Analysis of Electrical Faults Caused by Natural Phenomena in the Distribution System of Lagos State, Nigeria

*Samson A. Akanni, Adegoke O. Melodi, and Thomas O. Ale
Department of Electrical and Electronics Engineering, The Federal University of Technology, Akure, Nigeria
samsonagboibon@yahoo.com|{aomelodi|toale}@futa.edu.ng

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ORIGINAL RESEARCH ARTICLE

Abstract- This paper analysed empirical system data of nature-induced electrical faults, its variation, and ratings in the distribution networks of Lagos State, Nigeria, which affect the power distribution system infrastructure, end-users of electricity, and the economic development of the distribution companies, consumers, and the nation at large. Fault-based outage data (at installed 11 kV and 33 kV nominal network voltages) were obtained and analysed by natural phenomena (NPs) using relative frequency, seasonal variation, and probabilistic statistics. From obtained results, the following were established: NP-induced electrical faults are prevalent in the distribution systems of Lagos State, and it is more towards or closer to the mainland; vegetation (67%) and birds/snakes (24%) are the most predominant fault-causing NPs in the distribution networks; floods (0.1%) rarely cause electrical faults in these distribution networks despite being a coastal region; and NP-induced electrical faults vary periodically throughout the year. It was recommended that existing maintenance policy must be enhanced to control vegetation, birds, and reptile incursions into Lagos DNs. Modern software-based sensor technologies for monitoring vegetation growth and repelling bird/snake incursions in the network should be explored. Existing protection scheme should be evaluated for effectiveness in view of ensuing short circuit events from incidents of these NPs at various hotspots.

Keywords- electrical fault, natural phenomena, distribution system, coastal area

1 Introduction

The state of Nigeria electricity distribution networks (DNs) is critical to its reliability of power supply to the population. These networks receive electric power at 33 kV from 132/33kV substations for primary distribution, which is subsequently stepped down to 11 kV networks and further stepped down to 0.415kV consumer voltage. The administrative developments of Nigeria's power system since 1972 are known. However, these developments are yet to mitigate power outage problem. Currently, 11 electricity distribution companies (DisCos), under the Nigerian regulator (NERC), cover the entire power distribution operations in Nigeria.

Natural phenomena when related to the electrical distribution system refers to the observable events that occur naturally especially on the overhead lines. The most common among these natural phenomena are birds perching on the lines, wind-borne tree branches fouling the lines, wildlife especially rodents, and snakes bridging the lines. Others include flooding, windstorm, and lightning strikes (Umoh & Alaka, 2007). Lagos State is located along the southwest coast of Nigeria (at 6°35′N 3°45′E) and has the largest GDP in the country. The climate is tropical, and the weather and nature are coastal. This makes the State to be expectedly characterized by incursions of natural phenomena that are peculiar to coastal areas besides general ones, which Nigerian DNs are exposed to.

*Corresponding Author

Section B- ELECTRICAL/ COMPUTER ENGINEERING & RELATED SCIENCES
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The impact of outage in such location, with highest economic/revenue generation activity in Nigeria, is of concern to the DisCos and electricity customers. Therefore, analytical evaluations of cause-based outages on such Nigeria's DNs are vital and actual (Melodi & Temikotan, 2017; Melodi & Oyeleye, 2017; Oshin et al., 2019; Akintola, 2017). Two DisCos cover Lagos State DNs and operate about 591 11 kV feeders and 178 33 kV feeders. Natural phenomena are part of network challenges that occur on the distribution system (Omonfoman, 2016). Nigeria's DNs are 'in air' and are more prone to disruptive impact of natural phenomena.

The significance of natural phenomena (NP) on power (distribution) systems is discussed in literature. NP can cause serious damage to distribution systems infrastructure and consequently affect the economic development of the nation, besides possible loss of lives and property. NPs are considered uncontrollable factors of faults in DNs (Rudnick, 2011).

