International Journal of Engineering and Applied Physics (IJEAP)
Vol. 4, No. 3, September 2024, pp. 1083~1090
ISSN: 2737-8071

Natural Phenomena-Induced Electrical Faults Impacts in the Distribution System of Lagos

Samson Agboibon Akanni[1], Adegoke Oladipo Melodi[2], Thomas Olabode Ale[3]
[1,2,3]Department of Electrical and Electronics Engineering, Federal University of Technology, Akure, Ondo State, Nigeria

Article Info

Article history:

Received Jan 16, 2024
Revised July 12, 2024
Accepted Aug 10, 2024

Keywords:

Electrical Faults
Natural Phenomena
Impacts
Distribution System
Feeders

ABSTRACT

This study assessed the impacts of natural phenomena-induced electrical faults on the distribution system of Lagos, served by Ikeja and Eko electricity distribution companies. The research evaluated the frequency, technical, cost, and reliability impacts of these faults. The study employed statistical and software-based short circuit fault analyses as well as system reliability indices methods to identify the most vulnerable feeders to nature-induced faults. It also simulated the network's response to fault currents and estimated the monthly costs of nature-induced outages. For the data period, an average of 20 to 43 nature-induced faults occurred annually on the networks. The obtained fault currents ranged from 0.67kA to 0.78kA and 0.52kA to 1.02kA for the 11kV and 33kV networks, respectively, which was useful for setting up installed breakers. The estimated average monthly cost of nature-induced energy loss was found to be between ₦3 million and ₦143 million for Eko and between ₦0.01 million and ₦108 million for Ikeja. The System Average Interruption Frequency Index and System Average Interruption Duration Index did not exceed 4 and 60, respectively, on 33kV network. In conclusion, natural phenomena-induced electrical faults had significant impacts, particularly in terms of monthly costs and investments in its mitigation should be explored.

This is an open access article under the CC BY license.

Corresponding Author:

Samson Agboibon Akanni,
Department of Electrical and Electronics Engineering,
Federal University of Technology, Akure,
P.M.B 704, Akure, Ondo State, Nigeria.
Email: samsonagboibon@yahoo.com

1. INTRODUCTION

The year 2013 marked a significant point in the distribution of electricity in Nigeria. It was the year the responsibility of providing this essential service was delegated to eleven (11) Electricity Distribution Companies (DisCos), each of which was assigned a specific service region [1]. Lagos State, the region under study, is situated along the coast and is Nigeria's second most populous state [2, 3]. The region's power distribution is managed by two DisCos, Eko and Ikeja. The state is composed of about 600 and 200 feeders in the 11kV and 33kV distribution networks (DNs) respectively. The peak demand of the State is 2440MW, the highest in the country [4].

Existing attributed challenges to this region's distribution networks include overload, faulty equipment, over-demand, vandalisation, inadequate funding, limited network capacity, lack of automation, insulation collapse due to lightning, switching-based fault occurrences, and damage caused by natural phenomena [5, 6, 7]. Natural phenomena (NP) refer to the observable events that occur in nature, particularly affecting the overhead power lines. The most common NP include avian contact with the distribution lines, tree branches entangling the lines, ambulation of small mammals and reptiles on the distribution lines, flooding, windstorms, and lightning strikes [6].

It is supposed that these phenomena induce short circuit faults, which endanger network elements if left uncontrolled. This is the technical impact of NP-induced electrical faults on the distribution system (DS). The three-phase short circuit fault is the most severe while the line-to-ground short circuit fault is the most common [8]. Also, the cost-impacts of faults caused by NP in distribution systems are usually high. For example, in the US, it was estimated that the cost implication of storm-related outages is between \$20 billion and \$55 billion annually [9]. A case of an earthquake in Marmara, a Turkish region, caused system faults, power quality disturbances, and physical damage to the installed power system. The earthquake impacted the region which contributed 33.4% (\$60,295,823) of Turkey's Gross Domestic Product and consumes 32.2% (28,253,113 MWh) of Turkey's electricity [10]. Occurrences of similar cost impacts of natural hazards on the power system are corroborated by [11] and [12]. This category of faults equally has a reliability impact on the distribution companies and the electricity consumers, which is the measure of how the frequency and duration of outages caused by these natural phenomena affect them [13].

