was carried out to ascertain the state of health of the network before the power system was unbundled to private operators. This study also aimed at providing a tool for determining the performance of the new operators in post-privatization era. Relevant data on the 33/11kV injection station and five 11kV feeders were collected over the period of the five years preceding privatization. These were analyzed to determine load loss, downtime and revenue loss for each feeder. The reliability of each feeder with the economic impact was also determined and used to assess the overall reliability of the network. The result shows that the prevalent of faults on the feeders is associated with long span of Oyemekun and Ondo feeders mostly vulnerable. It was also observed that over N5 Billion was lost within the period of study to faults. The study shows that the performance of the network deteriorates gradually from 2008 with 48.85% to 11.7% in 2012 and the overall performance over the period stands at 12.13%. Since this was linked to irregular expansion of the network in the city, the study recommends the introduction of an additional 33/11 kV injection station to reduce the type of faults associated with the feeder length.

Keywords- *Availability, Downtime, Faults, Feeders, Power Loss, Reliability, Revenue*

I. Introduction

The history of electricity in Nigeria dates back to 1896 when two 30kVA generators were installed in Lagos which was later extended to some other parts of the city. In 1946, the Nigerian Government Electricity Undertaking (NGEU) was established under the public works department (PWD) to handle electricity supply to Lagos environs [1]. Alongside with NGEU, there were other electricity undertakings owned by the local Authorities and private organizations. The need to co-ordinate various electricity supply across the country and to facilitate even development culminated in the establishment of the Electricity Corporation of Nigeria (ECN) in 1950. In order to meet the subsequent growth in demand for electricity, other government bodies like Nigeria Supply Company (NESCO) in Jos and African Timber and Plywood Company in Sapele co-existed with the ECN. Further increase in electricity demand, which rose to 39MW in Lagos alone by October 1960 [1], was met by Ijora power station with a total output capacity of 45MW. Further development in electricity supply in the country resulted in the construction of the first 132kV transmission line that linked Lagos with Ibadan through Shagamu and was commissioned in June 1961. Niger Dams Authority (NDA) came into existence in 1962 to harness the River Niger and others for the purpose of hydroelectric power generation. The extension of the first 132kV line was to Oshogbo, Benin and Ugheli. The extension was referred to as the western system and its equivalent in the northern part of the country was termed K-Z-K system, which linked Kaduna and Kano via Zaria. In February 1969, the impact of the NDA was felt across the country when Kainji hydroelectric dam was commissioned with an installed capacity of 320MW [1]. The commissioning gave rise to the first Kainji-Lagos 330kV transmission line that was put into operation in June 1969. To ensure effective co-ordination, the NDA and the ECN were merged together in 1973 to form the defunct National Electric Power Authority (NEPA). Later on in 2002, NEPA was restructured and renamed Power Holding Company of Nigeria (PHCN) for better performance [1]. However, the operation of the system did not improve as electricity supply in Nigeria was riddled with a lot of problems ranging from inadequacy of supply to meet the rising demand and the attitude of the government to power issues. The economic growth and development of a country depends heavily on the reliability and quality of the electric power supply [2]. The last decade in Nigeria witnessed massive investment in increasing the generation capacity and expanding the transmission lines as shown in Figure 1. However, despite the important function of Electric power distribution system in the delivery of electricity, the system have generally grown in an unplanned manner resulting in high technical and commercial losses in addition to poor quality of power [3]. According to [4], the Nigerian electric power distribution system (EPDS) as a developing one is horizontally characterized by very long radial circuits, under sized distribution conductors and numerous other factors that affect reliability. The power distribution network is characterized with a number of distribution substations located over a vast geographical area which is prone to faults occasioned by wind storms, lightning, rain, insulation breakdown, overloading and short circuits. According to [4] distribution lines experience faults more often than the faults experienced by other power system facilities [4]**.** The need to improve the operational efficiency leads to the privatization of the Power Infrastructure in 2013. However, this was not until the state of health of the network was determined. This research work is based on assessing the performance of Electric Power Distribution Network in the selected area over a period of five years preceding the privatization. This was done to determine the state of the Network and also to providing the regulatory agency a platform to evaluate the performance of the new operators in post privatization era.

