

Unreliable Electric Power Supply in Nigeria (Akure 11kV feeders a case study)

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ABSTRACT

The study was undertaken to show the level of unreliability of supply in Nigeria, Akure Township a case study. The load loss in MW, failure rate, downtime and revenue loss of the feeders were computed analytically and graphically represented. The result from the study revealed that, the downtime, after every fault resulted in heavy load loss and in turn causes a huge revenue loss. Recommendations were therefore made on how the reliability can be improved.

Keywords: Unreliability, Feeders, Failure rate, Load loss, Downtime, Fault, Revenue loss

INTRODUCTION

Electric energy is an essential ingredient for the industrial and all-round development of any country [1]. It is a coveted form of energy; because it can be generated centrally in bulk and transmitted economically over long distance [2]. In recent years, electricity supply has become very significant owing to the seeming indispensable role played by electricity in every facet of our daily lives. Absence of electricity for long periods, causes, discomfort and hampers productivity. It is also a known fact that electricity consumption has become a parameter by which the standard of living as well as the level of industrialization of nations is measured [3]. The present-day advancement in science and technology has made it possible to convert electrical energy into any desired form [4].

Electricity supply in Nigeria is very unreliable and seems to be made available in what may be described from the consumer's point of view in an epileptic manner. Despite the allocation and expenditure of huge amounts of funds for the acquisition of new hardware and the repair of existing ones, it has been observed that while the installed capacity increases, any increase in available capacity appears to be transient [5].

RESEARCH PROBLEM

Over the years, it has been observed that the reliability of power supplies in Akure town has been a major concern. As a result of this, it therefore necessitates its study so as to outline the causes of unreliability and proffer probable solutions to the problems.

CONCEPT OF RELIABILITY

The term reliability has a very wide range of definitions and cannot be associated with a single definition [6]: [7]; however reliability is defined as the probability that an item will be able to perform a required function in a specified period under stated conditions [8].

The reliability of an electric power system is therefore defined as the probability that the power system will perform the function of delivering electric energy to customers on a continuous basis with acceptable service quality [9]. Since reliability is a measure of the probability of performance its value lies between 1 and 0, [let reliability be R] when $R = 1$ the item will work as intended but when $R = 0$ the item or equipment will absolutely not work as intended, i.e the item or equipment has failed [8].

As the world economy becomes increasingly dependent on technology that requires highly reliable electric power, reliable and qualitative electricity has been observed as a sine qua non element for

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modern living [10]. In order to assess the reliability of electric power utility at the transmission sub system, the approach adopted is the estimate of the revenue loss as well as other inconveniencies.

Related Theories

FAULT: It is highly impossible to design a fault proof power system, as it is neither practical nor economical. Modern power systems, constructed with as high insulation level as is economically practical, have sufficient flexibility so that one or more components may be out of service with a minimum interruption of service. Though faults occur principally due to failure of insulation, yet faults can also result from electrical, mechanical, thermal failures or from any combination of these.

A fault in an electrical equipment / apparatus is defined as a defect in the electrical circuit due to which current is diverted from the intended path [11]. The nature of a fault simply implies any abnormal condition which causes a reduction in the basic insulation strength between phase conductors or between phase conductors and earth or any earthed screen surrounding the conductors. Actually the reduction of insulation strength is not considered as fault until it creates some effect on the system.

In an electrical power system comprising of generator, switchgear, transformer, power receivers and transmission and distribution circuit, it is inevitable that sooner or later some failure will occur somewhere in the system. The probability of the failure or occurrence of abnormal condition is more on power lines – about one –half of the fault occur on the power lines. This can be explained by the fact that the power lines are widely branched, have greater length, operate under variable weather conditions are subject to the action of atmospheric disturbances of electrical nature.

Faults may be as a result of normal voltage breakdown due to deterioration or ageing of Insulation and damages caused by unpredictable happenings such as blowing of heavy winds, trees falling across lines, vehicles colliding with towers or poles, birds shorting out lines, air craft colliding with lines, line breaks etc. or abnormal voltages breakdown which may occur as a result of switching surges or lightning strokes.

