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Reliability Evaluation of Ayede 330/132KV Substation

Temitope Adefarati, Adedayo Kayode Babarinde, Ayodele Sunday Oluwole and Kehinde Olusuyi
[1]Department of Electrical & Electronics Engineering, Federal University, Oye Ekiti, Nigeria.
[2]Department of Electrical & Electronics Engineering, Federal University, Oye Ekiti, Nigeria.
[3]Department of Electrical & Electronics Engineering, Federal University, Oye Ekiti, Nigeria.
[4]Department of Electrical & Electronics Engineering, Federal University, Oye Ekiti, Nigeria.

Abstract— **Reliability is an analytical tool used to measure the ability of a power system to perform a function when required for a specified period of time in particular environment and conditions. Reliability analysis is a vital tool for critical identification of sensitive components of the electrical power systems that need more attention for better improvement and at the same time to increase the system availability. The aim of this research work is to carry out reliability assessment of electrical power system by using some reliability indicators. Hence this work presents a research on reliability assessment of 330/132KV substation by using Ayede 330/132KV substation as a case study. Ayede 330/132KV substation feeds six different 132/33KV substations, such as Jericho, Ijebu ode, Ibadan North, Sagamu, Ayede and Iseyin. In this study different parameters that determined optimum operation of a power system such as SAIDI, CAIDI, SAIFI, CAIFI, CIII, MAIFI and ASAI were deduced.**

Index Terms—**Availability, Maintainability, Mean Time between failures, Mean time to repair, Reliability.**

I. INTRODUCTION

Reliability is a probability that a power system will operate to an agreed level of performance for a specified period of time, subject to specified environmental conditions. Reliability is one of the characteristics of a power system which must be considered when designing a power system. Thus, reliability is the most rational standard for deciding which design is the best in terms of minimum total life cost of electrical systems. A power system is known globally as a cost-effective means of providing energy in any nation. It consists of three main hierarchical stages or sub-systems known respectively as generation, transmission and distribution [1]. Because of the size and complexity of an average sized of power system, an assessment of the complete power system as a unit is neither recommended nor is it practically useful. In practice, the reliability assessment of a power system is carried out by separately investigating the reliabilities of its different stages or sub-systems i.e. Generation, Distribution and Transmission systems [5]. A reliable power system is an effective mechanism for industrial and economic revolution in any country in the world. To increase economic activities in Nigeria, utility companies are expected to provide energy continuously at optimum quantity and quality for nothing less twenty-four hours a day[6]. Thus, It calls for a high reliability of its component parts and its operation. To ascertain that the electric power system maintains an acceptable reliability level, reliability assessments are needed to be carried out on it at regular intervals [2][3]

II. RESEARCH PROBLEM

The main research problem is how to analyze Ayede 330/132 KV substation reliability indices and improve the system availability with the application of reliability analysis. Since system failure affects availability, quality and quantity of the power system. Hence, it is necessary to optimize system failure rate in any power system. This is one of the basic roles of reliability assessment in electrical power system.

III. PURPOSE OF THE RESEARCH

The purpose of this research study is to describe the method of reliability analysis of power system using 330/132KV substation as a case study and explore the best method for improving the system availability. This analysis also studies the criticality and sensitivities of the subsystems or components of the system for continuous improvement. This analysis will help the power system planners and utilities to identify the sensitive components of the power system that need more attention for better improvement.

IV. OBJECTIVE OF THE RESEARCH STUDY

The objectives of this research study are stated below:

- To analyse operating reliability and availability indices of 132/33KV substation.
- To improve the availability of 132/33KV substation based on reliability analysis.
- To develop a methodology for improvement of power system availability using reliability analysis.
- To find the criticality of each electrical component in a power system that can cause system failure.

V. RELIABILITY INDICES

Reliability is probably that element or system will operate adequately in giving time and operating conditions. It is acknowledged that reliability is changing due to ageing and maintenance culture of electrical power system and this is observed having studied electrical system for a long period of time [7]. But for the purpose this paper, we are considering different reliability indices to quantify Ayede 330/132KV substation performance indicators.

VI. GENERAL RELIABILITY ASSESSMENT FORMULAS

1. Failure Density Function

The failure density function is expressed by

$$f(t) = -\frac{dR(t)}{dt} \quad (1)$$

Where t= time, f (t) =failure density (probability) function and R (t) =Reliability at time t.