Cases of DN-related NP include vegetations (tree contact), animals (birds and snakes) and weather. Other factors of fault-based outages include the following: vandalism and equipment failure (Csanyi, 2015; Awosope, 2014). Empirical cases of outages due to NP were noted in previous studies on developed systems or countries such as (Kjolle, 2011), which evaluated fault causes in Norway systems; Quiroga, Meledez, &Herraiz, (2011), which evaluated fault causes (including atmospheric influences) on overhead and underground feeders for power distribution networks; and Wang (2016), which also carried out similar studies using local data. Furthermore, Gunduz, Kufeoglu, & Lehtonen, (2017) noted and discussed the factor of climate change on NP intensity, frequency and electric power reliability. This (climate change factor) necessitates periodic or temporal validations of existing NP-based values. It is noteworthy that these studies did not apply sub-Saharan distribution system data as Lagos, Nigeria. Consequently, providing prevailing condition and values for the studied DNs and location is necessary.

2 METHODOLOGY

This study proposed and applied the following statistical procedure and terms for evaluating and analysing nature-induced electrical faults in the studied location which includes data collection or survey approach, determination of nature or NP-induced electrical fault frequencies, determination of seasonal variations of NP-induced faults, evaluation of the probability of nature-induced faults in a DN at given nominal voltage, and nature-induced electrical fault per year per feeder.

Network and fault data on all DNs feeders of the State were obtained from system records. The data are grouped under the two Discos (Eko and Ikeja or IKJ). Data periods, defined by data availability, is four years (2017 to 2020) for the IKJ, and three years (2016, 2019 and 2020) for Eko. The unavailable years were due to data loss at the DN, and covered by incorporating per unit or relative statistical approach in the study.

To determine the frequency of NP-induced electrical faults, obtained empirical fault data or fault records (FR) for all DN feeders were applied. Its scope and elements are expressed by equation 1.

$$FR = (F_{mth}, FC), \tag{1}$$

where F_{mth} and FC are monthly electrical fault frequency and faults causes respectively.

For the data period and specific DN (primary or secondary), the per unit value of fault frequency induced by np^{th} NP ($F_{pu(np)}$) is evaluated using equation 2.

$$F_{pu(np)} = \frac{F_{np}}{\sum_{np=1}^{m} F_{np}}, \qquad F_{np} = \sum_{mth} F_{np,mth} \tag{2}$$

where m is the number of the natural phenomena considered, $F_{np,mth}$ is recorded fault frequency induced by np^{th}NP for mth month, F_{np} is fault frequency induced by np^{th} NP for the data period and specific DN.

$$F_{np,mth} \in F_{mth} \tag{3}$$

The seasonal variation of electrical fault caused by NP was obtained from the frequency distribution of (1) using the ratio to moving average method as expressed by equation 4 (Okunade, 2009).

$$SI = D - T, \tag{4}$$

where SI is the seasonal index, D is the data and T is the centred moving average trend (or CMAT).

Probability of nature-induced faults (p_m) in a DN at given nominal voltage is evaluated using equation 5.

$$p_m = \frac{\sum_{np}^{m} F_{np}}{F_{gen}}, \tag{5}$$

where F_{np} is fault frequency induced by np^{th} NP for the data period and specific DN, $F_{gen}$is general fault frequency (NP-induced and others) for specific DN for the data period.

The frequency of nature-induced electrical fault per year (annum) per feeder ($F_{p.a,m}$) for specific DN was evaluated using equation 6:

$$F_{p.a,m} = \frac{\mathrm{F}_m}{N} = \frac{\sum_{np}^{m} F_{np}}{N}, \tag{6}$$

where F_m is the total frequency of nature-induced fault caused by a specific natural phenomenon m for the data period, N is the total number of feeders in the network.

The applied equations 1, 2, 3, 5, and 6 are composed based on basic probability and statistics theories as in Ross (2009). The data sorting, quantitative evaluations and graphical analysis of these equations were implemented in Microsoft Excel Spreadsheet software.