The line and apparatus insulation may be subjected to transient over – voltage because of the switching operations. The voltage which rises at a rapid rate may achieve a peak value approaching three times phase - to neutral voltage. This is the reason that a higher insulation level is provided initially. Lightning produces a very high voltage surge in the power system of the order of millions of volts and thus it is not feasible to provide insulation which can withstand this abnormality. These surges travels with the velocity of light in the power circuits, the limiting s factors are the surge impedance and the line reactance. The faults can be minimized by improving the system design, quality of the equipment and maintenance .however, faults cannot be eliminated completely [11].

Types of Faults

Design defects or errors, Manufacturing defects or improper methods in manufacture, Improper installation, Ageing and deterioration, Thermal over stressing, Voltage over stressing, Mechanical fracture and Chemical decomposition are causes of Insulation fault; Lightning surges, Switching surges and Dynamic over voltages are causes of Electrical faults; Wind, Snow or ice and Atmospheric pollution & contamination (in industrial areas) are causes of Mechanical fault; Over current and Over voltage are causes of Thermal fault.

The reliability of supply is governed by the frequency and the duration of interruption to supply and the number of customers affected by interruption. On an occurrence of an electrical fault, the corresponding feeder's circuit breaker opens at the substation. This disconnects the entire feeder from supply of electrical energy. Consequently, all customers on the faulted feeder by the operations control systems or by trouble calls from customers, but in some cases a crew has to be dispatched to locate the fault. Once the fault is located, it is isolated by separating it from the rest of the network before restoring service to the healthy section. The faulty component / section can then be repaired. Subsequently the distribution system returns to its normal operating state.

Reliability evaluation is an important and an integral feature of planning, design and operation of all engineering system. One of the measures for improving service reliability is through adequate and coordinated planning. The usefulness of a system therefore is determined by its steady availability and frequency of failures. In power system, stability can be measured based on system reliability indices.

Reliability Parameters

- a. Failure Rate, λ :** This is a basic index of reliability. It is a measure of the frequency at which fault occurs. Two definitions of failure rate are available depending on whether it relates to repairable or non-repairable items. The definition which relates to non-repairable items expresses failure rate as a percentage and is given by:

$$\lambda(\%) = \frac{\text{Number of units which failed} \times 100\%}{\text{Number of units tested}} \quad (1)$$

The other definition relates to repairable items or systems and expresses failure rate as the number of failures, which occurs per unit-hour of operation. It is denoted by $\lambda(N)$ and given as:

$$\lambda(N) = \frac{\text{Number of times that failure occurred}}{\text{Number of unit - hours of operation}} \quad (2)$$

The unit of $\lambda(N)$ is therefore failures per unit-hour but failures per thousand hours and failures per million hours are used [12]. Obviously, a high value of $\lambda(\%)$ or $\lambda(N)$ is indicated of low reliability.

b. Mean Time between Failures (MTBF)

This is another index of reliability. It expresses the average time, which elapses between consecutive failures of a repairable system or equipment. Mathematically, MTBF is given by:

$$MTBF = \frac{\text{Total system operating hours}}{\text{Number of failures}} \quad (3)$$

It can be shown that MTBF is the reciprocal of failure rate. Clearly the longer MTBF is, the more reliable is the system.

c. Mean Time to Repair (MTTR)

This is the average time that is needed to restore a system or an item to operational effectiveness once it fails. MTTR is therefore an index of maintainability and hence refers only to repairable items. MTTR is a function of the equipment design, the expertise of the personnel and the tools available. Clearly, a low value of MTTR indicates good maintainability [13].

d. Availability (A)

This is an important basic index of reliability. It is the probability that equipment will be available to perform as required or that it will be in a state of operational effectiveness within a given period. Mathematically, availability (A) is given as:

$$\text{Availability (A)} = \frac{MTBF - MTTR}{MTBF} \quad (4)$$

Administrative and logistics assumed to be negligible. Thus availability integrates both the reliability and maintainability parameters of the system. [14].

METHODOLOGY

A comprehensive study of 11kV feeders network in Akure were carried out on X16 - 33/11kV injection substation located along Oyemekun – Ilesha Rd, Akure. X16 is a control room with (2 X 15MVA) transformers (T2B & T2C) with five 11kV out-going feeders namely Oyemekun feeder, Oke Eda feeder, Ilesha Road feeder, Isikan feeder and Ondo Road feeder (Fig. 1).

Outages as a result of faults were recorded from PHCN Akure business unit daily reading sheets and log entry books from 2002 to 2011. The data recorded include Date and time a particular fault occurred, time restored, nature of fault, phase affected and load loss in (MW).

