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Reliability Assessment of 132 kV Ikorodu Transmission Sub-Station, Nigeria

[1]Peter Alao, *[2]Alexander Okandeji, [3]Frank Onaifo, [4]Olaolu Folorunsho

[1]Department of Electrical and Electronic Engineering, Olabisi Onabanjo University, Ogun State, Nigeria.
[2]Department of Electrical and Electronic Engineering, University of Lagos, Akoka, Lagos, Nigeria.
[3]Department of Electrical and Electronic Engineering, Olabisi Onabanjo University, Ogun state, Nigeria.
[4]Department of Computer Engineering, Olabisi Onabanjo University, Ogun state, Nigeria.

*Corresponding Author's email: aokandeji@unilag.edu.ng

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Abstract

In this paper, the reliability performance of 132 kV feeders in Ikorodu Transmission substation located in Ikorodu, Lagos was assessed using statistical method. The daily outage data of the feeders for six months were collected and probabilistic approach was used to determine the reliability of the substation using indices such as availability, reliability, mean time to repair, mean time before failure, and failure rate. Results obtained from the study during the period under investigation showed that the reliability of the industrial feeder performed better than the other feeders with a reliability of 74.27%, and availability of 93.9%. Hence, this paper proposes a star bus topology arrangement of the transmission line feeders for improvement of the reliability of the network. This will ensure that a fault in a given feeder cannot totally prevent consumers from accessing electricity as consumers can access alternative feeders.

Keywords: Reliability, Tree topology, Transmission feeders, Switch gears.

1. Introduction

In Nigeria, daily electric power interruption is largely becoming a consistent phenomenon in wide area network of electricity transmission, and this is basically due to insufficient power generation, transmission faults, and distribution system faults and failures [1]. Power systems across the globe are built with the intent of providing uninterrupted power supply for the energy needs of modern times. Reliable electricity supply can only be possible if all the available channels of generation, transmission, and distribution are in excellent condition of delivery power [1]. Any challenges on any of this channel will result in a poor power supply.

Reliability assessment of transmission lines is not new as seen in the report of Adefarati [2] which presented research findings on the reliability assessment of Nigeria 330/132 kV substations, using Ayede 330/132 kV substation as a case study. The work highlighted ways of improving power supply by minimizing system failures which directly affects availability of electricity in the system. Work done by Samuel et al. [3], Schweitzer et al. [6] employed the use of fault tree analysis to determine the reliability of transmission line protection. The analysis focussed on the arrangement of the protection scheme such that any fault on one should not affect the performance of the entire system. The assessment also revealed that relays, as a result of lack of automatic supervision, were the major weakness of the protection scheme. In work of Samuel et al. [4], system collapse incidence on the 330 kV national grid was investigated and overhauling of all the electrical infrastructure was proposed to ensure better reliability of the system. On the other hand, Makarov et al. [5] developed an index that showed the direct and indirect relationship between power system reliability and security. Security of electrical installations is one of the fundamental ways of improving reliability of electricity supply. Work done by Ralli et al. [7] collected data outage for 132/33 kV high-voltage (HV) substation with reliability evaluated over some period of time to determine the area with lowest reliability. According to Ralli et al. [7], the area with little reliability should be given a boost by investing more on such areas to improve its reliability. Work done by Aibangbee [8] determined the reliability of the transmission substation using mean service reliability index, consumer mean interruption duration index, maximum system mean interruption duration index, and maximum system mean interruption frequency index. The reliability index was quite satisfactory. The statistical method used is not distinct from the commonly used statistical parameters of reliability, availability and failure rate. The paper did not highlight methods of improving the reliability of the system. Najeem et al. [1] worked extensively on outages of 330 kV and 132 kV generation and transmission systems. Result obtained by Najeem et al. [1] showed that there are more disturbances in the transmission system and suggested the use of protective circuit to maintain stable supply system. Okhaifoh et al. [9] evaluated the reliability performance of 33 kV Benin transmission system using the method outlined by Aibangbee [8]. It was recommended that transmission station should intensify efforts to reduce outages.

