

**RELIABILITY ASSESSMENT OF POWER DISTRIBUTION FEEDERS**

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**ABSTRACT**

The study focuses on the analysis of 33kv distribution feeder network in Ibadan Electricity Company, Ota. The main aim of this research is to estimate the reliability of 33-KV feeders which are secondary distribution network of the system. The study determines the Failure Rate, the Mean Time between Failures (MTBF), Mean Time to Failure (MTTF), Availability and reliability of the network. This study uses statistical analytical method. Statistical analytical methods provide useful and higher accuracy of result since it provides high tolerance to uncertainties. The result shows that the mean reliability of the supply system was 74.41%, and thus for a developing nations like ours, the reliability is partly satisfactory.

**Keywords:** Reliability, failure rate, mean time between failure, availability, mean time to repair

## INTRODUCTION

Electrical power is the life wire of today's modern world. The availability of a reliable power supply at a cost-effective price is important for the national growth of a country. The utilities companies are evolving several methods to satisfy customers. A study shows that meeting up to 90% of customer demand is a key of enhancing customer reliability (Bhavaraju, *et. al.*, 2005). Power distribution network system is established mainly to provide adequate electricity supply to customers as economically as possible with reasonable assurance of reliability. Nowadays, the power distribution networks have grown exponentially in terms of size and technology over the past few years. As a result, utility company must strive to ensure that the customer's reliability requirements are met with optimum strategic planning and lowest possible cost. The ability of the system to provide adequate supply of electrical energy determines the term reliability (Bhavaraju, *et. al.*, 2005). Reliability analysis of distribution network is extremely important, thus several studies and research have been carried out as a result of inefficiency and unavailability of power supply.

Over this years, distribution network system has received less attention devoted to reliability studies compared to generation and transmission system. The reason being that the generation and transmission system are capital intensive, and the inadequacies can have widespread consequence for both consumers and suppliers. However, distribution system is cheaper compared to the other two, and its effect are localized.

Analysis of the consumer's failure statistics of most utilities show that distribution system make the greatest individual contribution to the unavailability of electrical supply to customer. It is very important to assess and evaluate the reliability of power system network in order to obtain the most accurate and effective way in decision making especially in planning, operation, and maintenance.

(Roystone, 2014) worked on the reliability of power system using Hierarchical Markov Modelling (HMM). The HMM decomposes the reliability problem into three levels according to system topology, integrated protection system behaviour, and individual protection devices behaviour. (Roystone, 2014) stated that proper evaluation of reliability of distribution system can be obtained with information of failure rate, repair time, and unavailability for the distribution infrastructure.

(Goran *et al.*, 2016 ) outlined the probabilistic method for a future efficient smart grid with non-wire network. This is born out of the fact that renewable energy are highly unpredictable which will in the future be added to the complete mix of Energy supply. (Lei. *et al.*, 2014) also pointed the use of power distribution topology reordering to ensure efficient flow of power to enhance the reliability of the system.

In this paper, availability of supply is a key indicator of the reliability of the system. Availability of supply is tied to maintenance of the power distribution infrastructure. (Akinola, 2017) uses analytical method to evaluate reliability of distribution feeders. (Muhammad, 2016) outlined replacing of aging underground cable infrastructure and transformers in order to improve reliability of the power installation components. In contrast to existing results, this paper aims to modify the statistical and graphical method, and make reliability study of feeder line easier to analyse.

## METHODOLOGY

In order to compute the reliability of Ibadan Electricity Distribution Company, Ota area, the following reliability parameters are considered and used to determine the reliability of the system. In other to access the performance of the feeders, the various reliability indices were computed.

