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Reliability Assessment of a Nigerian Distribution Substation Using Customer-Oriented Reliability Indices: A Case Study of Ikorodu Distribution Network

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Abstract
Reliable electric power supply is essential for economic growth and sustainable development. However, the Nigerian power distribution sector continues to experience frequent outages and poor service reliability. This study evaluates the reliability performance of the Ikorodu Distribution Network under Ikeja Electricity Distribution Company (IKEDC), Nigeria. Twelve months of outage data were analyzed using standard reliability indices including System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), Customer Average Interruption Duration Index (CAIDI), Average Service Availability Index (ASAI), and Average Service Unavailability Index (ASUI). The reliability assessment identified the major causes of service interruptions and evaluated their impacts on customer service delivery. Results indicate that transformer failures, fuse operations, and feeder faults are the dominant contributors to customer interruptions and network unavailability. The findings provide a basis for improving maintenance planning and network reinforcement strategies. Recommendations include implementation of preventive maintenance programs, deployment of intelligent monitoring systems, and modernization of aging distribution assets.
Keywords: *Reliability assessment, Distribution network, SAIDI, SAIFI, Power system reliability, Nigeria.*

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I. Introduction

Electric power distribution systems represent the final stage of the electricity supply chain, connecting distribution substations to residential, commercial, and industrial consumers. The reliability performance of distribution networks is therefore a major determinant of the quality of electricity service delivered to customers. A reliable distribution system is expected to provide continuous electricity supply with minimum interruptions, reduced outage duration, and acceptable power quality levels (Brown, 2009; Gonen, 2014).Power system reliability assessment has become increasingly important due to the growing dependence of modern society on electricity for industrial operations, communication systems, healthcare facilities, and digital technologies. Distribution networks are particularly significant in reliability studies because they account for the majority of customer interruptions experienced in electrical power systems. Unlike transmission networks, distribution systems are more extensive, exposed to environmental conditions, and consist of numerous components whose failures directly affect end users (Billinton& Allan, 1996).

Customer-oriented reliability assessment provides a practical approach for evaluating the performance of distribution networks from the consumer perspective. Reliability indices such as System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI), Average Service Availability Index (ASAI), and Average Service Unavailability Index (ASUI) are widely used by utilities to quantify outage frequency, outage duration, and service availability (IEEE, 2023). These indices provide valuable information for utility planning, maintenance optimization, regulatory assessment, and improvement of customer satisfaction.The reliability of distribution systems is influenced by several technical and operational factors, including equipment aging, transformer overloading, feeder faults, protection system failures, inadequate maintenance practices, environmental disturbances, and increasing electricity demand. These challenges often result in frequent interruptions, prolonged restoration times, and reduced quality of electricity supply. Reliability analysis therefore enables utilities to identify weak points within the network and develop appropriate strategies for improving service continuity (Mohammed et al., 2020).

In Nigeria, achieving reliable electricity supply remains a major challenge despite continuous reforms and investments within the power sector. Distribution companies experience persistent reliability problems arising from aging infrastructure, insufficient network capacity, poor maintenance practices, vandalism, and operational limitations. These challenges contribute to high interruption frequencies and extended outage durations experienced by electricity consumers across many regions of the country (Adewuyi et al., 2020;

NERC, 2024).Several studies have investigated the reliability performance of Nigerian distribution networks using customer-oriented reliability indices. Ajenikoko et al. (2021) evaluated reliability indices of selected Nigerian distribution systems and emphasized the importance of SAIFI and SAIDI in identifying areas requiring network improvement. Similarly, Akpojedje and Ogujor (2020) reported that frequent feeder interruptions and equipment-related faults contribute significantly to poor distribution system performance in Nigeria.