In contrast to the existing works, this paper determines the reliability of a transmission network and provides means of improving the availability of electricity supply. Since probabilistic (statistical) method is one of the best methods of determining the reliability of a system, this paper uses the statistical method to determine the reliability of a transmission network and provides means of improving the availability of electricity supply. Furthermore, this paper proposes star bus topology of transmission lines, where a given location is fed by at least two transmission or feeder lines to increase its overall availability thereby increasing its reliability.

2. Material and Method

This paper considers the reliability and availability evaluation of Ikorodu transmission substation using the statistical calculation method.

2.1 Data Collection

The daily data of outages and down time losses were collected from Ikorodu Transmission Substation for a period of six-months (from January to June 2018) for the six feeders namely: Industrial, Agege, Owubu, Obasha, Maryland, Pulkit of the 132 kV Ikorodu transmission substation. The data for the six months period are presented in Table 2.1 to Table 2.6. Outages recorded in the utility outage logbook were as a result of the feedback technology used by the transmission station. The substation system, unlike other substations in Nigeria, has intelligent devices that notifies the transmission company whenever there is failure of any equipment or any form of interruption to the delivery of electricity to the distribution stations.

Only forced outages, outages due to faults and failures, were taken into consideration for this research work to avoid extraneous circumstances. Outages due to scheduled maintenance and load shedding were not taken into consideration. This is so because scheduled outage or load shedding in the substation is intentional and cannot be attributed to any component failure which makes it hard for analysis to pin-point weak component if used. Effectively, this research work focuses on the reliability of the substation's transmission line.

Table 2.1: January Report Data

Transmission Feeder Line	Total Outage	Total outage duration (h)
Industrial	5	31
Agege	13	90
Owubu	10	200
Obasha	6	120
Maryland	5	99
Pulkit	9	156

3. Data Analysis and Presentation

In this section, the analysis of data, which involves series of mathematical computations focused on the determination of the failure rate, the mean time to repair, mean time before failure, the availability and the reliability of the 132 kV, outgoing feeders from Ikorodu electrical transmission company substation for the six months period is considered. The results were also interpreted graphically using Bar chart present in the Microsoft software.

Table 2.2: February Report Data

Transmission Feeder Line	Total Outage	Total Outage Duration (h)
Industrial	6	46
Agege	8	132
Owubu	5	178
Obasha	9	98
Maryland	7	120
Pulkit	10	70

Table 2.3: March Report Data

Transmission Feeder Line	Total Outage	Total outage duration (h)
Industrial	4	40
Agege	9	155
Owubu	11	120
Obasha	8	140
Maryland	7	116
Pulkit	9	90

Table 2.4: April Report Data

Transmission Feeder Line	Total Outage	Total outage duration (h)
Industrial	4	60
Agege	8	199
Owubu	10	180
Obasha	7	176
MaryLand	8	118
Pulkit	7	132

Table 2.5: May Report Data

Transmission Feeder Line	Total Outage	Total outage duration (h)
Industrial	5	60
Agege	10	134
Owubu	9	142
Obasha	8	126
MaryLand	6	100
Pulkit	7	96

Table 2.6: June Report Data

Transmission Feeder Line	Total Outage	Total outage duration (h)
Industrial	6	30
Agege	10	151
Owubu	8	146
Obasha	7	132
MaryLand	6	99
Pulkit	5	111

3.1 Mean Time before Failure Data (MTBF)

The MTBF refers to the predicted elapsed time between inherent failures of a system, during normal system operation. MTBF, which is the arithmetic mean (average) time between failures of a system [10] was calculated using (1).

$$\text{MTBF} = \frac{Total\ System\ Operating\ hours}{Number\ of\ Failures} \quad (1)$$

Table 3.1 shows the resulting MTBF of the feeders for the 132-kV substation, and Figure 3.1 is a graphical presentation of the results.