The data were collated, studied, analyzed and depicted graphically. Feeder by feeder load loss, downtime and revenue loss were evaluated for each year as shown in Table 1 with their corresponding charts as Figures 2 - 4

ANALYSIS AND DISCUSSION OF RESULTS

The outcome of the analysis on the load loss, downtime, revenue loss and fault frequency on Akure Township feeders (Oyemekun, Oke Eda, Ilesha Rd, Isikan and Ondo Road) were represented as shown in figures 2 - 5.

In year 2002, from the graphical analysis, Isikan feeder recorded the highest number of faults occurrence (39), highest number of load loss (153.4MW). As a result of values in load loss, fault outage duration, this made the revenue loss to be highly increased (#166,322) for a period of a year.

In year 2003, from the graphical analysis, Oke-eda feeder recorded the highest number of faults occurrence (61), highest number of load loss (210.47MW). As a result of values in load loss, fault outage duration, this made the revenue loss to be highly increased (#166,236) for a period of a year.

In year 2004, from the graphical analysis, Ilesha feeder recorded the highest number of faults occurrence (84), highest number of load loss (256.29MW). As a result of values in load loss, fault outage duration, this made the revenue loss to be highly increased (#72,325) for a period of a year.

In year 2005, from the graphical analysis, Oke eda feeder recorded the highest number of faults occurrence (286), highest number of load loss (1064.85MW). As a result of values in load loss, fault outage duration, this made the revenue loss to be highly increased (#474,176) for a period of a year.

In year 2006, from the graphical analysis, Oke-Eda feeder recorded the highest number of faults occurrence (144), highest number of load loss (776.42MW). As a result of values in load loss, fault outage duration, this made the revenue loss to be highly increased (#323,326) for a period of a year.

In year 2007, from the graphical analysis, Ondo Rd feeder recorded the highest number of faults occurrence (87), highest number of load loss (595MW) with outage duration of (244hrs). As a result of values in load loss, fault outage duration, this made the revenue loss to be highly increased (#231.98 Million) for a period of a year. Unlike Isikan feeder, for year 2007, it recorded the least in load loss, (102MW), faults occurrence (32), downtime duration of faults outages (193hrs). Isikan feeder recorded the least revenue loss of (#32.07Million) for the year.

In year 2008, Oyemekun feeder recorded the highest number of fault occurrence (92) times, highest load loss (519MW) and 714hrs for duration of fault outages. As a result of these values, the revenue loss increased to sum of (#388.01Million). Ranges of faults occurred in all the feeders, but Oke Eda feeder recorded least revenue loss (#101.28Million).

In year 2009, the number times that faults occurred on Oyemekun and Ilesha road were 198 and 189 respectively. Also the load loss in megawatts for the two feeders was 990 and 992 respectively. The revenue loss on Ilesha road for year 2009 was #432.75Million and that of Oyemekun was #424.04Million. Oke Eda feeder had the least revenue loss of #71.52Million simply because fault occurrence was minimal.

In year 2010, Ilesha road feeder has the highest revenue loss of #297.42 Million, just because downtime duration of faults outages and load loss were high i.e. 750hrs, 650MW) respectively.

In year 2011, Oyemekun feeder recorded #335.67Million as revenue loss. It is observed that the feeders remained for a longer period of time before they were restored. For example, Oyemekun stayed off service for 1153hours.

In summary, it is observed that the more the feeders stayed out of service, i.e. the downtime in hours, or the more load capacity of a feeder in (MW), then the more the revenue loss which is a disaster to economic growth of a nation.

Table1. Load loss, Downtime and Revenue loss for each feeder

Year	Oyemekun feeder			Oke Eda feeder			Ilesha Road feeder			Isikan feeder			Ondo Road feeder		
	Load loss (MW)	Down time (HRS)	Revenue loss (million ₦)	Load loss (MW)	Down time (HRS)	Revenue loss (million ₦)	Load loss (MW)	Down time (HRS)	Revenue loss (million ₦)	Load loss (MW)	Down time (HRS)	Revenue loss (million ₦)	Load loss (MW)	Down time (HRS)	Revenue loss (million ₦)
2002	9.05	3.52	0.00495	92.2	31.6	0.0049137	64.7	151.37	0.140383	153.4	77.5	0.166322	-	-	-
2003	17.83	10.87	0.01795	210.47	74.35	0.166236	88.83	102.72	0.150737	179.09	127.72	0.287916	-	-	-
2004	56.38	43.93	0.0755	256.29	54.20	0.121959	242.6	190.8	0.27232	254.7	140.4	0.28252	-	-	-