Internationally, reliability improvement strategies have increasingly focused on data-driven assessment, predictive maintenance, and advanced monitoring techniques. Modern reliability studies incorporate historical outage records, statistical analysis, and intelligent algorithms to evaluate system performance and support effective decision-making (Li et al., 2022). The integration of smart-grid technologies has also provided new opportunities for improving fault detection, reducing restoration time, and enhancing distribution network resilience (Zhang et al., 2023).The assessment of distribution reliability using customer-oriented indices is essential for understanding the actual impact of network failures on consumers. While equipment-based reliability studies provide information about component performance, customer-oriented indices directly measure the consequences of interruptions experienced by electricity users. Therefore, combining outage data analysis with reliability indices provides a comprehensive approach for evaluating distribution system performance.

This study focuses on the reliability assessment of the Ikorodu Distribution Network using customer-oriented reliability indices. The study evaluates the performance of the distribution substation by analyzing interruption frequency, interruption duration, and service availability based on historical outage data. The results provide useful information for identifying reliability challenges and developing strategies for improving electricity supply performance within the Nigerian distribution sector.

This study investigates the reliability performance of the Ikorodu distribution network using customer-oriented reliability indices.

1.1 The objectives of this study are to:

1. Evaluate the reliability performance of the Ikorodu Distribution Network using customer-oriented reliability indices.
2. Determine SAIFI, SAIDI, CAIDI, ASAI, and ASUI values for the study area.
3. Analyze outage frequency and duration patterns affecting consumers.
4. Compare the obtained reliability indices with acceptable industry standards.
5. Recommend measures for improving distribution network reliability and customer service quality.

II. Literature Review

2.1 Concept of Power System Reliability

Power system reliability refers to the ability of an electrical system to continuously supply electricity to consumers within acceptable standards and operating conditions. Reliability is generally divided into adequacy and security.

Adequacy concerns the existence of sufficient facilities to meet customer demand, while security concerns the ability of the system to withstand disturbances.

2.2 Reliability Assessment of Distribution Systems

Distribution systems are the final stage in electric power delivery and are responsible for the majority of customer interruptions. Reliability assessment methods include:

1. Analytical methods
2. Monte Carlo simulation methods
3. Markov modeling techniques
4. Failure Mode and Effect Analysis (FMEA)

Analytical methods are widely used due to their simplicity and computational efficiency.

2.3 Reliability Challenges in Nigerian Distribution Networks

Previous studies have reported poor reliability performance in Nigerian distribution systems due to:

1. Transformer overloading
2. Poor maintenance culture
3. Aging equipment
4. Inadequate protection coordination
5. Vegetation interference
6. Insufficient investment in infrastructure

These factors significantly affect customer satisfaction and utility performance.

2.4 Research Gap
Most previous studies focused on feeder reliability assessment without detailed analysis of customer-oriented reliability indices and substation component contributions. This study addresses this gap by investigating the reliability characteristics of the Ikorodu distribution network and evaluating customer interruption indices.

III. Reliability Indices and Methodology

3.1 Study Method
A quantitative reliability assessment approach was adopted. Historical outage records covering twelve months were obtained from the distribution utility.

3.2 Reliability Indices

3.2.1 System Average Interruption Duration Index (SAIDI)
SAIDI measures the average outage duration experienced by customers during a specified period.

3.2.2 System Average Interruption Frequency Index (SAIFI)
SAIFI measures the average number of interruptions experienced by customers.

3.2.3 Customer Average Interruption Duration Index (CAIDI)
CAIDI measures the average restoration time per interruption.

3.2.4 Average Service Availability Index (ASAI)
ASAI indicates the percentage of time power is available to customers.

3.2.5 Average Service Unavailability Index (ASUI)
ASUI represents the fraction of time customers are without service.

3.3 Data Collection
Twelve months of outage data were collected from the Ikorodu distribution substation. Data included:

1. Number of outages
2. Duration of outages
3. Component failure records
4. Customer interruption information

3.4 Data Analysis
MATLAB was used to compute reliability indices and perform statistical analysis of component failures and outage durations.

3.5 Study Area Description
The study was conducted on the Ikorodu distribution network operated by Ikeja Electricity Distribution Company (IKEDC), Lagos State, Nigeria.
The network consists of:

1. Distribution transformers
2. Incoming feeders
3. Outgoing feeders
4. Circuit breakers
5. Switchgear
6. Protection relays
7. Busbars
8. Surge arresters

The network is predominantly radial in configuration, making it susceptible to service interruptions whenever a major component fails.