Table 3.1: Mean Time between Failure Summary for the month of January, 2018 to June, 2018

Feeder	MTBF					
	January	February	March	April	May	June
Industrial	142.85	111.11	180	200	142.85	125
Agege	58.82	84	82.67	90	76.92	72
Owubu	76.92	134.4	66.67	72	83.33	90
Obasha	125	76.92	90.9	111.11	93	111.11
Maryland	142.85	100	111.11	90.0	124	125
Pulkit	83.88	66.67	83.33	111.11	111.11	142

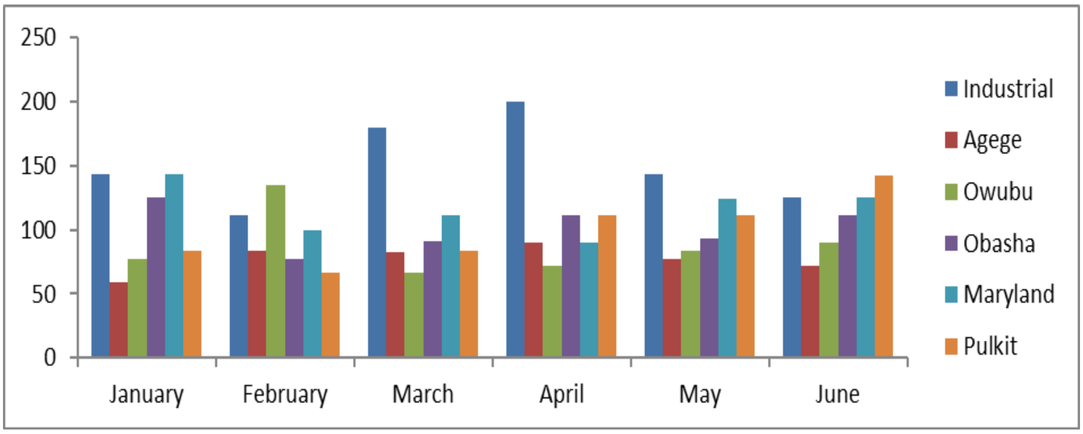

Figure 3.1: Mean Time between Failures for the month January 2018 to June 2018

3.2 Mean Time to Repair (MTTR)

Mean Time to Repair which refers to the average time it takes to detect an issue, diagnose the problem, repair the fault and return the system to being fully functional [10] was calculated using (2). Table 3.2 shows the resulting MTTR of the feeders for the 132 kV substation, and Figure 3.2 is a graphical presentation of the results.

$$MTTR = \frac{Total\ Duration\ of\ Outages}{Frequency\ of\ Outages} \quad (2)$$

Table 3.2: Mean Time to Repair Data for the month of January, 2018 to June, 2018

Feeder	MTTR					
	January	February	March	April	May	June
Industrial	6.2	7.67	10	15	12	5
Agege	6.92	16.5	17.22	24.88	13.4	15.1
Owubu	20	35.6	10.9	18	15.78	18.25
Obasha	20	10.89	17.5	24.14	15.75	18.85
Maryland	19.8	17.14	16.57	14.75	21.67	16.5
Pulkit	17.33	7	10	18.85	13.71	22.2