### Failure Rate:

This is a basic index of reliability and it is a measure of the frequency at which fault occurs. For repairable items or systems, the failure rate is expressed as the number of failures, which occurs per unit-hour of operation. It is denoted by  $\lambda(N)$  and given as:

$$\lambda(N) = \frac{\text{Number of times that failure has occurred}}{\text{Number of unit - hour of operation}} \dots(1)$$

### 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:

$$\text{MTBF} = \frac{\text{Total system operating hours}}{\text{Number of failures}} \dots\dots(2)$$

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

### 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.

$$\text{MTTR} = \frac{\text{Total system downtime}}{\text{Number of failures}} \dots\dots\dots(3)$$

### 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:

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

**RESULTS****CALCULATIONS FOR THE MONTH OF JANUARY****FSM FEEDER CALCULATION**

$$\text{Failure Rate} = 24/744 = 0.0323$$

$$\text{MTBF} = 1/(\text{Failure rate}) = 31$$

$$\text{MTTR} = 80.07/24 = 3.3363$$

$$\text{Availability} = (31 - 3.3363)/31 = 0.8924$$

**SUN METAL FEEDER CALCULATION**

$$\text{Failure Rate} = 32/744 = 0.0430$$

$$\text{MTBF} = 1/(\text{Failure rate}) = 23.25$$

$$\text{MTTR} = 5.3653$$

$$\text{Availability} = (23.25 - 5.3653)/23.25 = 17.8847$$

**SUMO FEEDER CALCULATION**

$$\text{Failure Rate} = 35/744 = 0.0470$$

$$\text{MTBF} = 1/(\text{Failure rate}) = 1/0.0470$$

$$\text{MTTR} = 429.74/35 = 12.2782$$

$$\text{Availability} = (21.2571 - 12.2782)/21.2571 = 0.4224$$

**IDIROKO FEEDER CALCULATION**

$$\text{Failure Rate} = 42/744 = 0.0565$$

$$\text{MTBF} = 17.7143$$

$$\text{MTTR} = 405.9/42 = 9.6642$$

$$\text{Availability} = (417.7143 - 9.6642)/17.7143 = 0.4544$$

**LUSAGA FEEDER CALCULATION**

$$\text{Failure Rate} = 45/744 = 0.0605$$

$$\text{MTBF} = 1/(\text{Failure rate}) = 16.5333$$

$$\text{MTTR} = 264.42/45 = 5.876$$

$$\text{Availability} = (16.3333 - 5.876)/16.3333 = 0.6402$$

**ODIGBO FEEDER CALCULATION**

$$\text{Failure Rate} = 29/744 = 0.0390$$

$$\text{MTBF} = 25.6552$$

$$\text{MTTR} = 114.94/29 = 3.9634$$

$$\text{Availability} = (25.6552 - 3.9634)/25.6552 = 0.8455$$

**CALCULATIONS FOR THE MONTH OF FEBRUARY****ODIGBO FEEDER CALCULATION**

$$\text{Failure Rate} = 18/(24*28) = 18/672 = 0.0259$$

$$\text{MTBF} = 1/0.0259 = 38.6667$$

$$\text{MTTR} = 55.3/18 = 3.0722$$

$$\text{Availability} = (38.67 - 3.0722)/38.67 = 0.9205$$

**FSM FEEDER CALCULATION**

$$\text{Failure Rate} = 14/(24*28) = 14/672 = 0.0201$$

$$\text{MTBF} = 1/0.0201 = 49.714$$

$$\text{MTTR} = 37.51/14 = 2.679$$

$$\text{Availability} = (49.714 - 2.679)/49.714 = 0.946$$

**IDIROKO FEEDER CALCULATION**

$$\text{Failure Rate} = 32/(24*28) = 36/672 = 0.046$$

$$\text{MTBF} = 21.75$$

$$\text{MTTR} = 203.82/32 = 6.369$$

$$\text{Availability} = (21.75 - 6.369)/21.75 = 0.707$$