It could be concluded that NP causes electrical faults in the distribution systems (DSs) and has technical, cost, and reliability impacts on power system infrastructure, consumers, and the economic development of the service area. However, these impacts as they relate to the DS of Lagos State, Nigeria require evaluation to obtain useful characteristic values for developing mitigating strategies.

2. RESEARCH METHOD

2.1. Collection of Outage Data and Fault Frequency Analysis.

To ascertain the frequency of natural phenomena-induced electrical faults within the network, the empirical fault data or records (FR) from the system records of Ikeja and Eko Discos were procured. The components of the obtained data are expressed in Equation 1. The period of available data for Ikeja and Eko DisCos is four and three years respectively. The years not available were caused by data loss at the Disco.

$$FR = \left(FC, F_{np,yr,mth}, L_i, LH_i\right) \tag{1}$$

where FC and $F_{np,yr,mth}$ represent electrical fault causes and monthly frequency due to np^{th} natural phenomenon in the data period respectively for the selected distribution networks. L_i is the load (MW) not supplied and LH_i is the duration in hours for an i^{th} outage when the feeder is out because of a fault.

The average annual frequency statistic of electrical faults caused by each of the NP ($F_{av,np}$) was measured as a ratio of the running total of yearly frequencies of electrical fault due to a specific NP to the number of years covered by the data as shown in Equation 2. The two equations 1 and 2 are prepared based on principles of basic probability and statistics as expounded in [14].

$$F_{av,np} = \frac{\sum_{yr=1}^{N} F_{np,yr}}{N};\ F_{np,yr} = \sum_{mth=1}^{12} F_{np,yr,mth} \tag{2}$$

where $F_{np,yr,mth}$ is monthly outage events in yr^{th} year for a given NP, obtained from outage data.

2.2. Technical Impact of Natural Phenomena-Induced Electrical Faults

The feeders that are most vulnerable to NP-induced electrical faults, identified by average annual frequency statistics were simulated for three-phase and single-phase to ground short circuit faults using NEPLAN V555 software, the algorithm of which applies basic generic Equations 3 and 4. The short circuit current obtained was used to determine the suitability of the installed protection scheme. For three-phase short circuit fault analysis, Equation 3 is the basic concept as discussed in [15].

$$I_{SC} = I_{SCpu} I_B;\ I_{SCpu} = \frac{V_{pu}}{Z_{pu}};\ I_B = \frac{S_B}{\sqrt{3} \times V_B};\ Z_{pu} = \frac{Z}{Z_B};\ Z_B = \frac{V_B^2}{S_B} \tag{3}$$

where I_{SC} is short circuit current of given distribution network feeders, $I_{SC\,pu}$ is per unit short circuit currents, I_B is the base current, V_B is the base voltage, Z_B is the base impedance, Z_{pu} is the impedance in per unit and S_B is the base power. The 3-phase line voltage and the 3-phase kVA rating were used as bases.

For the single-phase to ground short circuit faults evaluations, the equation of fault condition in the sequence domain is applicable, after indicating the grounded phase, as discussed in [16]. Equation 4 gives the fault currents in the phase domain assuming a red phase-to-ground fault.

$$\begin{bmatrix} I_R \\ I_Y \\ I_B \end{bmatrix} = \begin{bmatrix} I_0 + I_1 + I_2 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 3I_1 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{3V_F}{Z_0+Z_1+Z_2+(3Z_F)} \\ 0 \\ 0 \end{bmatrix} \quad (4)$$

where $I_0,\ I_1,\ I_2$ and $V_0,\ V_1,\ V_2$ as well as $Z_0,\ Z_1,\ Z_2$ are the sequence currents, voltages, and impedances. V_F and Z_F are the pre-fault voltage and fault impedance respectively.