Let the reliability of equipment be represented by the following function:

$$R(t) = e^{-\lambda t} \quad (2)$$

Where λ is the failure rate.

Substitute Equation 2 into Equation 1 in order to obtain an expression for the item's failure density function.

$$f(t) = -\frac{e^{-\lambda t}}{dt} \quad (3)$$

$$= \lambda\, e^{-\lambda t}$$

2. Hazard Rate Function

This is defined by $\lambda(t) = \frac{f(t)}{R(t)}$ (4)

Where $\lambda(t)$ is the items hazard rate or time dependent failure rate? By inserting Equation 3 into Equation 4

$$\lambda(t) = -\frac{1}{R(t)}\frac{dR(t)}{dt} \quad (5)$$

$$\lambda(t) = -\frac{1}{R(t)}\frac{e^{-\lambda t}}{dt} \quad (6)$$

$$\lambda(t) = \lambda \quad (7)$$

λ is the constant failure rate because it does not depend on time.

3. Mean Time to Failure

$$\text{MTTF} = \int_0^{\infty} R(t)\, d(t) \quad (8)$$

$$\text{MTTF} = \int_0^{\infty} e^{-\lambda t}\, d(t) \quad (9)$$

$$\text{MTTF} = \frac{1}{\lambda} \quad (10)$$

4. Failure Rate= λ

$$\lambda = \frac{\text{Fault Frequency}}{\text{Period of Occurrence}} \quad (11)$$

5. Mean Time between Failures (MTBF)

$$\text{MTBF} = \frac{\text{Total system operating hours}}{\text{Number of failures}} \quad (12)$$

6. 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 a function of equipment design, the expertise of the personnel and the tools available. Clearly a low value of MTTR indicates good maintainability [4][9].

7. 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[9][10].

$$\text{Availability (A)} = \frac{\text{MTBF - MTTR}}{\text{MTBF}} \quad (13)$$

8. Unavailability

Unavailable (UA) =1- Availability (A)

9. Customer Based Indices

The Utilities universally use different reliability indices for frequency and duration to quantify the performance of their systems [7][10].

10. System Average Interruption Duration Index (SAIDI)

SAIDI the total duration of sustained Customer power Interruptions within a given period divided by the total number of Customers served within the same period[8][9].

SAIDI = Σ (ri * Ni) / NT (14)

Where ri = Restoration time, minutes or hours

Ni = Total number of customers interrupted.

NT = Total number of customers served.

No = Number of interruptions.

IDi = Number of interrupting device.

T = Operations Time/ period under study, hours[8][9].

11. Customers Average Interruption Duration Index (CAIDI)

CAIDI is the total number of Customer Power Interruption Duration within a given period[8][9][10].

CAIDI = Σ (ri * Ni) / Σ (Ni) (15)

12. System average Interruption Frequency Index (SAIFI)

SAIFI is the total number of sustained Customer power Interruptions within a given time divided by the total number of Customers served within the same time[9][10].

SAIFI = Σ (Ni) / NT (16)

SAIFI= SAIDI / CAIDI (17)

13. Customer Average Interruption Frequency Index (CAIFI)

The CAIFI measures the average number of interruptions per customer interrupted per year. It is simply the number of interruptions that occurred divided by the number of customers affected by the interruptions[9][10].

CAIFI = Σ (No**)** / Σ (Ni**)** **(18)**

14. Customer Interrupted per Interruption Index (CIII)

CIII is the average number of customers interrupted during an outage[9][10]. CIII is the reciprocal of the CAIFI.

CIII = Σ (Ni) / Σ (No**)** **(19)**

CIII= 1/ SAIFI (20)

15. Momentary Average Interruption Frequency Index (MAIFI) MAIFI the total number of momentary Customer power Interruptions within a given period divided by the total number of Customers served within the same period[9][10].

MAIFI = Σ (IDi * Ni) / NT (21)

16. Average Service Availability Index (ASAI)

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ASAI is the ratio of the total number of customer hours that service was available during a given time period to the total customer hours demanded. This is sometimes called the service reliability index. The ASAI is usually calculated on either a monthly basis (730 hours) or a yearly basis (8,760 hours), but can be calculated for any time period[9][10].