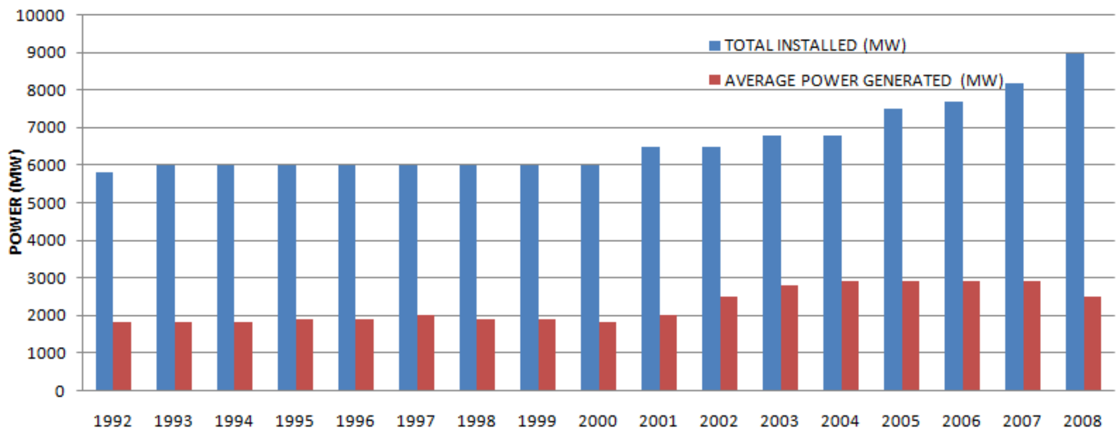

Figure 1. Average Power Generation against Total Installed Capacity

A. *Distribution System Faults*

Distribution networks of an electric power system link bulk sources of energy to customers' facilities. Distribution lines are usually operated in radial mode with loads tapped along the lines; which could be single or three-phase taps. The substation transformer steps the voltage down to 0.415 kV. It is estimated that 80% of all interruptions occur due to failures in distribution systems [5, 6, 7]. A fault condition is a sudden abnormal alteration to the normal circuit arrangement [7] that results in energy being dissipated in manner other than the serving of the intended load [9]. The circuit quantities, current and voltage, will alter, and the circuit will pass through a transient state to a steady state [6]. The different types of faults that occur in a network can be classified in three major groups [3, 5]: (a) short circuit faults; (b) open circuited faults and (c) simultaneous faults. The faults have different possible origin which includes electric, climatologic and human activity or error. Faults may be as a result of normal voltage breakdown due to deteriorating or ageing of Insulation damages caused by unpredictable happenings such as heavy winds, tree falling across lines, vehicles colliding with towers or poles, birds shorting out lines, line breaks etc. or abnormal voltage breakdown which may occur as a result of switching surges or lightning strokes. The consequence of this is interruption of supply to consumers. The reliability of supply is governed by the frequency and duration of interruption to supply and the number of consumers affected. According to David (1990) reliability is the probability that a system or equipment will function as expected under a stated condition. Reliability evaluation is an important and an integral feature of planning and design and operation of all engineering system. The usefulness of a system is determined by steady availability and frequency of failures. Understanding the reliability parameters will be useful in reliability evaluation. These include Failure rates (λ), Mean Time between Failures (MTBF), Mean Time to Repair (MTTR), Availability (A). These are expressed by the following equations:

$$\lambda = \frac{Number\ of\ failed\ unit}{Number\ of\ units\ Tested} \text{ x } 100\% \quad (1)$$

$$= \frac{Number\ of\ Times\ that\ failure\ occured}{Number\ of\ Unit{-}Hours\ of\ operation} \quad (2)$$

$$MTBF = \frac{Total\ System\ operating\ Hours}{Number\ of\ Failures} \quad (3)$$

$$MTBF = \frac{1}{\lambda} \quad (4)$$

$$A = \frac{MTBF - MTTR}{MTBF} \quad (5)$$

II. DATA COLLECTION

A compressive study of 11 kV Feeders in Akure Electric Power Distribution Network was carried out. The scope of this study covers Akure Township network which consists of 33/11 kV injection substation with a 2X 15MVA Transformers and five 11kV feeders namely:

(a) Oyemekun feeder

(b) Oke-Eda feeder

(c) Ilesha road feeder

(d) Isikan feeder

(e) Ondo road feeder

The load capacity of each feeder is shown in Table 1. Single line diagram showing the feeders are drawn and represented as shown in Figure 2**.**

Daily faults log of the Utility provider - PHCN was made available. The data for the period under consideration were extracted. The load loss for each feeder was determined and represented by Figures 3, 4, 5, 6 and 7. Similarly the down time for ach feeder over a period of five years was determined and represented by Figures 8, 9, 10, 11 and 12.

TABLE I. 11KV FEEDERS WITH PEAK LOADS (PHCN 2011)

Feeders	Oke-eda	Oyemekun Road	Ondo Road	Isikan	Ilesha Road	Alagbaka	Ijapo	Oba-ile
Peak Load (MW)	5.8	5.7	6.3	4.8	6.4	6.2	5.4	1.5