2.3. The Cost Impact of Natural Phenomena-Induced Electrical Faults

The cost impacts of natural phenomena-induced electrical faults were obtained using Equation 5. Similarly, the average monthly energy loss (MWh) was obtained using Equation 6. Equations 5 and 6 are prepared based on the principles of basic tariff theories as expounded in [15].

$$CI_{mth} = EL_{mth} 10^3 c_0. \quad (5)$$

where CI_{mth} and EL_{mth} are the average monthly cost of energy loss (in Naira) and average monthly energy loss (MWh) respectively, due to natural phenomena-induced electrical faults on the distribution system, and c_0 is the per-kWh cost of energy in the period under review.

$$EL_{mth} = \frac{\sum_{mth}^{M} \sum_{i=1}^{k} (L_{mth,i} LH_{mth,i})}{M}. \quad (6)$$

where k is the total number of NP-induced electrical faults in the data period, and M is the number of months in the data period. $L_{mth,i}$ and $LH_{mth,i}$ are extracted from data of L_i and LH_i data respectively for mth^{th} month.

2.4. Reliability Impacts on the Customers from Natural Phenomena-Induced Electrical Faults

The reliability impacts on the customers from natural phenomena-induced electrical faults were measured, using four and three years of data for Ikeja and Eko respectively. The measurement was in terms of the system average interruption frequency index (SAIFI, int/yr/feeder) and system average interruption duration index (SAIDI, h/yr/feeder) for each network as in Equations 7 and 8 [17].

$$SAIFI = \frac{Total\ numberof\ nature-induced\ interruption\ on\ feeders}{Total\ number\ of\ feeders\ serving\ the\ customers} = \frac{\sum F_{np(j)}}{\sum j} = \frac{\sum F_{np(j)}}{N} \quad (7)$$

where $F_{np(j)}$ is the yearly average of nature-induced interruptions on j^{th} feeder, N is the number of feeders serving customers in the given network [int/yr, feeder]

$$SAIDI = \frac{Sum\ of\ nature-induced\ interruption\ durations\ of\ feeders}{Total\ number\ of\ feeders\ serving\ the\ customer} = \frac{\sum D_{np(j)}}{\sum j} = \frac{\sum D_{np(j)}}{N} \quad (8)$$

where $D_{np(j)}$ is the yearly average duration of nature-induced interruptions on j^{th} feeder.

The processing and numerical calculation carried out using the above equations were executed through the Microsoft Excel Spreadsheet software and codes.

3. RESULTS AND DISCUSSION

The following results were obtained and discussed after applying the above-stated Equations 1 - 8. The total frequency of occurrence of natural phenomena-induced electrical faults in the networks of Lagos State in the data period is presented in Table 1. Table 1 validates substantial occurrences of nature-induced electrical faults in the State. This is in agreement with what happened in other climes. The percentage of faults caused by NP is 39% in Spain, 46% in North America, 43% for 11kV and 46% for 33kV in Norway [18, 19, 20].

The feeders that are most vulnerable to the NP-induced electrical faults in the networks of the State, determined by average annual frequency statistics, are presented in Table 2. They are identified as Bashorun-Okunsanya (11kV) and Badagry Express (33kV), Estate (11kV), and Agbowa (33kV) feeders respectively. These feeders have an average annual frequency in the data period ranging from 20 to 43 occurrences. Agbowa 33kV feeder is the highest. The frequency of faults recorded on each feeder and the period considered affect the average annual frequency during the data period. The topography of these feeders significantly affects the number of electrical faults caused by natural factors on them.

Table 1. Frequency of NP-Induced Electrical Faults in the DS of Lagos State.