4			6				9		5	1	5	4			
2005	195.08	153.86	0.33086	1064.83	220.87	0.474176	281.43	365.28	0.577703	614.3	437.35	1.041174	59.73	64.8	0.094450
2006	391.22	113.98	0.23148	776.42	159.02	0.323326	556.48	296.38	0.457776	573.40	302.45	0.629134	749.21	353.1	0.689773
2007	245	367	149.98	184	387	128.57	312	413	210.59	102	193	32.07	595	244	231.98
2008	519	714	388.01	383	237	101.28	470	529	261.67	285	586	156.73	507	536	249.93
2009	990	640	424.04	412	240	71.52	992	1206	432.75	256	528	151.66	568	455	162.04
2010	743	729	168.08	404	280	77.79	650	750	297.42	209	329	66.64	822	637	129.83
2011	1115	1153	335.67	1080	951	249.93	2195	2103	253.58	404	232	50.71	653	875	267.46

Over #5billion was lost just for a period of ten years after the summation of revenue losses of all the feeders only on faults outages only, without considering other forms of outages like load shedding and operation and maintenance times. This has also affected the stability of power system and it creates adhere effect on national growth of our country, Nigeria. Power is the back bone to economic and technological development of any nation. Industries, companies, Institution, hospitals, both small and large scale entrepreneurs depend on electricity for survival. But due to constant and regular power outages many companies and industries have run into bankruptcy and folded up. The few companies that are managing to survive have increase the price of their product by hundred percent as they have to pay for generators and diesels. Considering the probability that the system will work without failure in 24 hours, the supply in 2002 was most reliable with 73.9%. Year 2011 had the least with 14.5%.

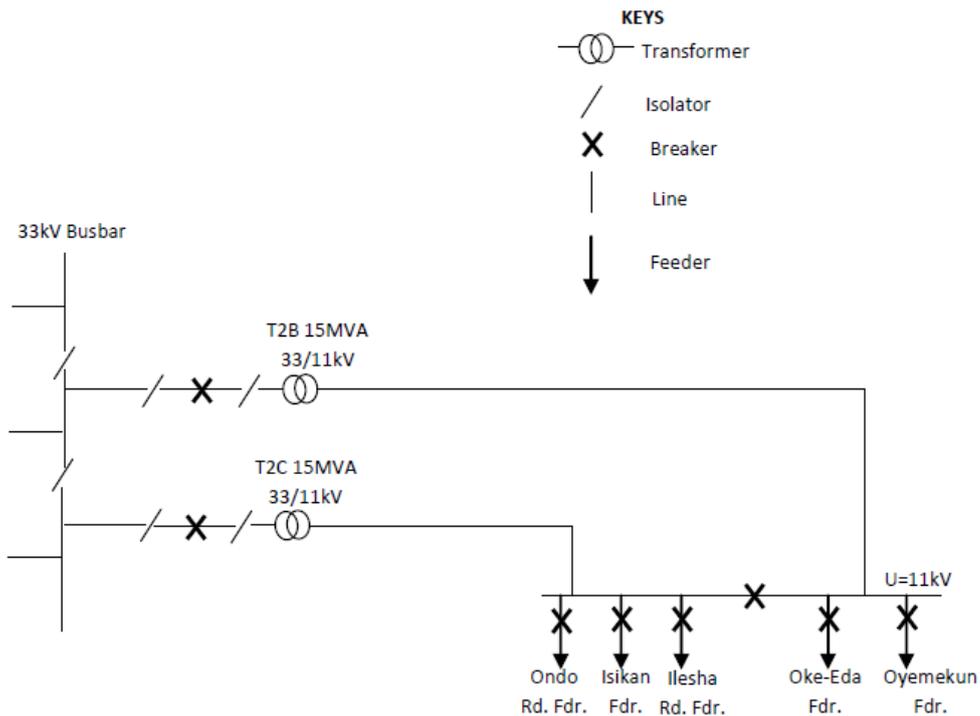


Fig1. Schematic Diagram Showing 33/11kV Network in Akure District

Table2. Fault frequency, failure rate and reliability of the network

Year	Oyemekun feeder	Oke Eda feeder	Ilesha Road feeder	Isikan feeder	Ondo Road feeder	Total Fault freq	FAILURE RATE/hour	$R = e^{-\lambda t}$
2002	4	29	38	39	-	110	0.0126	0.739
2003	12	61	34	43	-	150	0.0171	0.663
2004	19	68	84	66	-	237	0.0271	0.522
2005	57	286	94	134	20	591	0.0675	0.198
2006	29	144	97	86	107	463	0.0529	0.281