IV. Results and Discussion

Table1. Summary of Outage Frequency and Duration on Transformer

Month	No. of Outages	Outage Time (Hours)	Total Hour	Failure Rate(λ)
January	10	186	744	0.0134
February	8	207	696	0.0115
March	4	38	744	0.0054
April	0	0	720	0
May	1	1	744	0.0013
June	0	0	720	0
July	0	0	744	0

August	2	14	744	0.0027
September	1	6	720	0.0014
October	0	0	744	0
November	1	6	720	0.0014
December	0	0	744	0

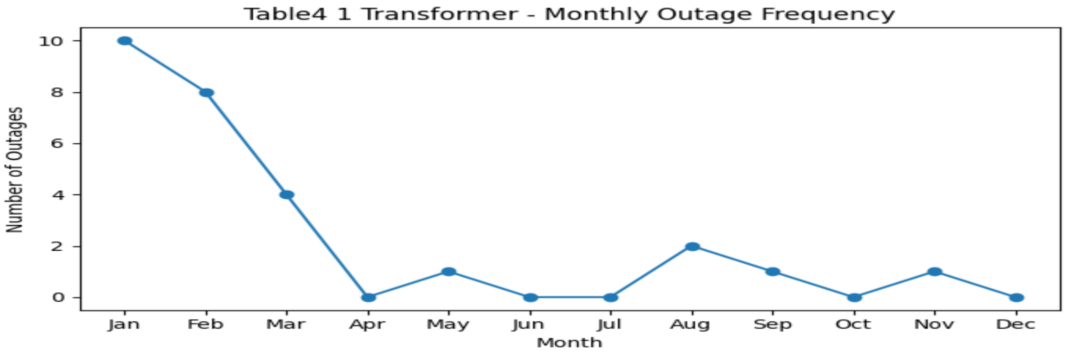

Figure 1: Monthly Outage Frequency of Transformer

Figure 1 shows the monthly outage frequency of the transformer throughout the study period. The highest number of transformer outages occurred in January (10 outages) and February (8 outages), while no outages were recorded in April, June, July, October, and December. The high outage frequency during the early months of the year suggests possible overloading, insulation deterioration, or aging-related failures. Since transformers recorded the highest annual outage time among all components, transformer reliability has a significant impact on the overall reliability of the distribution network. The reduction in outage frequency in subsequent months may indicate maintenance interventions or reduced loading conditions.

Table 2. Summary of Outage Frequency and Duration on Switchgear

Month	No. of Outages	Outage Time (Hours)	Total Hour	Failure Rate (λ)
January	13	24	744	0.0175
February	12	18	696	0.0172
March	7	9	744	0.0094
April	4	18	720	0.0056
May	0	0	744	0
June	0	0	720	0
July	0	0	744	0
August	0	0	744	0
September	0	0	720	0
October	0	0	744	0
November	2	8	720	0.0028
December	0	0	744	0