S/N	NP	Frequency of Occurrence of Faults Caused by NP in Data Period				
		11kV Eko	11kV Ikeja	33kV Eko	33kV Ikeja	Total
1	Animal	329	818	214	594	1955
2	Flood	2	2	7	0	11
3	Lightning	154	375	100	112	741
4	Vegetation	2031	2090	577	854	5552
	Total	2516	3285	898	1560	8259

Table 2. DN Feeders Most Vulnerable to NP-Induced Electrical Faults in the State.

Network	Name of Feeder	Average Annual Frequency of Occurrence in Data Period				
		Vegetation	Animal	Lightning	Flood	Total
11kV Eko	Bashorun Okunsanya	26.00	2.33	0.67	0.00	29.00
11kV Ikeja	Estate	19.25	0.00	0.25	0.00	19.50
33kV Eko	Badagry Express	13.33	13.67	1.00	0.00	28.00
33kV Ikeja	Agbowa	38.25	4.75	0.25	0.00	43.25

The single-line network diagrams of these feeders using NEPLAN V555 software are shown in Figures 1 to 4. Figures 1 – 4 were used for the simulation of the three-phase and the single-phase-to-ground short circuit faults on the feeders.

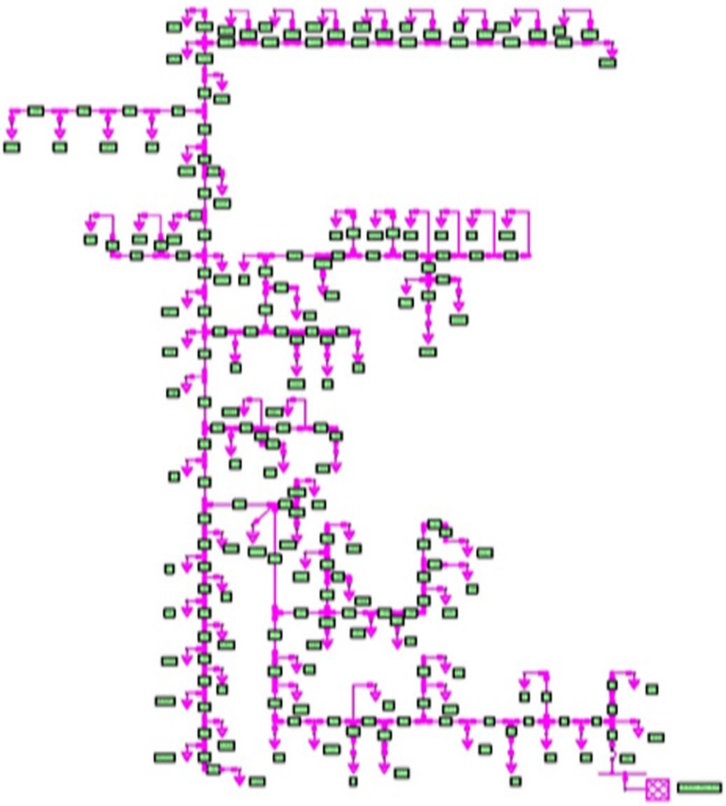

Figure 1. Network Diagram of Bashorun Okunsanya 11kV Feeder (Eko) using NEPLAN Software