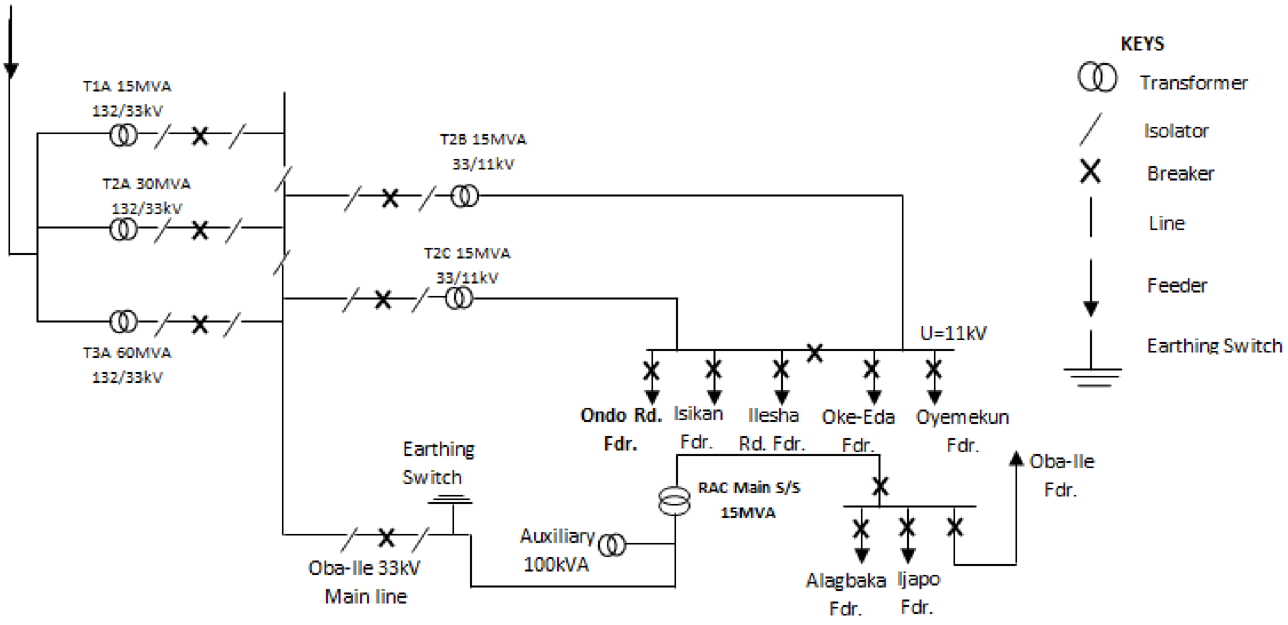

Figure 2. Schematic diagram showing 132/33/11kV network in Akure District

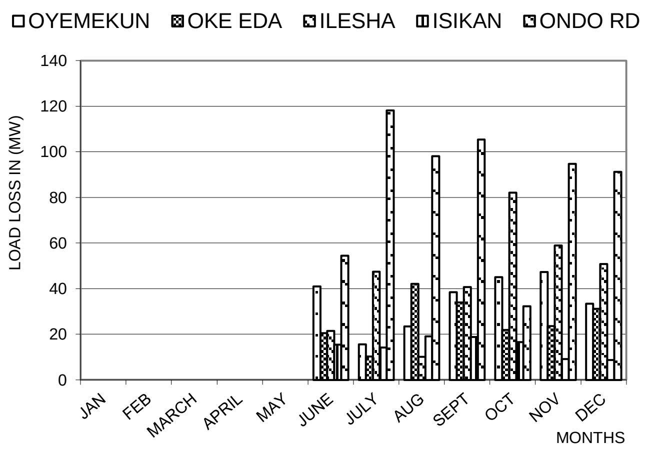

Figure 3. Cumulative Feeder loss for 2007

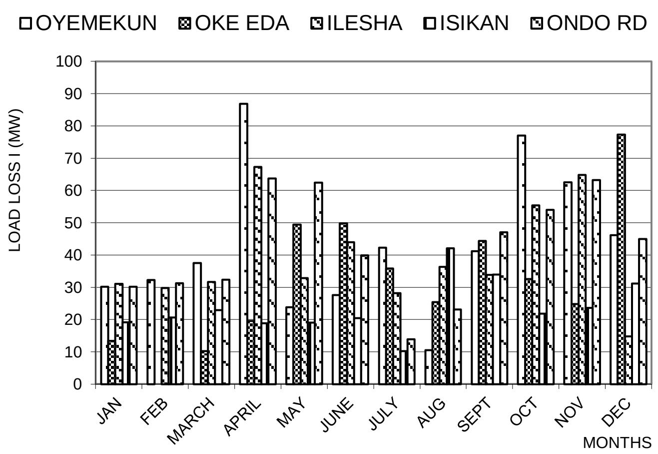

Figure 4. Cumulative feeders Loss for 2008

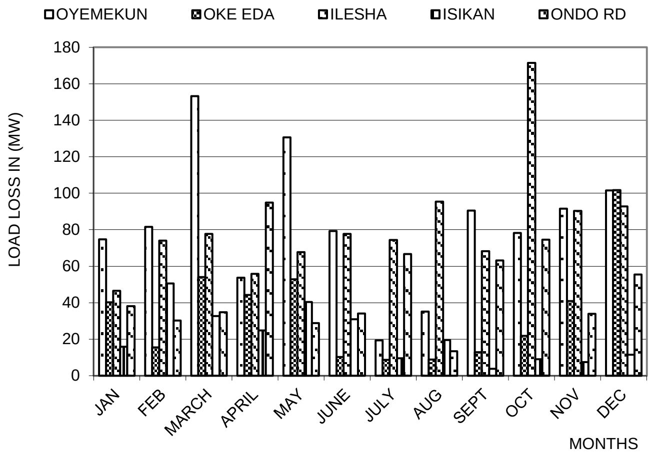

Figure 5. Cumulative Feeder Loss for 2009

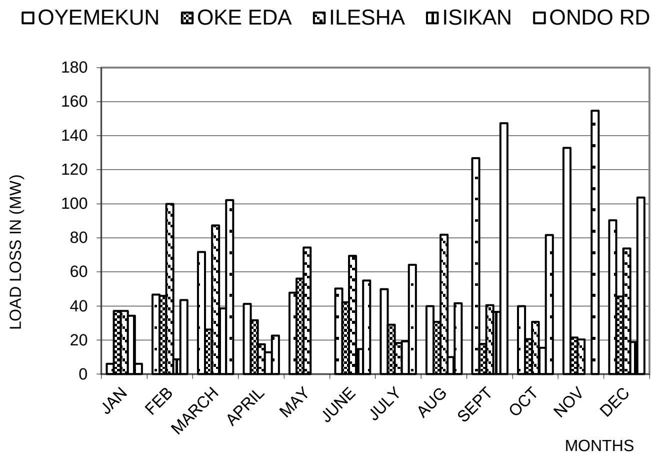

Figure 6. Cumulative Feeder Loss for 2010

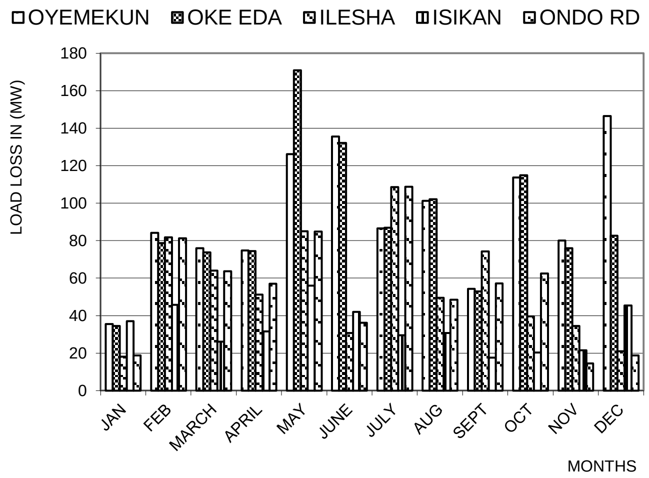