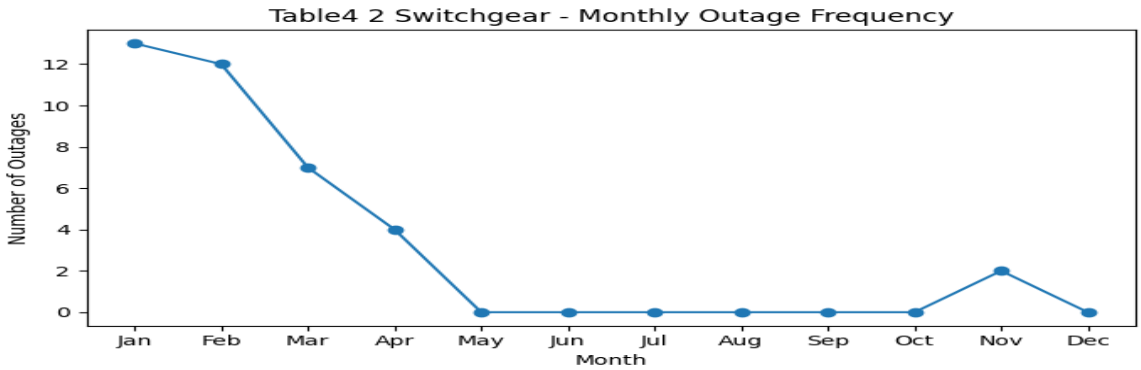

Figure 2: Monthly Outage Frequency of Switchgear

Figure 2 illustrates the monthly outage frequency of the switchgear. The highest outage frequencies were recorded in January (13 outages) and February (12 outages), followed by a gradual decline in subsequent months. No outages were recorded between May and October except for November. The results indicate that switchgear failures were more prevalent during the early part of the year, possibly due to mechanical wear, insulation failure, contact deterioration, or switching operations. The decline in failures suggests improved operational conditions or maintenance activities.

Table 3. Summary of Outage Frequency and Duration on Supply line (11kV)

Month	Frequency of failures	Outage Time (Hours)	Total Hour	Failure Rate (λ)
January	3	10	744	0.0040
February	1	4	696	0.0014
March	0	0	744	0
April	5	17	720	0.0069
May	0	0	744	0
June	0	0	720	0
July	3	10	744	0.0040
August	0	0	744	0
September	1	5	720	0.0014
October	4	15	744	0.0054
November	2	9	720	0.0028
December	0	0	744	0

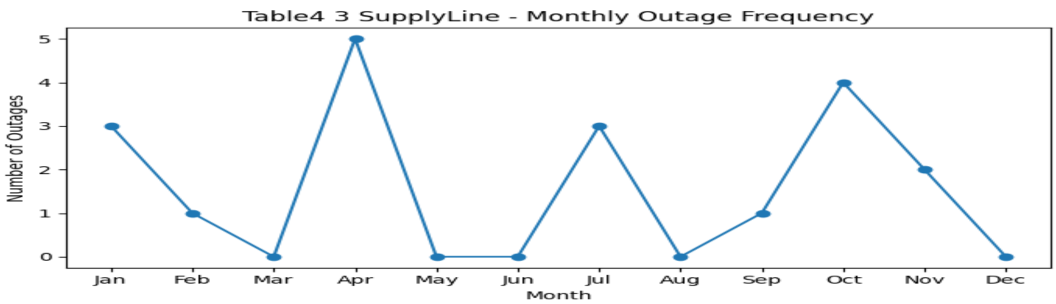

Figure 3: Monthly Outage Frequency of Supply Line (11 kV)

Figure 3 presents the outage frequency of the incoming 11 kV supply line. The highest number of outages occurred in April (5 outages) and October (4 outages). Several months recorded no outages, indicating relatively good reliability of the incoming feeder. The interruptions may be attributed to environmental factors such as storms, vegetation encroachment, lightning strikes, conductor faults, or maintenance activities. Although the supply line contributed to service interruptions, its impact was less significant compared to transformers and fuses.

Table 4. Summary of Outage Frequency and Duration on Busbar

Month	No. of failures	Outage Time (Hours)	Total Hour	Failure Rate (λ)
January	0	0	744	0
February	1	6	696	0.0014
March	0	0	744	0
April	0	0	720	0
May	0	0	744	0
June	0	0	720	0
July	0	0	744	0
August	1	8	744	0.0013
September	2	6	720	0.0028
October	0	0	744	0
November	0	0	720	0
December	0	0	744	0