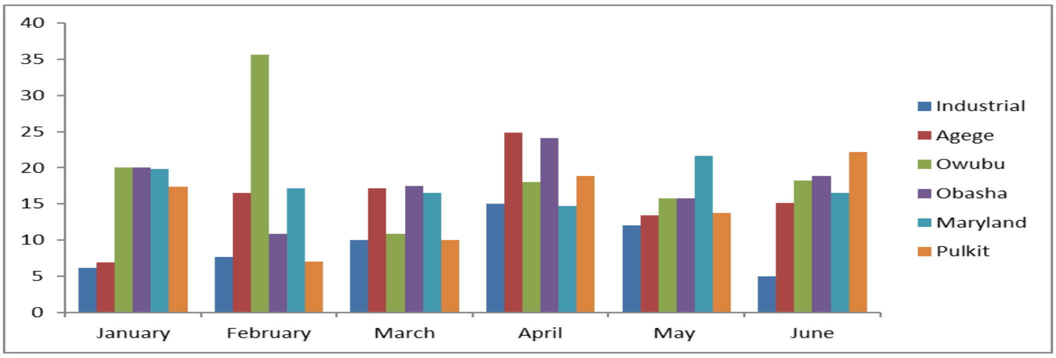

Figure 3.2: Mean Time to Repair for the month January, 2018 to June, 2018

3.3 Availability

Availability which refers to the quality or state of being available [10] was calculated using (3). Table 3.3 shows the resulting availability of the feeders for the 132 kV substation, and Figure 3.3 is a graphical presentation of the results.

$$Availability = \frac{MTBF}{MTBF + MTTR} \quad (3)$$

Table 3.3: Availability data for the month of January, 2018 to June, 2018.

Feeders	Availability					
	January	**February**	**March**	**April**	**May**	**June**
Industrial	96%	93%	94.44%	92%	92%	96%
Agege	88%	80%	79.17%	72%	83%	79%
Owubu	74%	74%	84%	75%	81%	80%
Obasha	84%	86%	80%	77%	83.08%	83%
Maryland	86%	83%	85%	84%	83%	87%
Pilkit	75%	89%	88%	83%	88%	84%

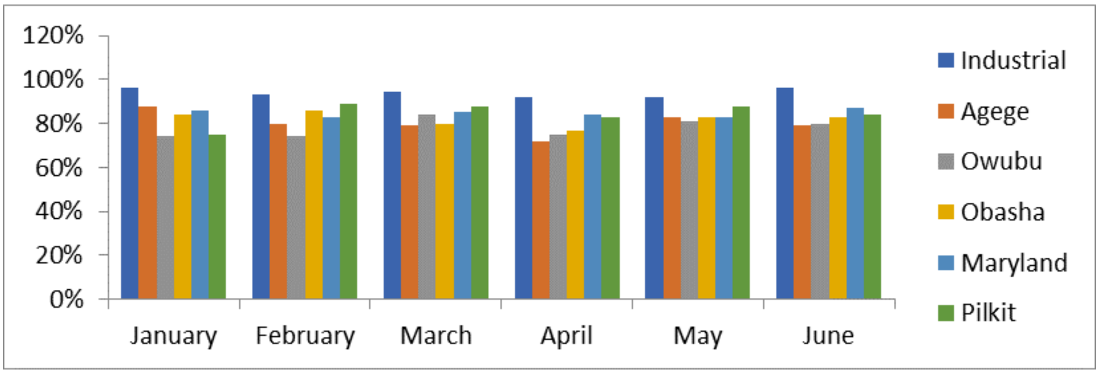

Figure 3.3: Availability for the month of January, 2018 to June, 2018

Table 3.4: Reliability Data for the Month of January, 2018 to June, 2018.

Feeders	Reliability					
	January	**February**	**March**	**April**	**May**	**June**
Industrial	80.49%	66%	80.09%	74.08%	66%	79%
Agege	21.65%	20.77%	15.35%	11%	17.50%	12.28%
Owubu	7.42%	26.59%	16.54%	8.20%	18.19%	19.75%
Obasha	38%	27%	21%	21%	26%	30%
Maryland	50%	30%	35%	27%	45%	45%
Pulkit	15.40%	35%	34%	30%	42%	46%