2007	50	48	52	32	87	269	0.0307	0.479
2008	92	75	88	61	81	397	0.0453	0.337
2009	198	81	189	67	101	636	0.0726	0.175
2010	102	79	101	74	135	491	0.0561	0.260
2011	192	191	125	79	118	705	0.0805	0.145

Graphical Analysis

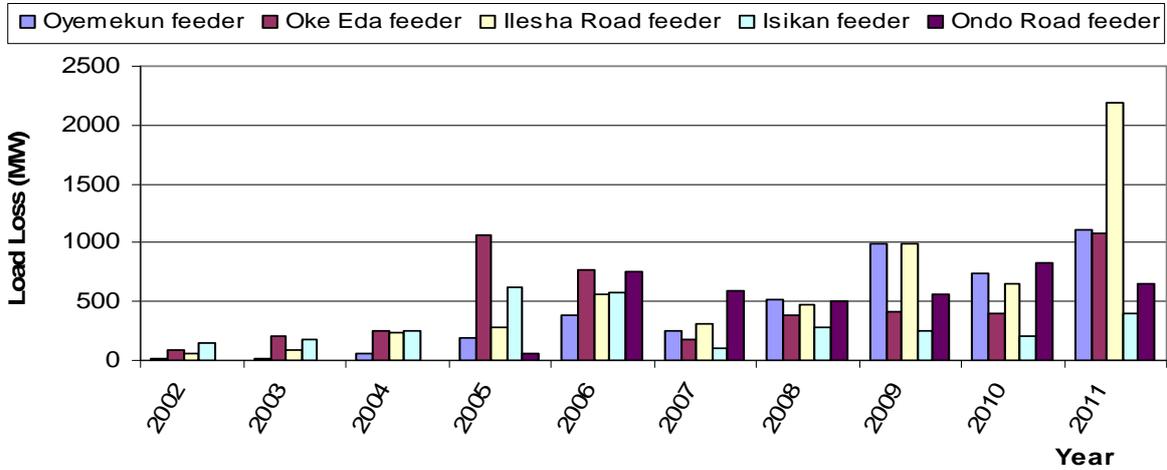


Fig.2: Feeder-by-feeder Load Loss

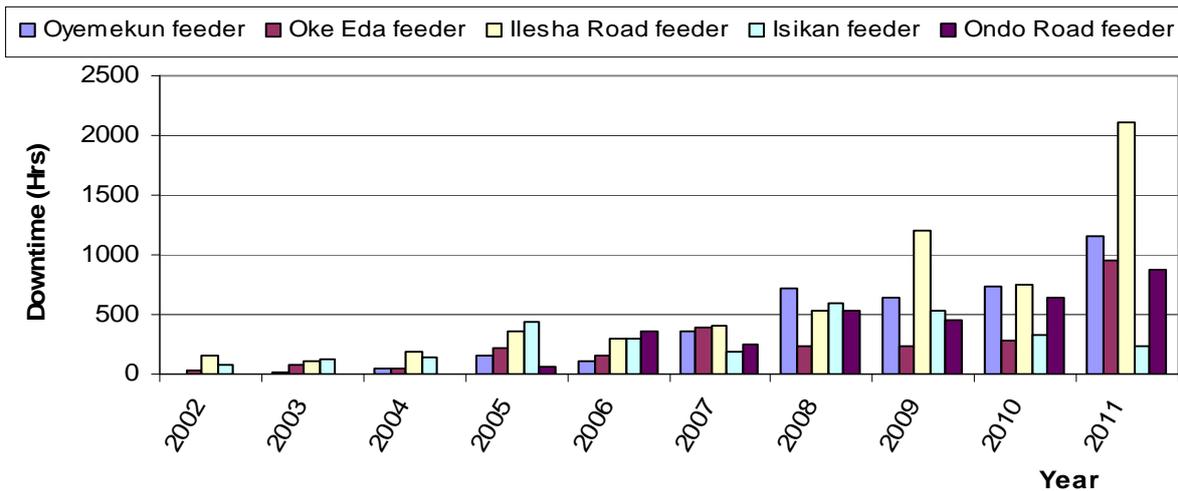


Fig.3: Feeder-by-feeder Downtime