ASAI = [1 – (Σ (ri * Ni) / (NT * T))] * 100 (22)

ASAI on an annual basis

ASAI = [(8,760 – SAIDI) / 8760] * 100 (23)

$$ASIFI=\frac{Connected\ KVA\ interrupted}{Total\ Connected\ KVA\ served}\ (/year) \quad (24)$$

VII. AYEDE 330/132KV SUBSTATION

Ayede 330/132KV substation consists of three numbers of 150MVA,330/132 KV step down transformers. The station was commissioned some years ago to feed six districts such as Ayede 132KV T/S , Jericho 132KV T/S, Ibadan North 132KV T/S, Sagamu 132KV T/S, Ijebu Ode 132KV and Iseyin 132KV T/S

S/N	STATION	33KV FEEDER
1	AYEDE 132kV T/S	Liberty
2		Oluyole
3		Iyaganku
4		Lanlate
5		Eleyele
6		Interchange
7		Apata
TOTAL		
8	IBADAN-NORTH 132kV T/S	N.B.L
9		Labo
10		lbadan North
11		I.I.T.A
12		Adogba
13		Asejire
14		Odogbo
15		UI
TOTAL		
16	JERICHO 132kV T/S	Agodi 1
17	Jericho	Agodi 2
18	Jericho	T1-15MVA 33/11KV
TOTAL		
19	SHAGAMU 132kV T/S	Shagamu
20		Real Infrastructure
21		Babcock
22		NNPC/Ogijo
23		Ikenne
24		Remo
25		Monarch
26		Celplass
TOTAL		
27	IJEBU-ODE 132kV T/S	Barrack
28		Ijebu-Igbo
29		Ijebu-ode
30		Epe
TOTAL		
31	ISEYIN 132kV T/S	Oyo
32	Iseyin	Iseyin
33	Iseyin	Shaki
TOTAL		

Table1: Ayede 330/132KV substation and six 132KV feeders

VIII. RESULT AND DISCUSSIONS

Table1 illustrates the monthly number of outages and outage duration that occurred from January to December, 2012.The month of April has the highest numbers of outage duration due to electrical and mechanical faults July has the least on a number of outages.

Table2: Monthly outage duration

Month, 2012	**Outage Duration(Hours)**	**No of Outages due to faults**
January	14.91	6
Febuary	7.5	2
March	8.55	3
April	26.78	4
May	30.6	4
June	18.77	6
July	1.65	4
August	1.43	3
September	14.88	4
October	1.44	3
November	2.22	3
December	3.93	8

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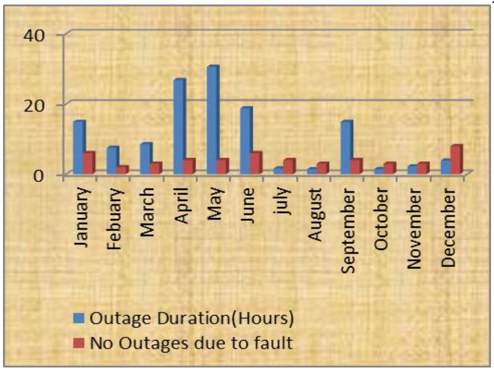