**LUSAGA FEEDER CALCULATION**

$$\text{Failure Rate} = 44/(28*24) = 0.0632$$

$$\text{MTBF} = 15.818$$

$$\text{MTTR} = 141.9/44 = 3.225$$

**SUMO FEEDER CALCULATION**

$$\text{Failure Rate} = 15/(24*28) = 0.022$$

$$\text{MTBF} = 46.4$$

$$\text{MTTR} = 47.48/15 = 3.093$$

$$\text{Availability} = (46.4 - 3.093)/46.4 = 0.933$$

**SUN METAL FEEDER CALCULATION**

$$\text{Failure Rate} = 25/(24*28) = 0.036$$

$$\text{MTBF} = 27.88$$

$$\text{MTTR} = 100.21/18 = 4.01$$

$$\text{Availability} = (27.84 - 4.01)/27.84 = 0.856$$

**CALCULATION FOR THE MONTH OF MARCH****SUN METAL FEEDER CALCULATION**

$$\text{Failure Rate} = 27/(31*24) = 0.036$$

$$\text{MTBF} = 27.55$$

$$\text{MTTR} = 158.33/27 = 5.864$$

$$\text{Availability} = 0.786$$

**SUMO FEEDER CALCULATION**

$$\text{Failure Rate} = 17/744 = 0.023$$

$$\text{MTBF} = 43.76$$

$$\text{MTTR} = 85.91/17 = 5.054$$

$$\text{Availability} = 0.881$$

**IDIROKO FEEDER CALCULATION**

$$\text{Failure Rate} = 42/744 = 0.056$$

$$\text{MTBF} = 17.71$$

$$\text{MTTR} = 342.59/42 = 8.157$$

$$\text{Availability} = (17.71 - 8.157)/17.71 = 0.540$$

**LUSAGA FEEDER CALCULATION**

$$\text{Failure Rate} = 53/(31*24) = 53/744 = 0.074$$

$$\text{MTBF} = 14.08$$

$$\text{MTTR} = 204.81/53 = 3.864$$

$$\text{Availability} = (14.08 - 3.864)/14.08 = 0.726$$

**ODIGBO FEEDER CALCULATION**

$$\text{Failure Rate} = 22/(31*24) = 22/744 = 0.030$$

$$\text{MTBF} = 33.818$$

$$\text{MTTR} = 169.17/22 = 7.599$$

$$\text{Availability} = (33.818 - 7.599)/33.818 = 0.775$$

**FSM FEEDER CALCULATION**

$$\text{Failure Rate} = 16/(31*24) = 16/744 = 0.022$$

$$\text{MTBF} = 46.5$$

$$\text{MTTR} = 99.19/16 = 6.199$$

$$\text{Availability} = (46.5 - 6.119)/46.5 = 0.867$$

**CALCULATIONS FOR THE MONTH OF APRIL****FSM FEEDER CALCULATION**

$$\text{Failure Rate} = 24/(30*24) = 24/720 = 0.0333$$

$$\text{MTBF} = 30$$

$$\text{MTTR} = 108.19/24 = 4.508$$

$$\text{Availability} = (30 - 4.508)/30 = 0.850$$

**SUN METAL FEEDER CALCULATION**

Failure =  $34/720 = 0.047$   
 MTBF = 21.81  
 MTTR =  $132.39/34 = 3.894$   
 Availability =  $(21.18 - 3.894)/21.18 = 0.816$

**SUMO FEEDER CALCULATION**

Failure =  $26/720 = 0.036$   
 MTBF = 27.69  
 MTTR =  $132.39/26 = 4.137$   
 Availability =  $(27.69 - 4.137)/27.69 = 0.851$

**IDIROKO FEEDER CALCULATION**

Failure =  $50/720 = 0.069$   
 MTBF = 14.4  
 MTTR =  $402.21/50 = 8.044$   
 Availability =  $(14.4 - 8.044)/14.4 = 0.441$

**LUSAGA FEEDER CALCULATION**

Failure =  $49/720 = 0.068$   
 MTBF = 14.69  
 MTTR =  $171/49 = 3.490$   
 Availability =  $(14.69 - 3.490)/14.69 = 0.762$

**ODIGBO FEEDER CALCULATION**

Failure =  $33/720 = 0.046$   
 MTBF = 21.818  
 MTTR =  $264.02/33 = 8.00$   
 Availability =  $(21.818 - 8)/21.818 = 0.633$

**CALCULATION FOR THE MONTH OF MAY****FSM FEEDER CALCULATION**

Failure =  $33/744 = 0.044$   
 MTBF = 22.55  
 MTTR =  $295.15/33 = 8.994$   
 Availability =  $(22.55 - 8.944)/22.55 = 0.603$

