ISSN: 2141-2987

JOURNAL OF THE NIGERIAN INSTITUTION OF MECHANICAL ENGINEERS (JNIMechE)

Journal homepage: https://journal.nimechehq.org

Volume 12
Issue 01

Date Received: July, 2024
Date Published: October 2024

Reliability Assessment of 11kv Feeders in Benin City, Edo State, Nigeria using Distribution Free Method.

[1]O.C. Onuigbo and [2]R.O. Edokpia

[1]Department of Mechanical Engineering, School of Engineering, Federal Polytechnic Ohodo, P.M.B. 01801, Enugu, Enugu State, Nigeria, 07068652572

[2]Department of Production Engineering, Faculty of Engineering, University of Benin, PMB 1154, Benin City, Edo State, Nigeria, 08023368811
(ralph.edokpia@uniben.edu and ositadimma.onuigbo@gmail.com)
Corresponding Author (Email: ositadimma.onuigbo@gmail.com. Phone: Tel: +234 7068652572)

ABS TRACT

Power supply in Nigeria has been experiencing incessant interruptions due to failures in the distribution system. Reliability of the power system is essential in meeting customers demand. The reliability of three 11kv feeder in Benin Electricity Distribution Company (BEDC), Edo State Nigeria is evaluated in this study. the failure data which includes; failure time, time outage was restored, causes of failure from the Injection substations of the three feeders for the year, 2020 and 2021 was collated, collected and applied. Daily, Monthly and Yearly time between failures (MTBF) and failure rate were also calculated after which 'distribution free method was deployed in the analysis. The results of the analysis revealed that the year 2020 had a better reliability and this implies that reliability decreases with time.

Keywords: Failure time, time between failures (TBF), Failure Data, Reliability, and Distribution Free Method.

1. INTRODUCTION

The unreliable electrical power supply in Nigeria has made it one of the most lucrative markets for generator dealers worldwide [1]. Over the half century, power systems have expanded exponentially worldwide, paving the way for industrial development. [2]. There has been modification of Electric Power System since the year 1896 till date. Over the years, there has been restructuring and reorganization of power sector in Nigeria aimed at improving the energy demands [3, 4]. However, the energy demands of the country are yet to be met [5]. The power supply chain was unbundled and decentralized with the emergence of Generation companies (GENCOS), Transmission Company of Nigeria (TCN), and Distribution Companies (DISCOS). And each of these Unbundle companies has their own line of responsibilities to ensure that there is a continued power supply and meeting the ongoing sustainable development goals [6].

A stable and reliable electric power supply system is a pre-requisite for the technological and economic growth of any nation [7]. Nigeria's power supply has been experiencing incessant power interruptions caused by failures in

the generation, transmission, and distribution *system. Electric power is a vital element in any modern economy. The maint*ainability of reliable power supply at a reasonable cost is crucial for the economic growth and development of a country [8]. The satisfaction and importance of maintainability of electricity supply to consumers at the time of usage cannot be over-emphasized. A reliable power supply boost productivity and reduces waste in any system [9, 10, 11]. The electric power supply in the feeder under study has become alarming and a source of concern to all stakeholders.

Distribution systems are large-scale systems that comprises many components and assets to provide reliable energy and power to customers [12]. Although relevance of distribution system fault/failure are much greater than other parts of power systems like generation and transmission. Studies shows that around 90% of all customer reliability problems are due to the problem in the distribution system [8] hence, improving 'response to faults' in a distribution system is the key to improving customer reliability. Many power systems studies have carried out different optimization studies via heuristic, network configuration, integration of renewable energy resources, and coordination of distributed generation aimed at improving the system network. Therefore, improving distribution reliability through 'maintainability assessment' is the key to improving customer reliability [8, 13, 14].

The aim of this research is to carry out the reliability of the feeders under study using distribution free method. Despite the realization of the importance of the distribution sector, the performances of Nigerian distribution utilities of these feeders have not been measured empirically. The performance evaluation of the distribution sector is important in order to assess the impact of reform measures. The computation of reliability of electric power supply is crucial for economic development because of electricity's role as a powerful engine of social and economic change. 78% of firms in Africa experienced power outages yearly. Also, 41% of firms identified electricity as a major constraint to their business operations [15, 16, 17, 18]. The predominant factor that differentiate modern man from his ancestor is the ability to manage energy/power [18].