Figure 7. Cumulative Feeder Loss for 2011

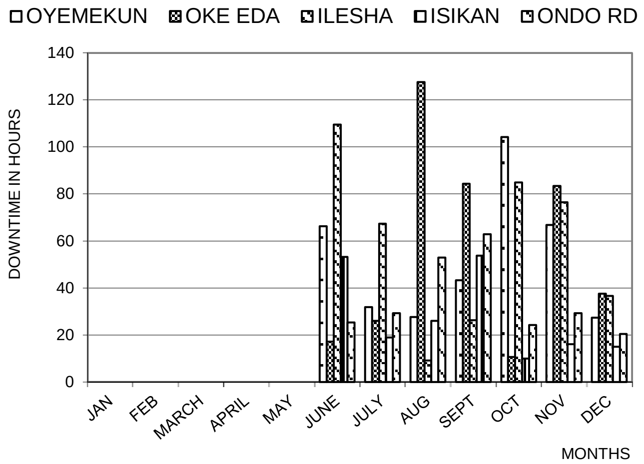

Figure 8. Feeders' Downtime for 2007

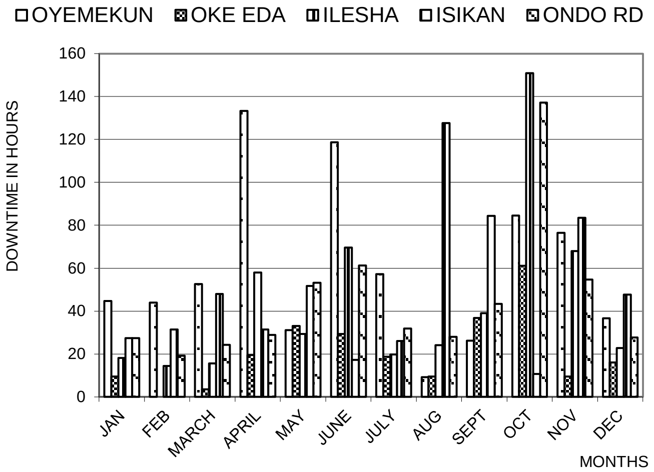

Figure 9. Feeders' Downtime for 2008

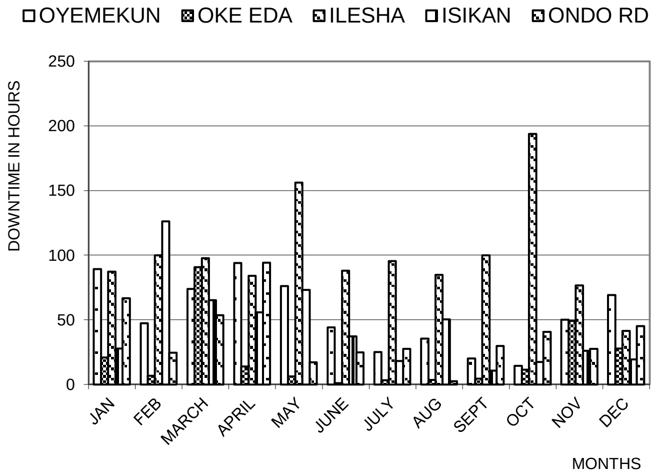

Figure 10. Feeders' Downtime for 2009

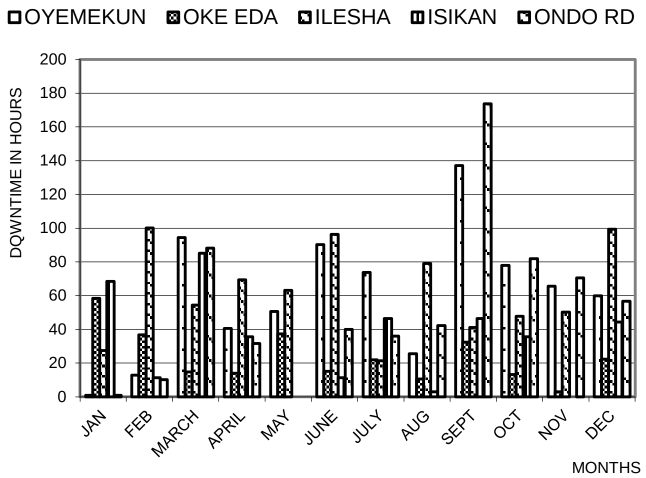

Figure 11. Feeders Downtime for 2010

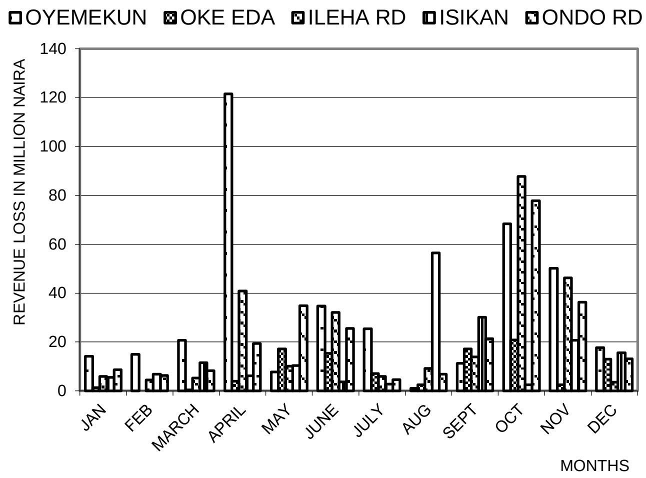

Figure 14. Feeders' Revenue loss for 2008

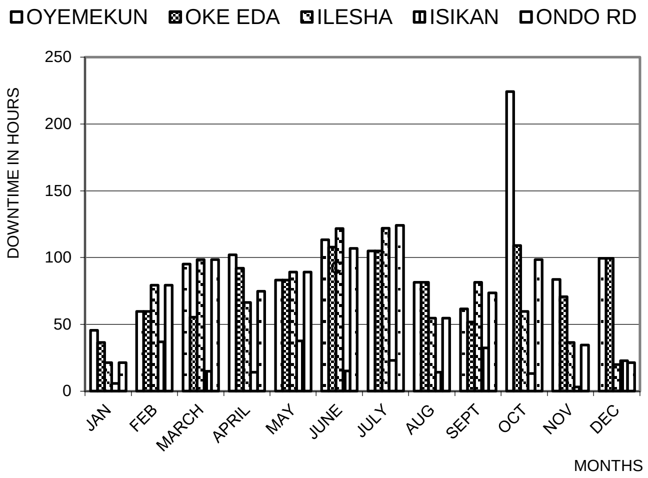

Figure 12. Feeders' Downtime for 2011