**SUN METAL FEEDER CALCULATION**

Failure =  $22/744 = 0.030$   
 MTBF = 33.818  
 MTTR =  $70.46/22 = 3.203$   
 Availability =  $(33.818 - 3.203)/33.818 = 0.905$

**SUMO FEEDER CALCULATION**

Failure =  $20/744 = 0.027$   
 MTBF = 37.2  
 MTTR =  $64.8/20 = 3.24$   
 Availability =  $(37.2 - 3.24)/37.2 = 0.913$

**IDIROKO FEEDER CALCULATION**

Failure =  $44/744 = 0.059$   
 MTBF = 16.909  
 MTTR =  $348.28/44 = 7.915$   
 Availability =  $(16.909 - 7.915)/16.909 = 0.332$

**LUSAGA FEEDER CALCULATION**

Failure =  $53/744 = 0.071$   
 MTBF = 14.038  
 MTTR =  $167.91/53 = 3.168$   
 Availability =  $(14.038 - 3.168)/14.038 = 0.774$

**META FRIQUE FEEDER CALCULATION**

Failure =  $21/744 = 0.028$   
 MTBF = 35.43  
 MTTR =  $232.58/21 = 11.09$   
 Availability =  $(35.43 - 11.09)/35.43 = 0.687$

**LUSAGA FEEDER CALCULATION**

Failure =  $40/720 = 0.055$   
 MTBF = 18  
 MTTR =  $189.22/40 = 4.731$   
 Availability =  $(18 - 4.731)/18 = 0.732$

**ODIGBO FEEDER CALCULATION**

Failure =  $11/720 = 0.015$   
 MTBF = 65.45  
 MTTR =  $134.97/11 = 12.27$   
 availability =  $(65.45 - 12.27)/65.45 = 0.813$

**CALCULATION FOR THE MONTH OF JUNE****FSM FEEDER CALCULATION**

Failure =  $20/720 = 0.028$   
 MTBF = 36  
 MTTR =  $139.31/20 = 7.965$   
 Availability =  $(30 - 7.965)/30 = 0.734$

**SUN METAL FEEDER CALCULATION**

Failure =  $15/720 = 0.021$   
 MTBF = 48  
 MTTR =  $127.49/15 = 8.50$   
 Availability =  $(48 - 8.5)/48 = 0.823$

**SUMO FEEDER CALCULATION**

Failure =  $9/720 = 0.013$   
 MTBF = 80  
 MTTR =  $87.14/9 = 9.682$   
 Availability =  $(80 - 9.682)/80 = 0.879$

**IDIROKO FEEDER CALCULATION**

Failure =  $28/720 = 0.039$   
 MTBF = 1/0.039 = 25.641  
 MTTR =  $279.5/28 = 9.982$   
 Availability =  $(25.71 - 9.928)/25.71 = 0.612$

**LUSAGA FEEDER CALCULATION**

Failure =  $40/720 = 0.055$   
 MTBF = 18  
 MTTR =  $189.22/40 = 4.731$   
 Availability =  $(18 - 4.731)/18 = 0.732$

**ODIGBO FEEDER CALCULATION**

Failure =  $11/720 = 0.015$   
 MTBF = 65.45  
 MTTR =  $134.97/11 = 12.27$   
 Availability =  $(65.45 - 12.27)/65.45 = 0.813$



FAILURE RATE RESULT DATA AND ANALYSIS

Table 1: Summary of the 33-kv Feeder’s Failure rates over six months

FEEDER/ RATE	JAN.	FEB.	MAR.	APR.	MAY.	JUNE
SUN METAL	0.0430	0.036	0.036	0.047	0.030	0.021
SUMO	0.0470	0.022	0.023	0.036	0.027	0.013
IDIROKO	0.057	0.046	0.056	0.069	0.059	0.039
LUSAGA	0.061	0.0632	0.071	0.068	0.071	0.055
ODIGBO	0.039	0.0259	0.030	0.046	0.028	0.015
FSM	0.032	0.0201	0.022	0.033	0.044	0.028