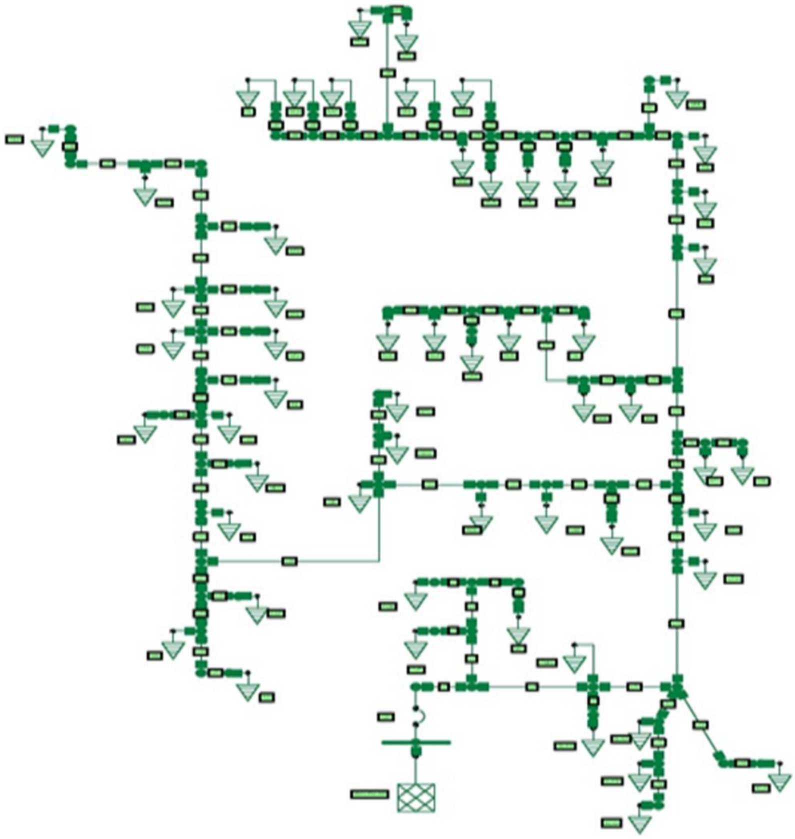

Figure 2. Network Diagram of Estate 11kV Feeder (Ikeja) using NEPLAN Software

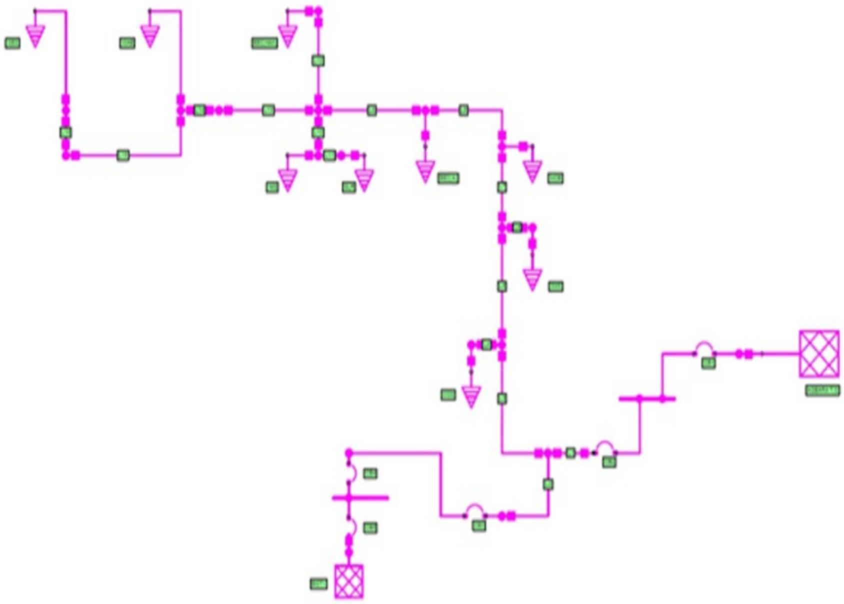

Figure 3. Network Diagram of Badagry Express 33kV Feeder (Eko) using NEPLAN Software

Figure 4. Network Diagram of Agbowa 33kV Feeder (Ikeja) using NEPLAN Software

The results of three-phase and single-phase to-ground short circuit tests carried out on the distribution transformer substations and segments of the four feeders, mostly affected by the NP-induced electrical faults, are summarised in Table 3. It was observed from Table 3 that the short circuit current is high for the three-phase fault and low for the single-phase to ground fault. For the 11kV network, it ranges from 0.67kA to 0.78kA while it is from 0.52kA to 1.02kA for the 33kV network in the State. These currents are within the short circuit current breaking capacity of the installed protection scheme for the 11kV and 33kV networks.