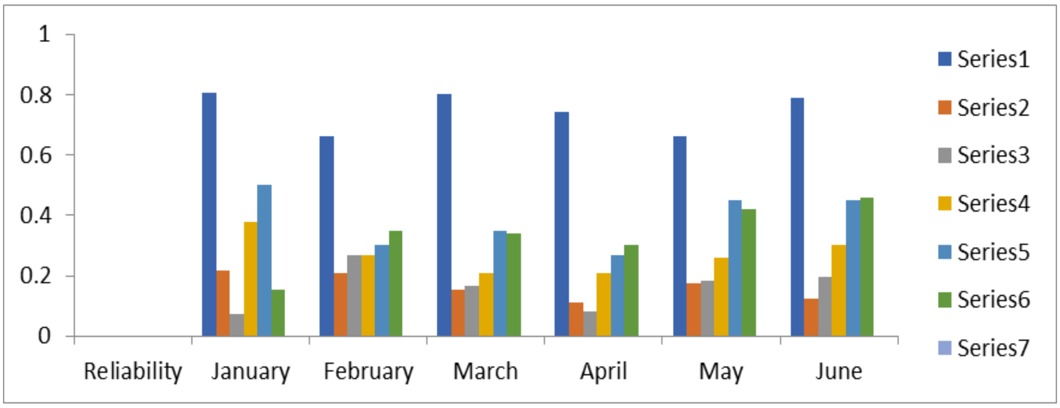

Figure 3.4: Reliability Data for the Month of January, 2018 to June, 2018

3.4 Reliability Data

Reliability which refers to the quality or state of being reliable [10] was calculated using (4). Table 3.4 shows the resulting reliability of the feeders for the 132 kV substation, and Figure 3.4 is a graphical presentation of the results.

$$Reliability\ (R) = e^{-\mathrm{t/MTBF}} \quad (4)$$

3.5 Failure Rate

Failure rate which is the frequency with which a system or component fails, expressed in failures per unit of time [10] was calculated using (5). Table 3.5 shows the resulting failure rate of the feeders for the 132 kV substation, and Figure 3.5 is a graphical presentation of the results.

$$Failure\ Rate = \frac{Number\ of\ outage\ on\ component\ in\ a\ given\ period}{Total\ Time\ component\ is\ in\ operation} \quad (5)$$

Table 3.5: Failure rate for the month of January, 2018 to June, 2018.

Feeders	**Failure Rate**					
	January	**February**	**March**	**April**	**May**	**June**
Industrial	0.007	0.009	0.005	0.006	0.007	0.008
Agege	0.017	0.011	0.012	0.011	0.013	0.014
Owubu	0.013	0.007	0.015	0.014	0.012	0.011
Obasha	0.008	0.013	0.011	0.009	0.011	0.009
Maryland	0.007	0.011	0.009	0.011	0.008	0.008
Pulkit	0.012	0.015	0.012	0.009	0.009	0.007