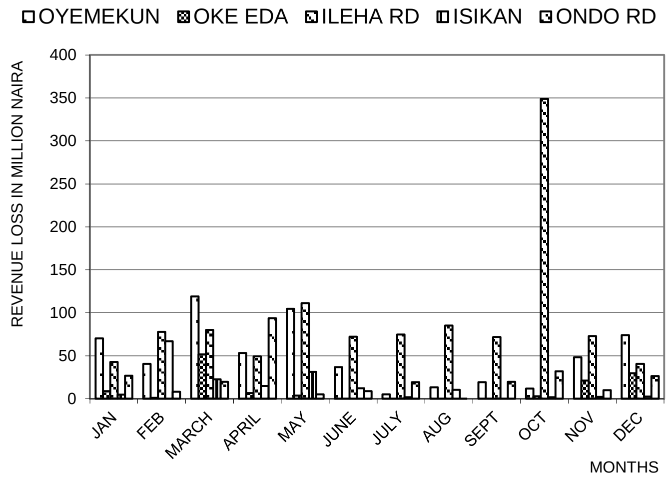

Figure 15. Feeders' Revenue loss for 2009

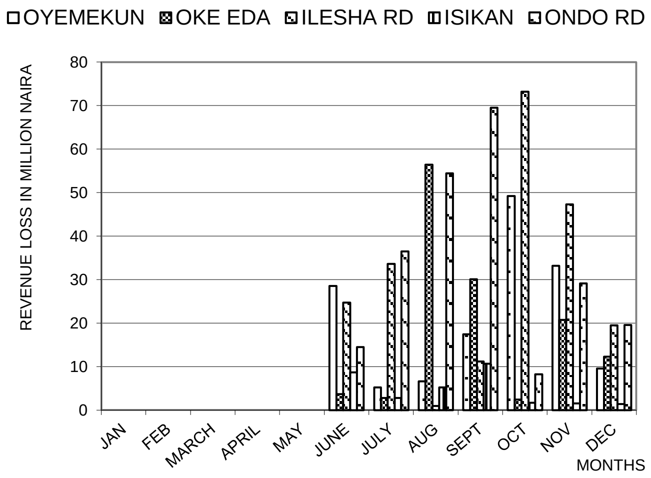

Figure 13. Feeders' Revenue loss for 2007

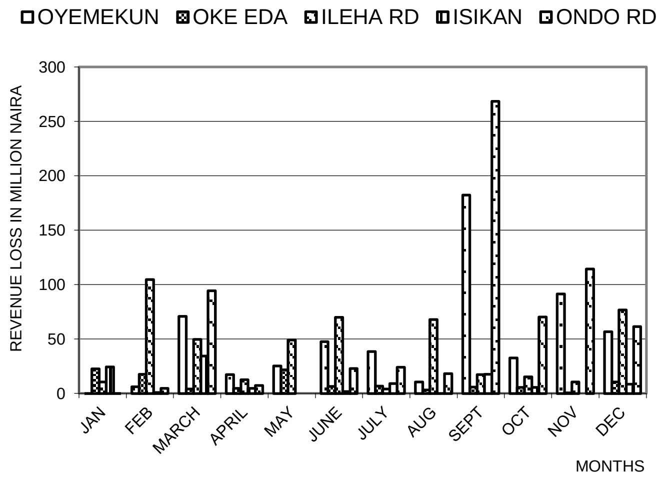

Figure 16. Feeders' Revenue loss for 2010

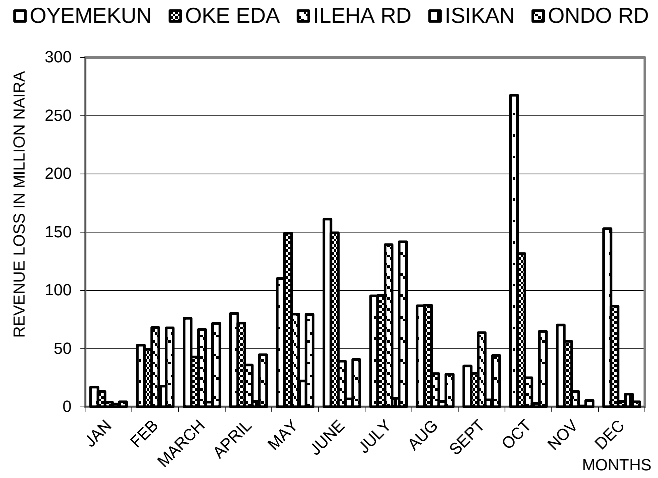

Figure 17. Feeders' Revenue loss for 2011

The revenue loss on each feeder as a result of faults over the period was also estimated and depicted graphically as shown in figures 13, 14, 15, 16, and 17.

The prevalent of faults on each phase on each of the feeders as observed in the entire Network was also determined. The result of the study on the effect of faults on each of the feeders over the period is presented in Figure 18. The performance of each feeder in terms of the downtime and the revenue loss are presented in Figure 19.

The study further investigates the prevalent of faults per phase as shown in figures 21, 22 and 23. This was considered important to verify if the unbalance load contributes to interruptions.