Table 3. Short Circuit Results of Four Feeders Prone to NP-Induced Electrical Faults in the DNs of Lagos

S/N	Name of Feeder	Three-Phase Short Fault Current (kA)	Single Phase to Ground Fault Current (kA)	Range of Fault Current (kA)	Installed Breaker Capacity (kA)
1	Bashorun Oku. (11kV)	Highest - 0.76	Highest - 0.68	0.67 - 0.76	26.3
		Lowest - 0.75	Lowest - 0.67		
2	Estate (11kV)	Highest - 0.78	Highest - 0.73	0.68 - 0.78	25
		Lowest - 0.74	Lowest - 0.68		
3	Badagry Express (33kV)	Highest - 1.02	Highest - 0.95	0.72 - 1.02	26.3
		Lowest - 0.85	Lowest - 0.72		
4	Agbowa (33kV)	Highest - 0.68	Highest - 0.57	0.52 - 0.68	25
		Lowest - 0.63	Lowest - 0.52		

The average monthly cost impacts of NP-induced electrical faults on Eko and Ikeja Networks are expressed in Tables 4 and 5 respectively. From Tables 4 and 5, the average monthly cost is ₦3 million for floods (the lowest) and ₦143 million for vegetation (the highest) for Eko and ₦0.01 million for floods (the lowest) and ₦108 million for vegetation (the highest) for Ikeja networks. These cost impacts are high for the two DisCos. If these costs are minimised, the saved costs could fund the replacement of obsolete and ageing equipment and network expansion. The veracity of the aforementioned cost impact has been validated through analogous incidents in other geographical locations. In the US, weather-connected natural disasters triggered half of the total power outage events during the years 2000 to 2016 and also caused 70% of the total electric power revenue loss [21]. A report put the estimate of power outages caused by severe weather between 2003 and 2012 in the US to range between \$18 billion and \$33 billion on average [22]. In China, the estimate of the total business interruption cost of an outage event caused by a natural disaster is 1.44 billion Yuan [23]. The cost impact of Gudrun storm-related outages in January 2005 for Sweden was estimated to be between 400 million and 500 million Euros [24].

Table 4. Average Monthly Costs of NP-Induced Electrical Faults on Eko DN

S/N	NP	Network	MWh	Unit Cost, (₦/kWh)	CI, (₦)	Total (₦)
1	Animal	11kV	185	40.44	7,481,400	
		33kV	527	40.44	21,311,880	28,793,280
2	Flood	11kV	6	40.44	242,640	
		33kV	69	40.44	2,790,360	3,033,000
3	Lightning	11kV	134	40.44	5,418,960	
		33kV	251	40.44	10,150,440	15,569,400
4	Vegetation	11kV	1404	40.44	56,777,760	
		33kV	2144	40.44	86,703,360	143,481,120

Table 5. Average Monthly Cost of NP-Induced Electrical Faults on Ikeja DN

S/N	NP	Network	MWh	Unit Cost, (₦/kWh)	CI, (₦)	Total (₦)
1	Animal	11kV	414	37.95	15,711,300	
		33kV	578	37.95	21,941,365	37,652,665
2	Flood	11kV	0.28	37.95	10,626	
		33kV	0	37.95	0	10,626
3	Lightning	11kV	249	37.95	9,449,550	
		33kV	233	37.95	8,842,350	18,291,900
4	Vegetation	11kV	1059	37.95	40,189,050	
		33kV	1785	37.95	67,740,750	107,929,800

On power reliability, measured SAIFI and SAIDI caused by natural phenomena are expressed in Table 6. Table 6 reveals that the average yearly frequency (count) and duration of NP-induced outages was more on the 11kV than the 33kV networks in the State. The 11kV network is more prone to NP-induced electrical faults owing to the larger number of these feeders only. However, the interruptions per year per feeder are about the same on 33kV networks as on 11kV networks, while the duration per year per feeder is more in 33kV networks. This shows that repair or restoration is slower on 33kV feeders. On a feeder, the observed maximum SAIDI is about 60 hours in a year and this will amount to about 97 hours for an 11kV feeder, considering that an outage at 33kV affects 11kV networks. However, the above SAIFI and SAIDI are far higher than the International Acceptable Standard Values (IASV) of SAIFI (0.01) and SAIDI (2.5 Hrs) [25]. The SAIFI and SAIDI obtained on the distribution system of Lagos State are above the acceptable values because the number of interruptions on the network and their durations are high.