Reliability assessments have been conducted both domestically and internationally for electric power generation, transmission, and distribution. Upon reviewing various articles and research on reliability assessments, it is clear that only a few have focused on the feeders of the distribution system. And none have applied the concept of the 'distribution-free method' to the feeders in the Benin Electricity Distribution network, specifically G.R.A Etete, Ihama, and Oko in Edo State, Nigeria.

2.0. METHODOLOGY

2.1. Area of Study

This study will analyze the reliability of three feeders (G.R.A Etete, Ihama, and Oko) within the Government Reserve Area (G.R.A) Business Unit using the Distribution-Free Method, as illustrated in Figure 1 below.

2.1.1. G.R.A Etete 11KV Feeder

The feeder originates from the G.R.A Injection Sub-station and serves both residential and commercial customers in the area. It has a total customer base of 7,023 customers. There are 104 transformers connected to the feeder, with 83 being private or point load transformers and the remaining 21 being public transformers. Notably, International Trade Network Limited, various companies, hotels, and residential customers are connected to this feeder [19].

2.1.2. Ihama 11KV Feeder

The feeder originates from the Etete Injection Sub-station, serving both residential and commercial customers in the area. It supports a total customer population of 5,513. The feeder is connected to 82 transformers, with 28 being private or point load transformers and the remaining 54 being public transformers. Notably, the NNPC Club House, House of Tara, Military Base Hospital, several hotels, and residential customers are connected to this feeder [19].

2.1.3. Oko 11KV Feeder

The feeder originates from the Iyekogba Injection Sub-station and serves both residential and commercial customers in the area, with a total customer population of 6,364. It is connected to 44 transformers, 21 of which are private or point load transformers, while the remaining 23 are public transformers. Notably, the INEC office, Benin City Airport, Oko Wines and Sports Shop, and many other establishments are connected to this feeder. [19].

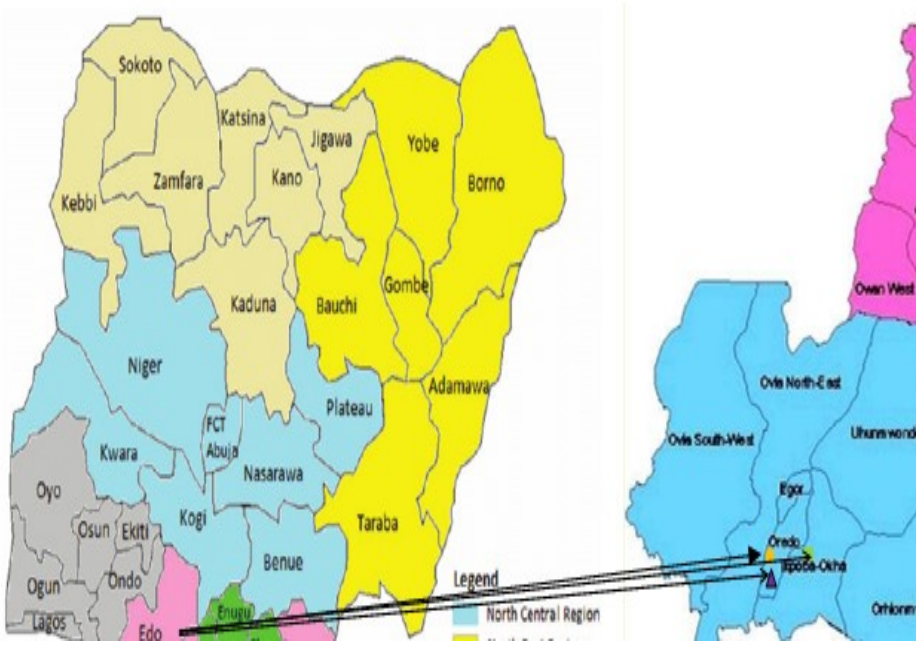


Figure 1: Maps indicating the location of the three feeders in Benin City, Edo State, Nigeria.