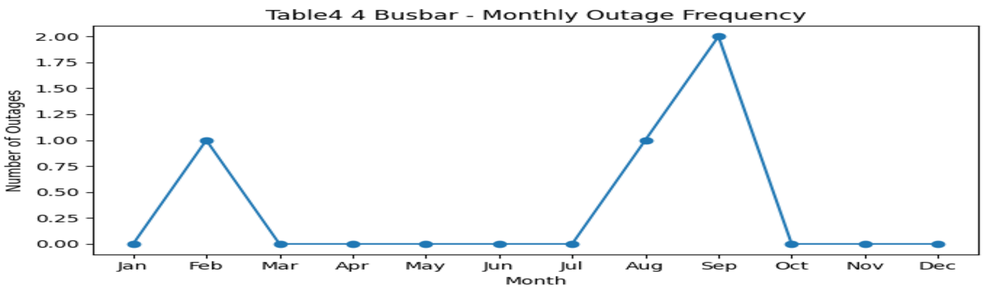

Figure 4: Monthly Outage Frequency of Busbar

Figure 4 shows the outage frequency of the busbar. Only a few outages were recorded throughout the year, with the highest occurring in September (2 outages). Most months experienced no busbar failures, indicating that the busbar is one of the most reliable components in the distribution substation. The low outage frequency suggests adequate design capacity, proper installation, and relatively stable operating conditions.

Table 5. Summary of Outage Frequency and Duration on Circuit Breakers

Month	No. of failures	Outage Time (Hours)	Total Hour	Failure Rate (λ)
January	0	0	744	0
February	0	0	696	0
March	0	0	744	0
April	2	13	720	0.0028
May	0	0	744	0
June	1	6	720	0.0014
July	0	0	744	0
August	0	0	744	0
September	0	0	720	0
October	1	3	744	0.0013
November	0	0	720	0
December	2	3	744	0.0027

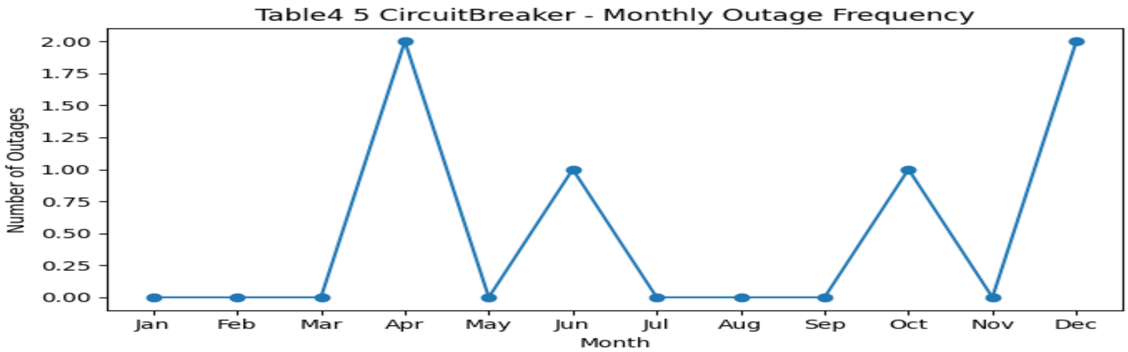

Figure 5: Monthly Outage Frequency of Circuit Breaker

Figure 5 illustrates the monthly outage frequency of circuit breakers. Failures were observed only in April, June, October, and December, with the highest frequency occurring in April and December (2 outages each). The relatively low outage frequency indicates that the circuit breakers performed satisfactorily during the study period. However, occasional failures may be associated with mechanical wear, contact erosion, protection malfunctions, or failure to operate under fault conditions.

Table 6. Summary of Outage Frequency and Duration on Fuse

Month	No. of failures	Outage Time (Hours)	Total Hour	Failure Rate (λ)
January	9	14	744	0.0121
February	2	12	696	0.0029
March	5	17	744	0.0067
April	7	32	720	0.0097
May	3	12	744	0.0040
June	5	14	720	0.0069
July	5	18	744	0.0067
August	9	23	744	0.0121
September	0	0	720	0
October	8	35	744	0.0108
November	1	5	720	0.0014
December	0	0	744	0