Table 6. Reliability Impacts of NP-Induced Electrical Faults on the DNs of Lagos State

S/N	SUMMARY	11kV IKJ	33kV IKJ	11kV EKO	33kV EKO
1	Average Yearly Count of NP Outages	821	390	839	299
2	Average Yearly Duration of NP Outages (hr)	7684.81	3668.93	11213.98	5446.70
3	Number of Feeders	287	94	300	91
4	SAIFI (int/yr/feeder)	3	4	3	3
5	SAIDI (h/yr/feeder)	27	39	37	60
6	NP-Outage Rate (event/hr) (event/day)	0.1 (2)	0.1 (1)	0.07 (2)	0.05 (1)
7	Average Repair Time (hr(s))	9.36	9.41	13.37	18.22

4. CONCLUSION

The following can be summarised from the analyses of the results. Firstly, the incidence of NP-induced electrical fault in the coastal study area is considerable, with an observed estimate of 8259 incidences in the data period. The most vulnerable feeders were identified for each voltage level, having over 20 annual incidences per annum, which were applicable to evaluating fault current limits and installed protection scheme capacity. Obtained fault currents ranged from 0.52 kA to 1.02 kA, which was coverable by installed breaker capacities of 25 to 26.3 kA. The cost estimate of NP-induced electrical faults in the State is an average of 190.876 million per month, which is prohibitive. The most significant contributor to this amount is the vegetation problem. This is corroborated by the conducted power supply reliability assessment for the networks. Applied system average reliability indices on the power supply to network feeders indicate an average outage duration of 27 hours to 60 hours on a feeder in a year due to NP. In other words, NP contributes this range of hours to the total outage hours on a feeder annually, which is significant when considering the total annual outage duration on a feeder in the context of other (non-NP) causes. The random outage rate of faults in the network is about 2 times per day in 11 kV networks and 1 event per day in 33 kV networks of the State. The duration of each outage ranges between 9 to 18 hours, which is less than a day. Generally, the impact of NP-induced electrical faults is significant, especially in terms of monthly costs, and investment in its mitigation should be explored given the cumulative impact from other outage causes. Therefore it is recommended that the existing preventive maintenance policy and application of these networks should be reviewed to mitigate these electrical fault factors on the coastal networks.

REFERENCES

[1] A. U. Adoghe, *et al*., "Performance Evaluation of the Prospects and Challenges of Effective Power Generation and Distribution in Nigeria," *Heliyon,* Vol. 9, pp. 1-2, 2023.

[2] FGN, "Federal Republic of Nigeria Official Gazette – Legal Notice on Publication of 2006 Census Final Results," *The Federal Government Printer, Abuja, Nigeria FGP16/22009/10,000(OL02)*, vol. 96, B3, 2009.

[3] G. N. Okeke, "The Nigeria Perspective of Global Climate Change: A Case Study of Coastal Areas of Lagos," *Open Journals of Environmental Research,* vol. 3, pp. 42-43, 2020

[4] L. Olurode, *et al*., "Urbanisation and Energy Crisis: The Case of Lagos State," *Sociology and Anthropology,* vol. 6, pp. 845-853, 2018.

[5] O. O. Mohammed, *et al*., "The Challenges and Panaceas to Power Distribution Losses in Nigeria," *Arid Zone Journal of Engineering, Technology & Environment,* vol. 16, pp. 121-122, 2019

[6] M. Waseem and S. D. Manshadi, "Electricity Grid Resilience amid Various Natural Disasters: Challenges and Solutions," *The Electricity Journal,* vol. 33, pp. 1-7, 2020

[7] H. H. Alhelou, *et al*., "A Survey on Power System Blackout and Cascading Events: Research Motivations and Challenges," *Energies,* vol. 12, pp. 12-13, 2019.