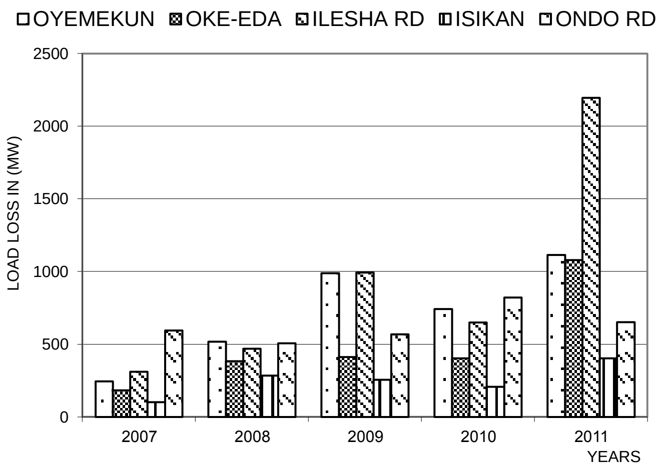

Figure 18. Load loss for five years on the Feeders

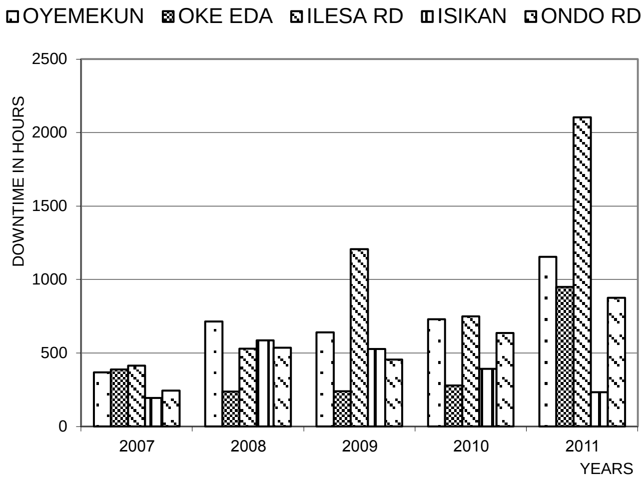

Figure 19. Five Years Feeders' Downtime

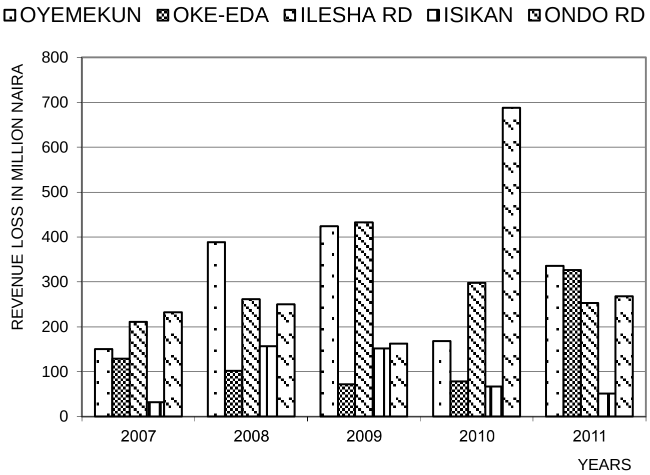

Figure 20. Five Years Feeders' Revenue Loss

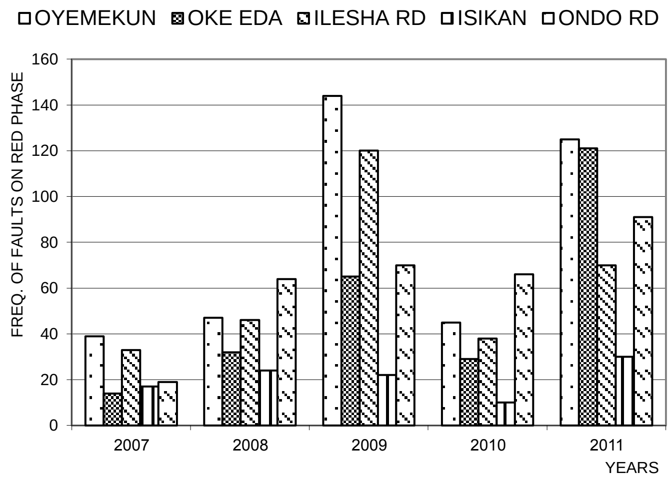

Figure 21. Five Years Frequency of Faults on Red Phase

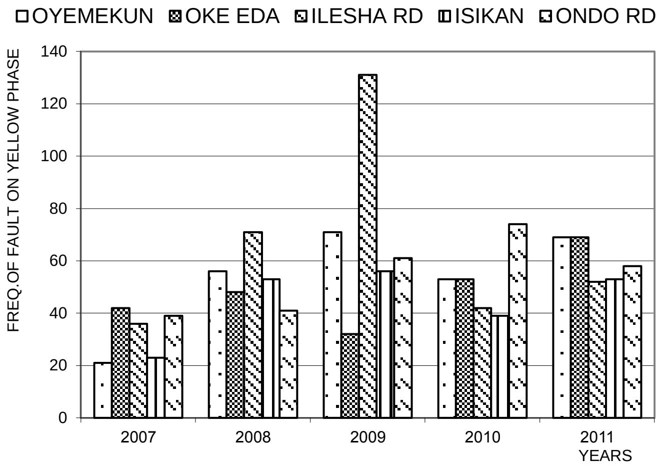

Figure 22. Five Years Frequency of Faults on Yellow Phase

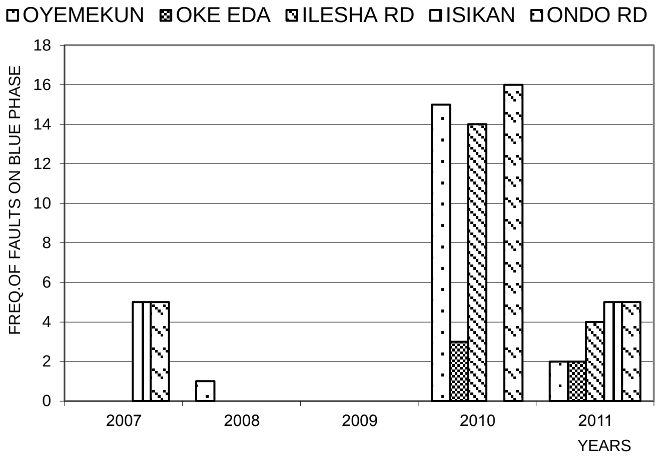

Figure 23. Five Years Frequency of Faults on Blue Phase

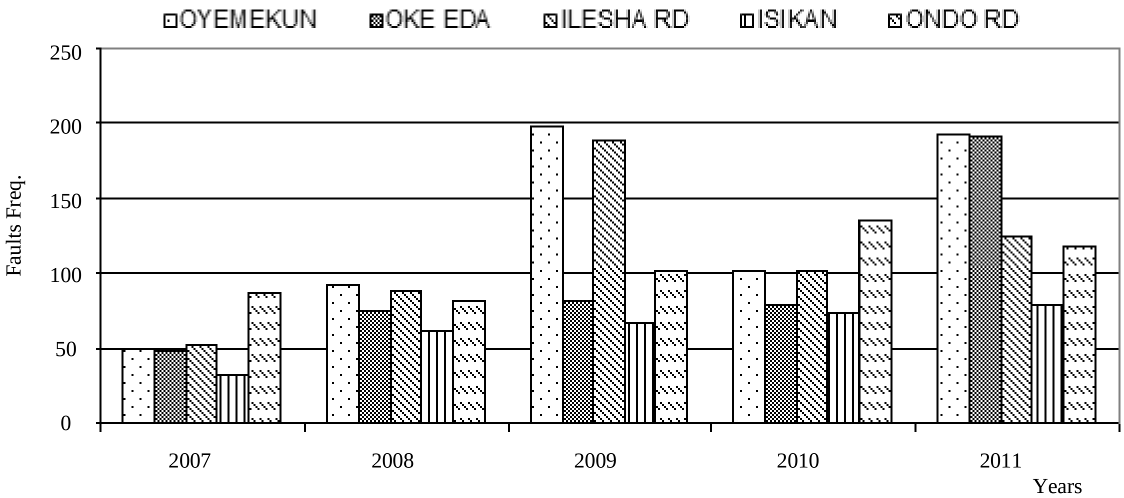

Figure 24. Fault Frequency for the Period

In summary the fault frequency for five years in all the feeders is presented in Figure 24.

A. Reliability Assessment of the Network

The extracted data for determining the reliability of the network over the period is presented in Table 2. Using the information in Table 2, the reliability for each year was calculated using equation (6)

$$R = e^{-\lambda t} \tag{6}$$

TABLE II. EXTRACTED DATA WITH CALCULATED FAILURE RATES

Years	Fault Freq.	Total Hours	Downtime in Hours	Failure Rate
2007	269	8760	244	0.03159
2008	397	8760	536	0.04827
2009	636	8760	455	0.07661
2010	491	8760	632	0.06042
2011	705	8760	875	0.08941

The percentage reliability for each year from the first year in 2007 to 2011 is presented in Figure 25. The Reliability of the system over five years is 12.13%

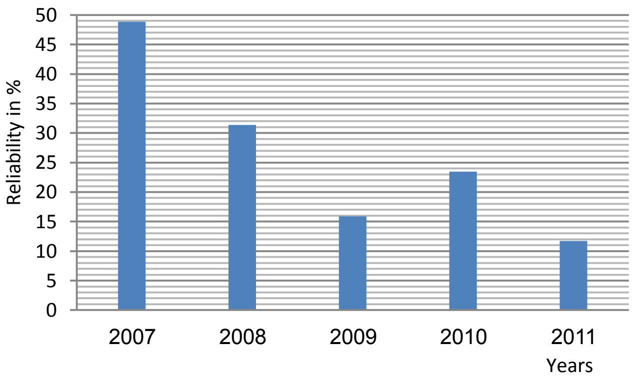

Figure 25. Reliability in Percentage

III. ANALYSIS AND DISCUSSION OF RESULTS

In 2007, Ondo road feeder recorded the highest number of faults about 87 and highest load loss (595MW) with outage duration of 244 hours. Isikan feeder recorded the least load loss of 102MW, least number of faults occurrence which stood at 32 and least down time of 193 hours. However in 2008 Oyemekun was highly affected by faults. The trend continues in 2009 with Oyemekun and Ilesha road mostly affected. This trend continues with Ilesha recording the highest number of faults. Three of the feeders Ondo, Ilesha and Oyemekun suffered greatly in 2010. The reliability of the network gradually decreases in 2007 with 46.85% to 11.79% in 2011. The trend must be arrested with injection of an additional 33/11 kV station. This recommendation was arrived at based on the results obtained from the study carried out on all the feeders.