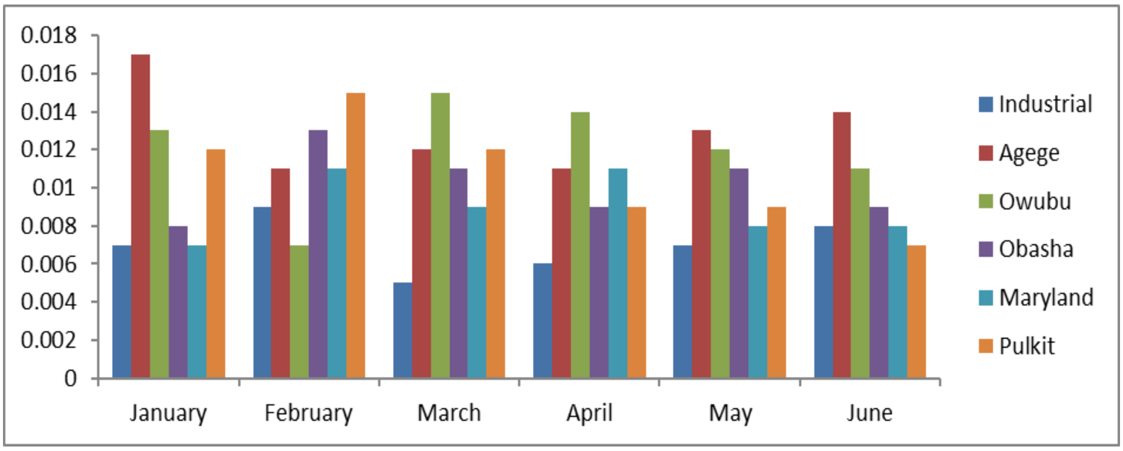

Figure 3.5: Failure Rate for the Month of January, 2018 to June, 2018

3.6 Discussion and Findings

Industrial feeder has the least failure rate for January, March, April and May as shown in Table 3.5. Also, it was more reliable for the six months duration compared to the other feeders as shown in Table 3.4. Industrial feeder has the highest availability for the six months period as shown in Table 3.3. It also has the lowest Mean Time to Repair for January, March, May and June as shown in Table 3.2. Industrial feeder also has the highest operating hours as the Mean Time between failures was one of the highest for January, March, April, and May as shown in Table 3.1. Therefore, Industrial feeder performed better than the other feeders as shown in Table 3.1 to Table 3.5. This is due to the fact that Industrial feeders has the least failure rate, more reliable with a high reliability value, more available, least mean time to repair, and has higher operating hours with a higher mean time between failure. In summary, Industrial feeder has an average availability of 93.9%, reliability of 74.27%, and average mean time to repair of 9.14hours. Agege and Owubu feeders performed least compared to the other feeders as shown in Table 3.1 to Table 3.5. The Feeder from Agege has an availability of 80.19% while Owubu feeder has the availability of 78% as shown in Table 3.3. The effect of this can only be felt by the amount of power made available to the feeders. The least failure rate occurred at the Industrial Feeder. The lower the failure rate, the higher the reliability and vice versa.

4. Conclusion

The study shows the reliability of the industrial feeder of Ikorodu sub-station is 74.27%. The paper, therefore, proposes a star bus topology arrangement of transmission line feeders where all feeders from a substation are linked together through switchgear. This will increase the availability of supply.

References

1. Najeem OA, Banji AO. Outage Analysis and system Disturbances on 330 kV and 132kV Transmission System in Nigeria. *International Journal of Science and Engineering investigation.* 2020; 9(96): 43-47.
2. Adefarati T. Reliability Evaluation of Ayede 330/132 kV Substation. *International Journal of Engineering and Innovative Technology*. 2014; 4(4): 86-91.
3. Samuel IA, Katende A.Fault Tree-based Reliability Assessment of 132 kV Transmission Line protection scheme. *America Journal of Engineering Research.* 2013; 2(10): 100-106.
4. Samuel I, Katende SA, Daramola SA, Awelewa A. Review of System Collapse incidences on the 330 kV Nigerian National Grid. *International Journal of Engineering Science invention.* 2014; 3(4), 55-59.
5. Makarov YV, Maharar NS. A Generalized Power System Reliability and Security Index. In: *Proceedings of IEEE Power Technology conference*, Budapest, Hungary; Aug. 29-Sep. 2, 1999.
6. Schweitzer EO, Flemming B, Lee TJ, Anderson PM. Reliability Analysis of a Transmission Protection using Fault Tree Methods. In Proceedings of Southern African Conference on Power System Protection, Nov. 3-4, 1998, Midrand South Africa.
7. Ralli S, Devchandra SP, Rajen P. Reliability Evaluation of a 132/33Kv HV Substation. *International Journal on Current Science and Technology*. 2016; 4: 1-7.
8. Aibangbee JO, Chukwuemeka IN. (2017) Reliability Assessment of Apo 132/33 kVA Electric Transmission Substation Abuja. *American Journal of Engineering Research*. 2017; 6(8):170-176.
9. Okhaifoh JE, Aghelegin J. Reliability Assessment of the Etete and GRA 33 kV Feeder in Benin Transmission Station, Nigeria. Advances in Electrical and Telecommunication Engineering. 2018; 1(2): 85-92.
10. Wang T, Wu Y. The Reliability Evaluating Method Considering Component Aging for Distribution Network. *Elsevier energy procedia.* 2012; 16:1613-1618.