2.2. Data Collection and Analysis

The interruption data (comprising of the time power went off and the time it was restored) were gotten from the substation of the feeders Feeder [19]. The analysis started with computing the failure time which implies the duration of power before failure for each period of interruptions in the year 2020 and 2021. After which Distribution Free method was deployed to compute and analyse the reliability for each of the two-years using Spreadsheet (Microsoft Excel). The flow chart of the research is represented in figure 2 below.

2.2.1. Reliability Function

Reliability is defined as the probability that a system (component) will function over some period. It is defined by a function R (t). For some certain number of failures (n)

$$F(t_i) = \frac{i}{n+1} \quad (1)$$

$$R(t_i) = 1 - \frac{i}{n+1} = \frac{n+1-i}{n+1} \quad (2)$$

$$f(t) = \frac{R(t_{i+1}) - R(t_i)}{t_{i+1} - t_i} \quad (3)$$

$$f(t) = \frac{1}{(t_{i+1} - t_i)(n+1)} \quad (4)$$

Where n is the number of failure/repair times

t_i is the time of failure of ith unit

t_n is the time of failure of nth unit

$R(t_i)$ is the reliability at the ith time

$F(t_i)$ is the Failure at the ith time

$f(t)$ is the probability density function (PDF)

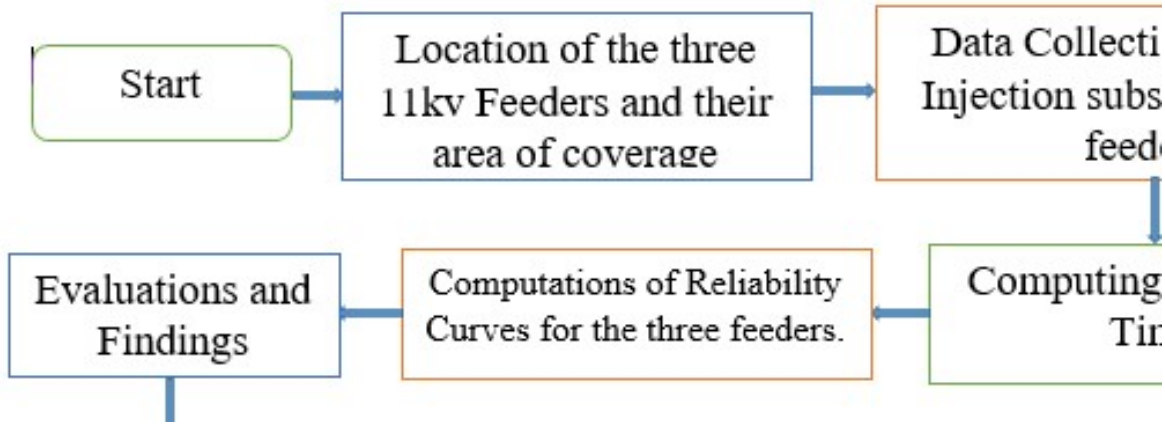


Figure 2: Research flow diagram [20, 21, 22, 23, 25]

3.0. RESULTS AND DISCUSSION

Figure 3 describes the reliability curves for G.R.A Etete for the year 2020. It can be deduced from the curve that reliability R (t) is a step function that decreased by 1/ (n + 1) just after each observed failure time of 372.60 hours. The curve shows the values of reliability over time, showing trends in the system's failure behaviour.