Fig 1: The numbers of power outage on monthly basis

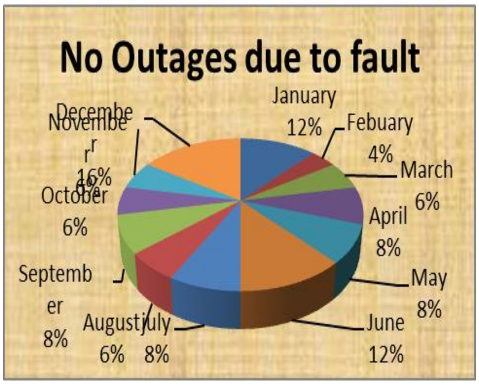

Fig 2: Percentage of outages due to faults on monthly basis

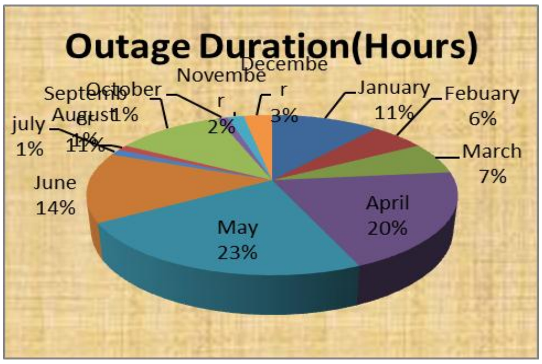

Fig 3: outages duration of ouatages on monthly

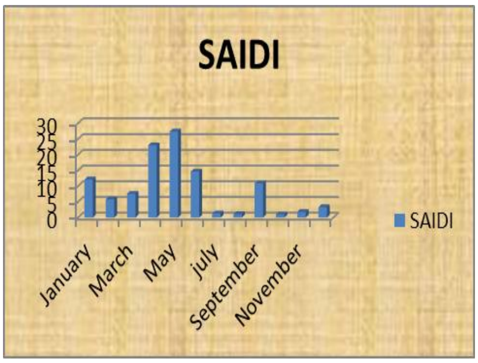

Fig 3: SAIDI from January to December

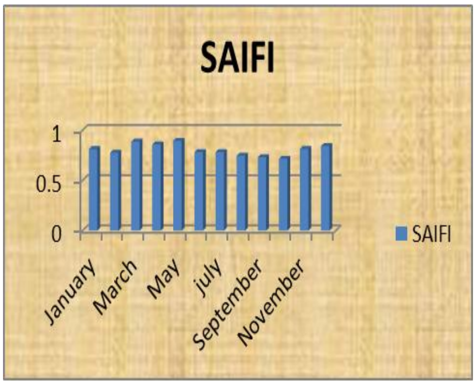

Fig 4: SAIFI from January to December

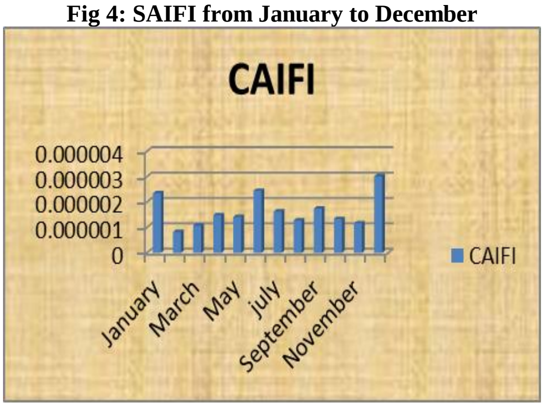

Fig 5: CAIFI from January to December

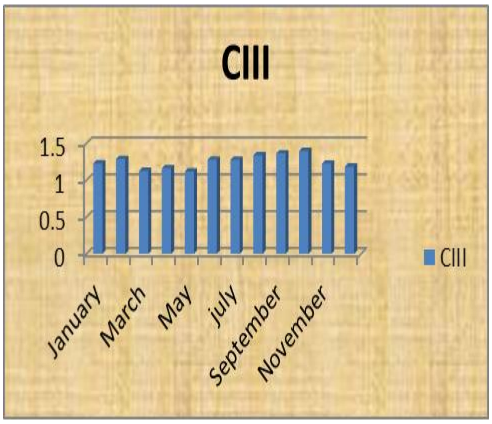

Fig 6: CIII from January to December

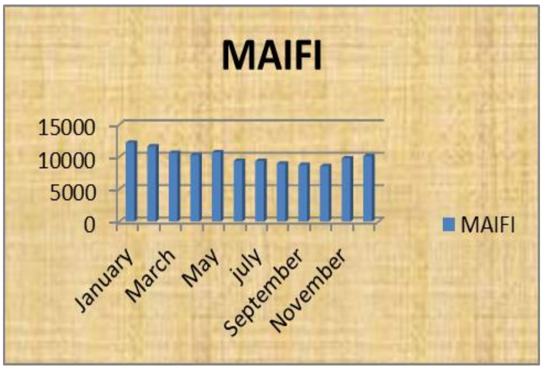

Fig 7: MAIFI from January to December

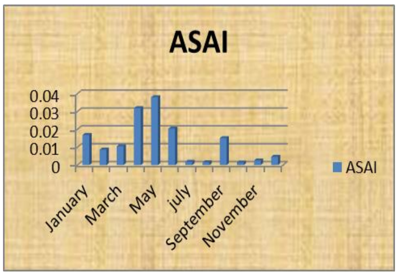

Fig 8: ASAI from January to December

IX. METHODS OF IMPROVING POWER SYSTEM RELIABILITY

The following techniques must be applied in order to increase reliability assessment of Ayede 330/132KV substation.