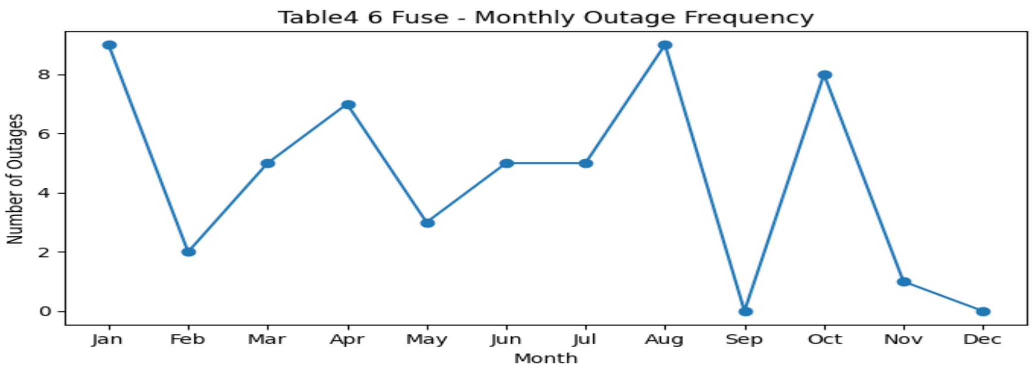

Figure 6: Monthly Outage Frequency of Fuse

Figure 6 presents the monthly outage frequency of fuses. The highest outage frequencies were recorded in January and August (9 outages each), followed by October (8 outages) and April (7 outages). Fuses experienced more frequent outages than most other components, indicating their active role in protecting the network from overloads and fault currents. The high frequency of fuse operations suggests the presence of recurrent overload conditions, short circuits, or downstream feeder faults. This finding supports the reliability analysis, which identified fuses as one of the major contributors to service interruptions within the network.

4.2 Overall Observation

The comparative analysis of Figures 1–6 reveals that:

1. Transformer and fuse outages are the dominant causes of reliability deterioration.
2. Switchgear failures were significant during the early months of the year.
3. Supply lines and circuit breakers exhibited moderate failure frequencies.
4. Busbars recorded the least number of outages and demonstrated the highest reliability.

These results indicate that reliability improvement efforts should focus primarily on transformers, fuses, and feeder protection systems through preventive maintenance, asset replacement, load balancing, and condition monitoring programs.

4.3 Reliability Performance of Components

Analysis of outage records revealed that:

1. Transformer failures recorded the highest annual outage time.
2. Fuse failures ranked second in contribution to service interruptions.
3. Outgoing feeder faults were the third highest source of outages.

4.4 Customer Reliability Performance

The calculated reliability indices indicate that customers experienced frequent interruptions and extended outage durations throughout the study period.

The reliability performance falls below internationally accepted utility standards.

4.5 Causes of Poor Reliability

Major causes identified include:

1. Transformer overloading
2. Fuse failures
3. Feeder faults
4. Aging infrastructure
5. Inadequate maintenance

4.6 Discussion

The high outage duration associated with transformer failures suggests the need for transformer capacity enhancement and condition monitoring systems. Preventive maintenance and protection coordination can significantly reduce customer interruptions.

4.7 Comparison with IEEE Reliability Standards

The calculated reliability indices were compared with IEEE distribution reliability benchmarks.

Results indicate that:

- SAIDI values exceed recommended utility benchmarks.
- SAIFI values are significantly higher than international standards.
- ASAI values are lower than expected for reliable distribution systems.

These findings indicate the need for substantial improvements in network operation and maintenance practices.

V. Recommendations

1. Upgrade overloaded transformers.
2. Replace aging fuses and protection equipment.
3. Implement Reliability-Centered Maintenance (RCM).
4. Deploy Supervisory Control and Data Acquisition (SCADA) systems.
5. Introduce predictive maintenance strategies.
6. Improve feeder protection coordination.
7. Establish routine asset condition monitoring programs.
8. Strengthen vegetation management around distribution lines.

VI. Conclusion

This study assessed the reliability performance of the Ikorodu distribution network using customer-oriented reliability indices. The findings revealed that transformer failures, fuse operations, and feeder outages are the major contributors to customer interruptions and system unavailability. The reliability indices obtained indicate that the network performance falls below international standards. Adoption of modern maintenance practices, intelligent monitoring technologies, and infrastructure upgrades will significantly improve reliability and customer satisfaction.