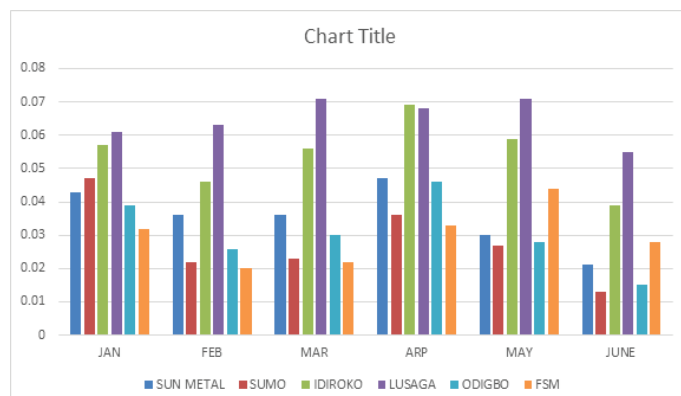


Fig 1: Bar Chart showing failure rate for a period of six months

MEAN – TIME – BETWEEN- FAILURE RESULT DATA AND ANALYSIS

Table 2: Summary of the 33-kv Feeder’s MTBF for six months

FEEDER	JAN.	FEB.	MAR.	APR.	MAY	JUNE
SUN METAL	23.25	27.82	27.55	21.18	33.82	48.00
SUMO	21.26	46.40	42.76	27.69	37.20	80.00
IDIROKO	17.71	21.75	17.71	14.40	16.90	18.00
LUSAGA	16.53	15.82	14.08	14.96	14.04	18.00
ODIGBO	25.67	38.67	33.82	33.00	22.50	36.00
FSM	23.1	49.71	46.50	30.00	22.50	36.0

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MEAN- TIME- TO –REPAIR RESULT DATA AND ANALYSIS

Table 3: Summary of the Feeder’s MTTR for six month

FEEDERS	JAN.	FEB.	MAR.	APR.	MAY	JUNE
SUN METAL	5.37	4.01	5.86	3.89	3.20	8.50
CALPLASS	12.28	3.09	5.05	4.14	3.24	9.68
IDIROKO	9.66	6.37	8.16	8.04	7.92	9.98
LUSAGA	5.88	3.23	3.86	3.49	3.17	4.73
METAFRIQUE	3.96	3.07	7.60	8.00	11.09	12.27
FSM	3.34	2.68	6.20	4.51	8.94	7.96

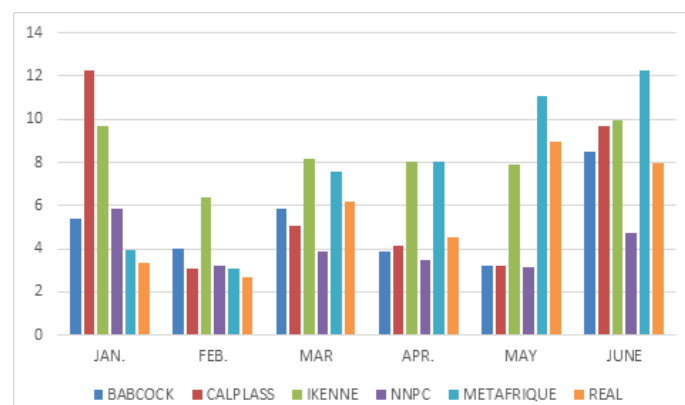


Fig3: Bar Chart showing availability of supply for a period of six months

CONCLUSION

The study shows that the mean availability of supply is 74.41% which is partially satisfactory. The availability of supply was at its lowest in January with 56.83% and highest occur in February with availability value of 85.5%. In order to increase the reliability of a distribution system, there should be routine maintenance when availability of supply falls below 90%.

Quality electricity supply to consumers is desirable for progress and advancement of the living standard of people thus, the need for system reliability. To facilitate this, accurate monitoring of power system is necessary to help operator detect dangerous conditions that might damage or cause loss of service.