A. Economic Impact

It is important to understand the economic implication of the losses as result of faults experienced during the period under investigation. Only the direct cost on the operator is considered. The indirect cost definitely will swell up the economic impact if considered also. In privitisation era, where consumers' right are guaranteed and protected, the indirect cost cannot be neglected. The revenue loss shows that more revenues are lost in all the feeders during the rainy season. This is attributed to the frequency of faults during this period which is associated with the length of the overhead line Aluminum conductors. It was observed that more feeders stay out of service which has significant impact the on the revenue. In 2007, over Two hundred Million Naira was lost to outages in Ondo road feeder. In 2008, Oyemekun feeder recorded the highest revenue loss of about Four hundred Million Naira. The loss increases in 2009 with Oyemekun and Ilesha road Feeders mostly affected with over Four hundred Million Naira. In 2011, the Ondo road feeder recorded the highest loss of over half a billion Naira. In summary over five billion was lost on all the feeders during the period under investigation.

IV. CONCLUSION

Privitisation of Electric Power Network in Nigeria was carried out to unbundle the power infrastructure to private operators. This was informed by the need to improve the efficiency of operations. However, this could not be addressed without assessing the state of the network. The results show that more feeders stay out of service for more than 50% of the period. This was reflected in the gradual decline of the reliability from about 50% in 2007 to about 12% in 2011 which leads to about 12% for the Akure Electric Power Distribution Network. This was amplified by the loss of revenue incurred of about five Billion Naira. It beholds on the new owner to implement policies that will improve the Network reliability which includes additional injection station that will bring about introduction of more feeders that will relieve the installed injection station of its load and consequently results in the reduction of the length of existing feeders

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