1. Application of different maintenance measures to improve power system reliability such as Corrective Maintenance, Routine Maintenance and Preventive Maintenance reduces both the momentary and sustained outage frequency.
2. By using different protective devices such as circuit breakers, relays, current transformers and voltage transformers. This will not only reduce the outage frequency and duration but increase the system availability
3. Better trees management and animal protection.
4. Application of power system automation, communication and control devices such as HMI, SCADA and DCS .These will lead to a total reduction of power outage duration.
5. Staff training and management.
6. Public information campaign is another way to reduce the power system outage frequency.
7. Equipment replacement programs and lightening arrester application.
8. A thorough construction work audits to ensure quality and periodic power system.

X. CONCLUSION

Reliability of 132/33KV substation used as a case study can be achieved by reducing the failure rate of the sensitive components or subsystems in the power system or by increasing the mean time between failures. Power system reliability can be achieved by reducing the mean down-time. Reliable electric power will reduce the costs and losses that are associated with inadequate and non-availability of electric power and the same time increase efficiency, productivity, effectiveness and the quality of power output. Reliability has a vital role to play on total optimization of hardships and disrupted services caused by power interruptions and reduction of expenditures made by the power consumers/end users to maintain and operate their generators owing to inadequate power supply. From the data obtained and analyzed, Ayede substation is facing power interruption during the peak periods. Hence, additional techniques are needed to increase reliability of the substation.

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AUTHOR'S PROFILE

Engr. Temitope Adefarati obtained OND at the Federal Polytechnic Ado-Ekiti (1998) and proceeded to the Federal University of Technology, Akure for his Bachelor of Engineering in Electrical and Electronics Engineering (2004). He later obtained a Master of Engineering in Electrical and Electronics Engineering (2010).Engr. Adefarati is Certified and registered by Council of Regulation of Engineering in Nigeria (COREN). He is a lecturer II and a researcher with the department of Electrical and Electronics Engineering with interest in Power System Reliability and Maintainability, Electromechanical devices and machines, Power System control and stability and Renewable Energy and Power Generation.

Engr Mr. Adedayo K. Babarinde obtained Bachelor of Technology in Electrical and Electronics Engineering from Ladoke Akintola University of Technology and proceeded to University of Lagos where he obtained Master of Science in Electrical and Electronics Engineering Mr. Babarinde is a Member, Nigerian Society of Engineers (MNSE) and Institute of Electrical

and Electronics Engineering.He is a lecturer and researcher with the department of Electrical and Electronics Engineering with interest in Control of Industrial drives, Industrial Automation, Application of Smart Grids in Wind power systems, Stochastic and Adaptive control

Engr. Sunday A. Oluwole obtained Bachelor of Engineering in Electrical and Electronics Engineering from University of Ado-Ekiti (2003) and proceeded to Federal University of Technology Akure where he obtained Master of Engineering in Electrical and Electronics Engineering (2010). He has being admitted for a Doctor of Philosophy degree program in University of Ibaban. Engr. Oluwole is Certified and registered by Council Of The Regulation Of Engineering In Nigeria (COREN), he is a Member, Nigerian Society of Engineers (MNSE) and Institute of Electrical and Electronic Engineers, (IEEE). He is a lecturer and researcher in the department of Electrical and Electronics Engineering with an interest in Signal processing for digital communications, Numerical Methods in Electromagnetic, Smart Antennas, Microwave Circuits and Adaptive Filters.

Engr. Olusuyi Kehinde is presently a Lecturer II in the Department of Electrical and Electronic Engineering, Federal University, Oye-Ekiti. He received his B. Eng and M. earns degrees in Electrical and Electronic Engineering from the Federal University of Technology, Akure. Professionally, Engr. Olusuyi is a Registered Engineer with the Council for The Regulation of Engineering in Nigeria (COREN) and also, a Corporate Member of The Nigerian Society of Engineers. Before joining the university, he worked as a Senior Engineer in Ekiti-State Local Government Service Commission. He also worked as a Senior Engineer in Planning unit of Federal University, Oye Ekiti where he was involved with planning and designing of Electrical works in the Institution’s infrastructure. Engr. The Olusuyi’s current research interest is in the area of Electrical Power Distribution Systems.