[8] P. S. Ayobo, *et al*., "Electric Power Faults Evaluation On 33KV Distribution Network," *Iconic Research and Engineering Journals,* vol. 4, pp. 24, 2020.

[9] R. J. Campbell, "Weather Related Power Outages and Electric System Resiliency," *2012 Congressional Research Service Report for U.S. Congress*, pp. 2, 2012.

[10] B. Oral and F. Donmez, "The Impacts of Natural Disasters on Power Systems: Anatomy of the Marmara Earthquake Blackout," *Acta PolytechnicaHungarica,* vol. 7, pp. 107–118, 2010.

[11]] N. Gunduz, *et al.*, "Impacts of Natural Disasters on Swedish Power Policy: A Case Study," *Sustainability,* vol. 9, pp. 1-11, 2017.

[12] P. L. Watson, *et al*., "Improved Quantitative Prediction of Power Outages Caused by Extreme Weather Events," *Weather and Climate Extremes,* vol. 37, pp. 1, 2020.

[13] M. S. S Fogliatto, *et al*., "Power Distribution System Interruption Duration Model Using Reliability Analysis Regression," *Electric Power Systems Research,* vol. 211, pp. 1, 2022.

[14] S. Ross, "*Introduction To Probability and Statistics For Engineers and Scientist,"* London: Elsevier Academic Press, pp. 9-22, 2009.

[15] J. B. Gupta, "*A Course in Electrical Power*," 14th ed. India: S.K. Kataria & Sons, Delhi, pp. 22-23, 40, 588-595, 2005.

[16] J. D. Glover, *et al*., "*Power System Analysis*," 4th ed. USA: Cengage Learning, USA, pp. 446-448, 2007.

[17] Nazaruddin, *et al*., "Reliability Analysis of 20 KV Electric Power Distribution System," *in IOP Conference Series: Materials Science and Engineering, 2020. Second International Conference on Science and Innovated Engineering*, pp. 4-5, 2020.

[18] O. A. Quiroga, et al., "Fault Causes Analysis in Feeders of Power Distribution Networks," *in International Conference on Renewable Energies and Power Quality*, *2011. ICREPQ 2011. EA4EPQ,* pp 1269-1271, 2011.

[19] L. Wang, "The Fault Causes of Overhead Lines in Distribution Network," *in MATEC Web of Conferences, 2016. APOP2016. MATEC Web of Conferences Sixty-one*, pp 1-4, 2016.

[20] G. H. Kjolle, "What do Fault Statistics tell us regarding causes resulting in Power Outages?" in *Workshop DNV – NTNU Risk and Vulnerabilities in Power Systems in light of climate changes*, *2011. NTNU2011. SINTEF*, pp 1 – 32, 2011.

[21] R. Ali, *et al*., "Financial Hazard Prediction due to Power Outages Associated with Severe weather-related natural disasters Categories," *Energies,* vol. 15, pp 7, 2022.

[22] Y. Tan, A.K. Das, P. Arabshahi and D.S. Kirschen, "Distribution Systems Hardening Against Natural Disasters," *arXiv:1711.02205v1 [math.OC], Nov 6, 2017*, pp 1, 2017.

[23] H. Chen, *et al*., "Assessing the business interruption costs from power outages in China," *Energy Economics,* vol. 105, pp 5, 2022.

[24] N. Gunduz, *et al*., "Impacts of Natural Disasters on Swedish Power Policy: A Case Study," *Sustainability.,* vol. 9, pp 1 -11, 2017.

[25] D. A. Folarin, *et al*., "Appraisal of Electric Power Distribution Feeders Reliability in the Region unit in Nigeria," *International Journal of Engineering Research and Technology,* vol. 6, pp 99, 2017.