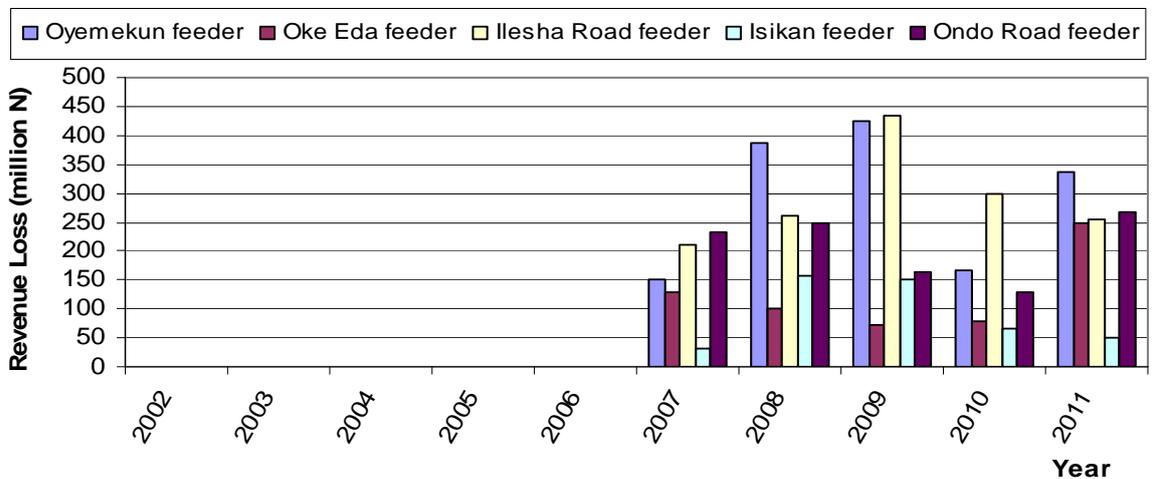


Fig.4: Feeder-by-feeder Revenue Loss

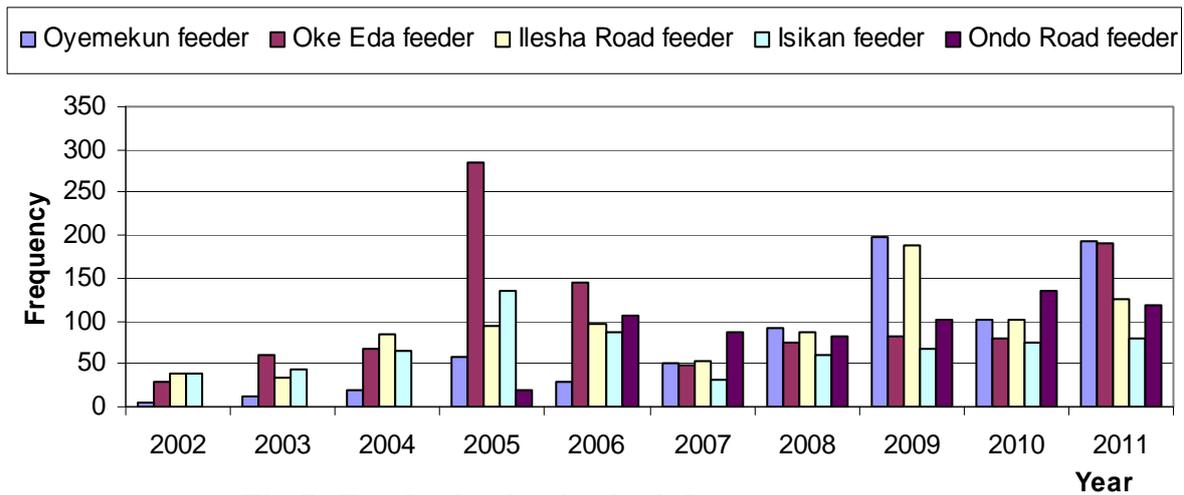


Fig.5: Feeder-by-feeder fault frequency

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 the power system is necessary to help the operator detect dangerous conditions that might damage equipment or cause loss of service.