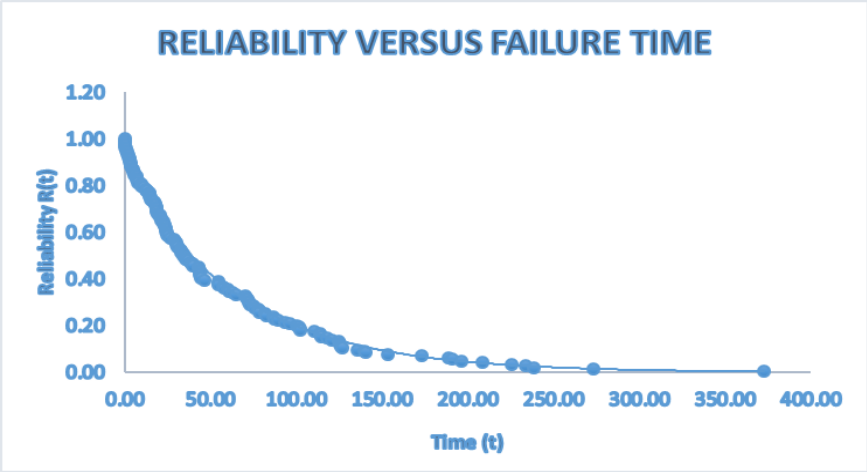


Figure 3: Reliability curve for G.R.A Etete 2020

Figure 4 describes the reliability curves for G.R.A Etete for the year 2021. It can be deduced from the curve that reliability R (t) is a step function that decreased by 1/ (n + 1) just after each observed failure time of 357.27 hours. The curve shows the values of reliability over time, showing trends in the system's failure behavior. This indicates that G.R.A Etete feeder had a better performance in the year 2021 than the year 2020.

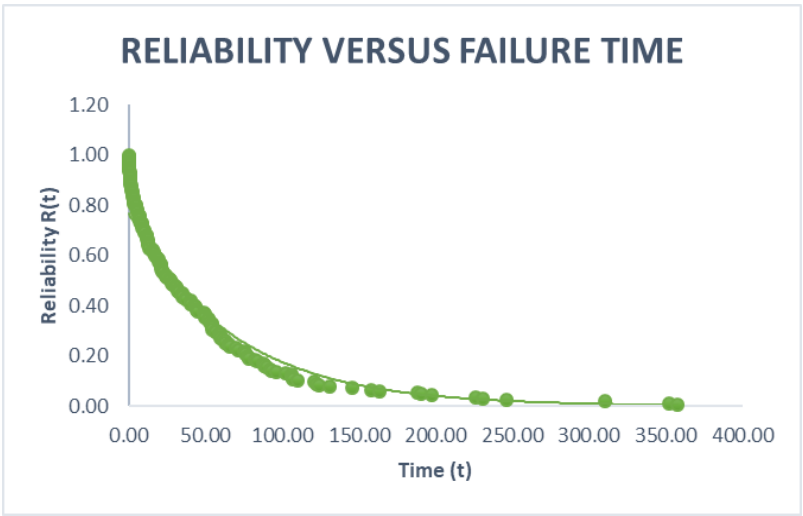


Figure 4: Reliability curve for G.R.A Etete 2021

Figure 5 describes the reliability curves for Ihama for the year 2020. It can be deduced from the curve that reliability R (t) is a step function that decreased by 1/ (n + 1) just after each observed failure time of 308.23 hours. The curve shows the values of reliability over time, showing trends in the system's failure behaviour.

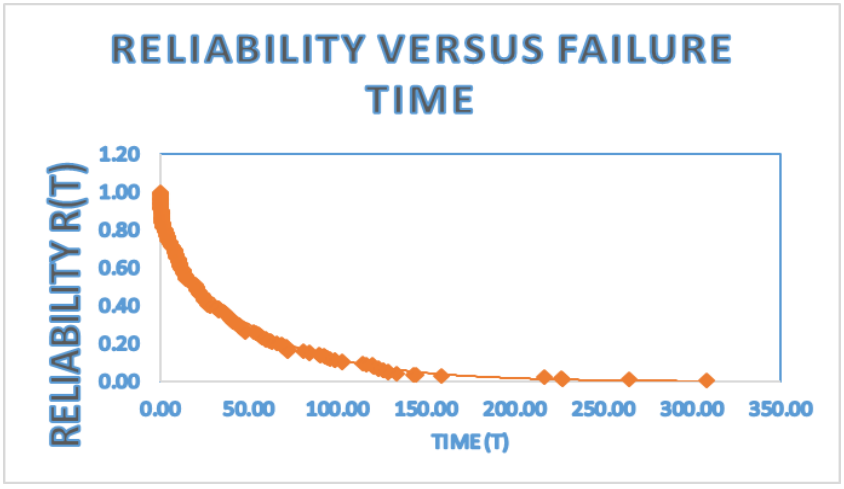


Figure 5: Reliability curve for Ihama 2020

Figure 6 describes the reliability curves for Ihama for the year 2021. It can be deduced from the curve that reliability R (t) is a step function that decreased by 1/ (n + 1) just after each observed failure time of 216.72 hours. The curve shows the values of reliability over time, showing trends in the system's failure behavior. This indicates that Ihama feeder had a better performance in the year 2021 than the year 2020