References

[1]. Adewuyi, O. B., Kiptoo, M. K., Afolayan, A. F., Amara, T., Alawode, O. I., Senjyu, T., & Lotfy, M. E. (2020). Challenges and prospects of Nigeria's sustainable energy transition. *Energy Reports, 6*, 993–1009.

[2]. Akpojedje, F. O., &Ogujor, E. A. (2020). Analysis of frequent power cuts on Ugbowo 2×15 MVA, 33/11 kV electric power distribution network feeders. *NIPES Journal of Science and Technology Research, 2*(3), 282–295.

[3]. Ajenikoko, G. A., Okeniyi, S. O., Mukhtar, Y., &Akinropo, S. (2021). An evaluation of reliability indices of selected Nigerian power distribution systems. *Computer Engineering and Intelligent Systems, 12*(3), 20–31.

[4]. Ali, W., Farooq, H., Rehman, A. U., Awais, M., Jamil, M., & Noman, A. (2020). Reliability assessment of smart distribution networks using advanced reliability indices. *International Journal of Electrical Power & Energy Systems, 117*, 105664.

[5]. Billinton, R., & Allan, R. N. (1996). *Reliability Evaluation of Power Systems* (2nd ed.). Springer.

[6]. Brown, R. E. (2009). *Electric Power Distribution Reliability* (2nd ed.). CRC Press.

[7]. Das, D. (2021). Distribution system reliability evaluation considering distributed generation and renewable energy penetration. *Electric Power Systems Research, 194*, 107089.

[8]. Ezeh, C. I., Agwu, N. N., & Nwosu, C. C. (2022). Assessment of reliability performance of distribution networks in developing countries: A Nigerian perspective. *Energy for Sustainable Development, 68*, 221–232.

[9]. Gonen, T. (2014). *Electric Power Distribution System Engineering* (3rd ed.). CRC Press.

[10]. Institute of Electrical and Electronics Engineers. (2023). *IEEE Std 1366-2023: IEEE Guide for Electric Power Distribution Reliability Indices*. IEEE Standards Association.

[11]. Kumar, A., Singh, S., & Verma, P. (2021). Reliability enhancement of distribution systems through preventive maintenance planning. *Reliability Engineering & System Safety, 214*, 107768.

[12]. Li, Y., Wang, Z., Shahidehpour, M., & Su, C. (2022). Data-driven reliability assessment of modern distribution systems. *IEEE Transactions on Power Systems, 37*(4), 2856–2868.

[13]. Mohammed, Y. S., Mustafa, M. W., & Bashir, N. (2020). Reliability evaluation techniques for electric power distribution systems: A review. *Renewable and Sustainable Energy Reviews, 123*, 109756.

[14]. Nigerian Electricity Regulatory Commission. (2024). *Nigerian Electricity Supply Industry Performance Report*. Abuja, Nigeria: NERC.

[15]. Okafor, E. C., Nwohu, M. N., & Ike, C. C. (2023). Reliability assessment of distribution feeders in Nigeria using customer-oriented reliability indices. *Journal of Electrical Systems, 19*(2), 145–159.

[16]. Olatomiwa, L., Mekhilef, S., Ismail, M. S., &Moghavvemi, M. (2020). Reliability and resilience assessment of modern power distribution systems. *Sustainable Energy Technologies and Assessments, 42*, 100842.

[17]. Sharma, V., Gupta, N., & Singh, B. (2022). Evaluation of SAIFI, SAIDI and CAIDI for distribution system performance assessment. *International Journal of Energy Sector Management, 16*(5), 1121–1138.

[18]. Wang, P., Goel, L., Billinton, R., & Chanan, S. (2021). Reliability worth assessment of electric utility systems. *IEEE Transactions on Power Systems, 36*(6), 5437–5448.

[19]. Zhang, X., Chen, H., & Liu, Y. (2023). Artificial intelligence applications in power system reliability and maintenance management. *Energy AI, 12*, 100241.