It is a fact that the major difficulty in managing an ageing network is determination of asset life. In Nigeria today, no sufficient convincing statistics that proved a case to replace most aged assets. But considering other conditions, the reliability of the system was determined as 24.38%

RECOMMENDATION AND SUGGESTIONS FOR FURTHER WORK

Having carried out this research work, these recommendations will serve as a guide line:

System Network Restructuring

The existing radial system network should be changed to ring system so that there will be supply to all consumers except at the fault's point.

System Network Re-Distribution

NEPA authority should re-distribute 11kV network and house-to-house servicing, so that the load on each feeder or phase will be balanced and unduly lengthy network route should be avoided.

Redundancy in the System

There should be provision of "installed spares" so that excess capacity is available at all time so that any unit needing repairs may be taken out of use without interrupting consumers' supply, thus mitigating the effects of faults.

Increased Repair Facilities

Sufficient repairs facilities should be made available at all times to carry out corrective maintenance, so that system downtime (MTTR) would be reduced to the barest minimum. This in overall saves the authority a lot of revenue loss.

Planned Maintenance

Certain parts of the system or equipment should receive attention and perhaps replacement before fault occurs, this would reduce the incidence of system / equipment failure.

Constant Training of Personnel

Training and re-training of technical staffs should be encouraged.

Finally, if above recommendation were given due considerations, there will be stability of power supply and power system reliability will improve.

REFERENCES

- [1] Ike, S.A and Egedi-Idu, S.O (2012): "The choice of a swing bus in a power system network; A case study of the Nigerian National Grid ", *Journal of the Nigerian association of Mathematical Physics appli.Sci.Research*, Vol. 21, pp. 439-448
- [2] Weedy, B.M and Cory, B. J(1998): "Power system analysis and design" , 4th edition John Wiley and Sons. London England
- [3] Muhammed (2005): "Checking the odds ", *NEPA Review Magazine*.
- [4] Mehta V.K and Mehta R (2008): "Principles of Power Systems", 4th revised edition Scand Publishers.
- [5] Ale, T.O and Odesola, A.O (2013): "Effects of distance on transmission; Akure 33kV line a case study ", *International Journal of Research Findings in Engineering Sci. and Technology*. Vol. 1, No1, pp 27 – 32.
- [6] Popoola, J.J; Ponnle, A.A and Ale, T.O (2011): "Reliability worth assessment of electric power utility in Nigeria system: Residential customer survey result ", *American Union Journal of Technology*, Vol.14 no 3, pp 217-224.
- [7] Abdullahi M.I; Akinsanmi O; Muazu M.B and Jubril Y (2007): "Reliability assessment of an electronic system; A case study of a British siren in Nigeria ", *Journal of Appli.Sci.Research*, 3:1, pp 671-5.
- [8] Oroge, C. O (1991); "Fundamentals of Reliability and Testing Methods" Sooji Press Ltd Kaduna Nigeria.
- [9] Bhavaraju M.P; Billinton R ; Brown R.E ; Endrenyi J ;Li W ; Meliopoulous A.P and Singh C (2007): "IEEE Tutorial on Electric delivery system reliability evaluation ", *Journal IEE power engineering society (PES), Publication*, 305TP125 pp 39-51.
- [10] Ali, N.A; Achinaya, U.D and Nuhu, M.S (2004): "Frequency failures of equipment of power system network – the Nigeria experience ", *Proc. 8th IEE Int. Conf. Dev. Power Syst. Protection 2 (5- 8): 603-6*.
- [11] Gupta, J.B (2005): "A Course in Power System" S.K Kataria and son, New Delhi pp 2-15.
- [12] Dhillon, B. S. and Reiche, H. (1987): "Reliability and Maintainability Management". C.B.S Publishers and Distributors, pp 604-701
- [13] Heizer, J. and Render, B. (1988): "Production and Operations Management". Strategies Tactics Allyn and Bacon Incorporated pp 551-680.
- [14] Billinton R. and Allan R.N. 1992. Reliability Evaluation of Engineering Systems: Concepts and Techniques. 2nd Edition. Plenum Press.