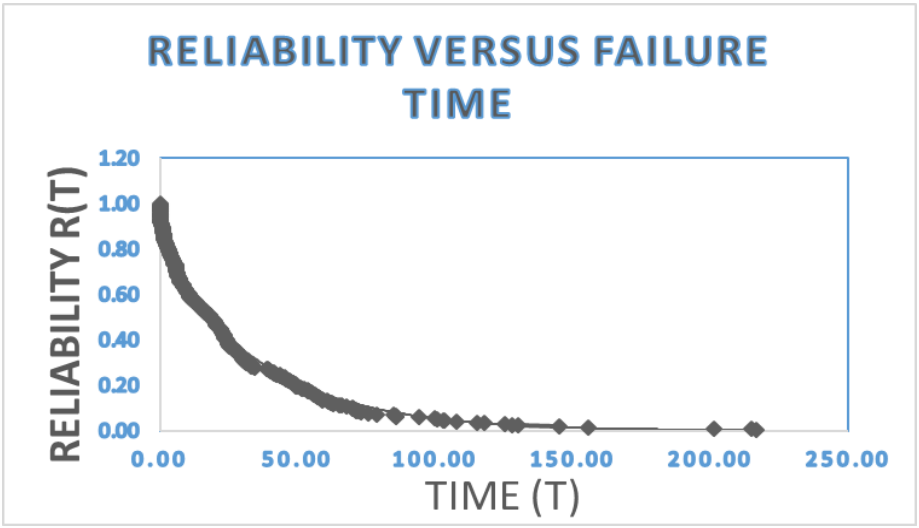


Figure 6: Reliability curve for Ihama, 2021

Figure 7 describes the reliability curves for Oko for the year 2020. It can be deduced from the curve that reliability R (t) is a step function that decreased by 1/ (n + 1) just after each observed failure time of 482.30 hours. The curve shows the values of reliability over time, showing trends in the system's failure behaviour.

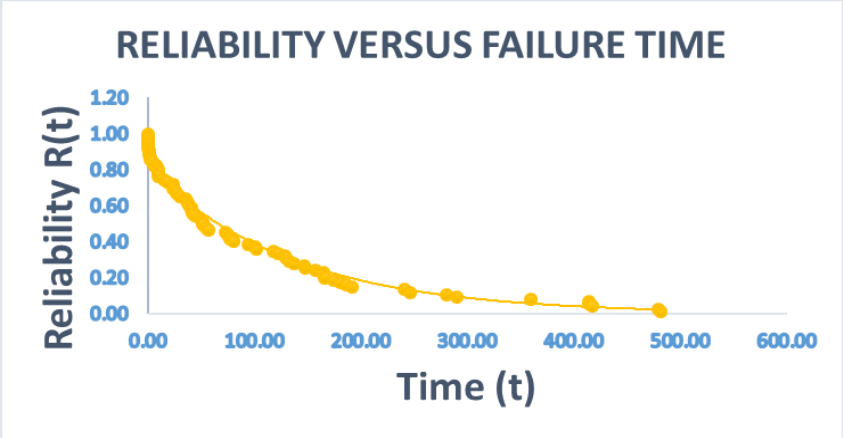


Figure 7: Reliability curve for Oko, 2020

Figure 8 describes the reliability curves for Oko for the year 2021. It can be deduced from the curve that reliability R (t) is a step function that decreased by 1/ (n + 1) just after each observed failure time of 409.87 hours. The curve shows the values of reliability over time, showing trends in the system's failure behavior. This indicates that Ihama feeder had a better performance in the year 2021 than the year 2020

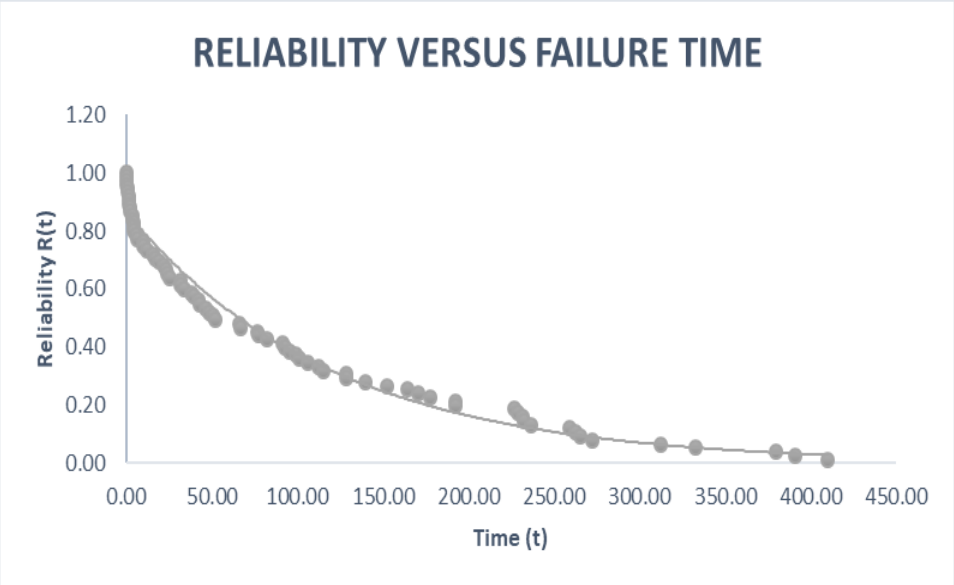


Figure 8: Reliability curve for Oko, 2021

4.0. CONCLUSION

The analysis was conducted on Three (3) 11 KV feeders (G.R.A Etete, Ihama, and Oko) in Benin Electric Distribution Company (BEDC) which covers four states in Nigeria (Edo, Ekiti, Ondo, and Delta). Two (2) years failure data for the feeder (which consist of the following; time of outage, time outage was restored, causes of outages, load interrupted) were collated and collected from their Injection sub-station.

'Failure time (t)' were computed from the data collected after which 'time between failure (TBF) and Reliability R (t) were calculated. Reliability R (t) were plotted against failure time t for the year 2020, and 2021. The analysis from this study revealed that the reliability R (t) is a step function that decreased by 1/ (n + 1). There were decrease in the performance of the three feeders in the year 2021. This can be attributed to the fact that the feeders have less loads in the year 2021 as a result of Covid-19 pandemic.

5.0 REFERENCES

[1] Airoboman, A.E., Ogujor, E.A., and Okakwu, I.K. "Reliability Analysis of Power System Network: A Case Study of Transmission Company of Nigeria, Benin City, International conference on African development issues, pp.2-7, 2nd Edition, 2017. DOI:10.1109/PowerAfrica.2017.7991206.

[2] Alvarez-Alvarado M.S., Donaldson D.L, Recalde A.A., Noriega H.H., Khan Z.A., Washington V. and Rodriguez-Gallegos C.D. "Power System Reliability and Maintenance Evolution: A Critical Review and Future Perspectives", Open Access Journal, Vol 10, pp 51922-51950, 2022.

[3] Adejumobi, I.A. "Electricity, Man, and Development: The Complexity of the Distribution System Management in a Power Network", *FUNAB Inaugural lecture*, Series No 64, Pp.7-81, ISBN: 978-978-992-948-1, 2021.

[4] Akpan, P. "Electricity and Water supply in Nigeria: A case study of Markudi Town", *Journal of Historical Society of Nigeria*, Vol.16, pp. 48-71, 2006.

[5] Komolafe O.M. and Udofia K.M. "Review of Electrical Energy losses in Nigeria", *Nigeria Journal of Technology* (NIJOTECH), Vol 39, No 1, pp. 246-254, ISSN: 0331-8443, 2020

[6] Ukoko J., Odogwu T. and Adenusi O. "Power Discos Still Fumbling Six Months After" *Daily News watch* April 5, 2014 (http://www.mydailynewswatching.com/power-Discos-still-fumbling-six-months/), retrieved: 3rd May, 2014.

[7] Ukoima K.N. and Ekwe O.A. "Review of Impact of Electricity on Economic Growth: A Nigerian Case Study", *IOSR Journal of Electrical and Electronics Engineering* (IOSR-JEEE), Vol 14, Issue 1, pp. 28-34, ISSN: 2320-3331, 2019

[8] Nweke, J.N., Gusau, A.G, and Isah, L. M. "Reliability and Protection in Distribution Power System considering Customer-Based Indices", Nigerian Journal of Technology (NIJOTECH), Vol.39, No 4, pp.1198-1205, 2020

[9] Akpojedje F.O., Abu Y.O., and Onowighose. O. "Tripping Profile Analysis of the 33KV Feeder of Ugbowo 2 x 15 MVA, 33/11 kV Injection Substation", *Equity Journal of Science and Technology*, Vol 8 No 1, pp 19 – 26, ISSN 2354-1814; E-ISSN 2682-5961, 2021. Available online at www.equijost.com.

[10] Ohajianya, A.C., Abumere, O.E., Owate, I.O., and Osarolube, E. "Erratic Power Supply in Nigeria: Causes and Solutions", *International Journal of Engineering Science and Innovation,* Vol 3, Issue 7, and pp.51-55, ISSN: 2319 – 6726, 2014.

[11] Momoh Z., Anuga J.A., and Obidi J.A. "Implications of Poor Electricity Supply on Nigeria's National Development", Vol.6, No.2, PP.31-40, ISSN (p): 2312-5659, 2018. https://doi.org/10.18488/journal.73.2018.62.31.40.

[12] Olajuyin E. A. and Eniola O. "Reliability and Maintenance of Assets in Electric Power Distribution Network", *Current Journal of Applied Science and Technology*, Vol. 41, No. 9, pp 8-17, *Article no.CJAST.80761* ISSN*: 2457-1024, 2022*.

[13]. Mirhosseini M. and Keynia F. "Asset management and maintenance programming for Power distribution systems: a review", pp 2287–2297, 2021. https://doi.org/10.1049/gtd2.12177.

[14] Mirhosseini M., Azim Heydari1 A., 2 · Davide Astiaso Garcia D. A., Mancini F. and Keynia, F. "Reliability based maintenance programming by a new index for electrical Distribution system components ranking", *Optimisation and Engineering, Research Article*, pp. 2315-2333, 2022 https://doi.org/10.1007/s11081-022-09767-8.

[15] Oseni, M.O., & Pollitt, M.G. "A firm-level analysis of outage loss differentials and Self-generation: Evidence from African business enterprises", *Energy Economics* (52), 2015

[16]. Airoboman A. E., Salihu-Ango H., Ibrahim, S. O and Ahmed H. "Risk Assessment of Injection Substation within Kaduna Metropolis using Failure Mode and Effect Critical Analysis (FMECA)", *Journal of Sciecnce Technology and Education*, Vol 9, No 2, pp 308-319, ISSN: 2277-0011, 2021; Journal homepage: www.atbuftejoste.com.

[17] Airoboman A.E. "Reliability Assessment of Power System Network: A Detailed Review", *International Journal of Engineering Technologies-IJET* Vol.7, No.4, pp90-103, 2022.

[18] Olusuyi K., Oluwole A.S., Temitope Adefarati T. and Babarinde A.K. (2014). "A fault Analysis of 11kv distribution system (a case study of Ado Ekiti Electrical Power Distribution District)", *American Journal of Electrical Power and Energy Systems*.Vol.3, No. 2, pp. 27-36, 2014, https://doi.org/10.11648/j.epes.20140302.13.

[19] Log Book Data Outages of Benin Electricity Distribution Company Plc, G.R.A Unit, (G.R.A, Etete, and Iyekogba Injection Sub-station), 2020 and 2021.

[20] Adediran, Y. A. *Introduction to Reliability Engineering*, Finom Associates, ISBN: 978 – 978 - 52341- 2-1, First Edition, 2014.

[21] Lewis, E.E. *Introduction to Reliability Engineering*, John Wiley and Sons, Inc, 2nd Edition, Pp.1-9; 145-153, 1994.

[22] Marko, C. “Assessment of Power System Reliability (Methods and Application)”, pp.28, 52-56, 215-224, ISBN: 978-0-85729-687-0, 2011. https://doi.org/10.1007/978-0-85729-688-7.

[23] Troyer, D.D. “Reliability Engineering Principles for Plant Engineers”, *Article*, pp.1-13, 2019

[24] Ebeling C.E. Introduction to Reliability and Maintainability Engineering Textbook, ISBN: 0-07-018852-1, pp 283-300, 359-375, 2003