3 RESULTS

On application of the statistical algorithm above, the following results were obtained and discussed for DNs of the studied location (Lagos State, Nigeria): Total NP-based DN and per unit value of Faults Frequency Distribution by Causes in Data Period, as shown in Tables 1 and 2 respectively; seasonal variations (SI_{mth}) of nature-induced DN faults, as shown in Figs. 1 to 4; Probability of nature-induced electrical faults in DNs of Lagos State, as shown in Table 3; and Nature-induced electrical fault per year per feeder in the DNs of Lagos State, as shown in Table 4.

Table 1. Total NP-based DN Faults Frequency Distribution by Causes in Data Period

		F_np				
		Eko DN		Ikeja DN		State
S/N	NP	11 kV	33 kV	11 kV	33 kV	Sum
1	BIRD/SNAKE	329	210	819	601	1959
2	FLOOD	2	7	2	0	11
3	LIGHTNING	154	100	376	113	743
4	VEGETATION	2031	577	2092	853	5553
	SUM	2516	894	3289	1567	8266

Table 2. Per unit values of Faults Frequency Distribution by Causes in Data Period

		F_pu(np)				
		Eko DN		Ikeja DN		State
S/N	NP	11 kV	33 kV	11 kV	33 kV	Sum
1	BIRD/SNAKE	0.13	0.23	0.25	0.38	0.24
2	FLOOD	0	0.01	0	0	0.001
3	LIGHTNING	0.06	0.11	0.11	0.07	0.09
4	VEGETATION	0.81	0.65	0.64	0.54	0.67
	SUM	1	1	1	1	1

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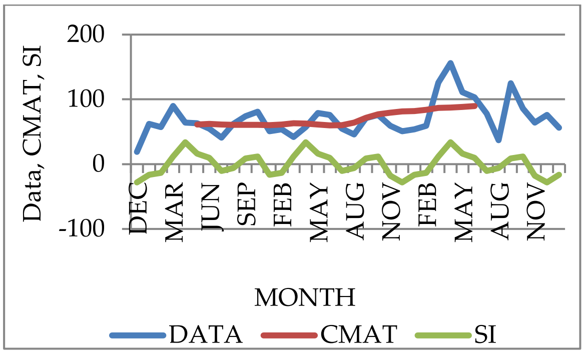

Fig. 1: Plots of data, CMAT and SI of NP-induced Faults on Eko 11 kV DN.

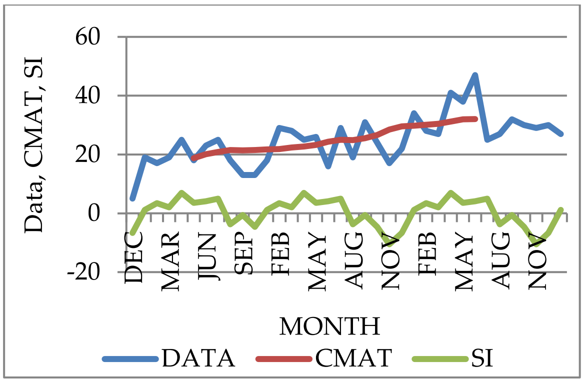

Fig. 2: Plots of data, CMAT and SI of NP-induced Faults on Eko 33 kV DN.

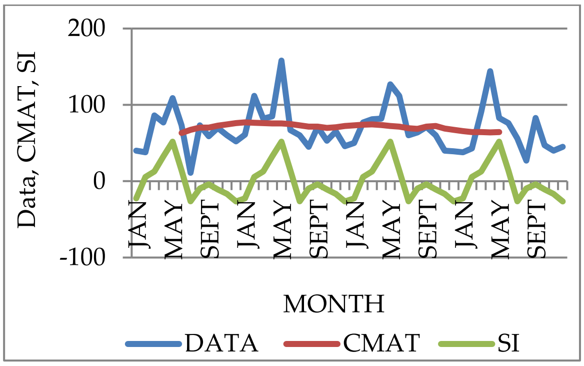

Fig. 3: Plots of data, CMAT and SI of NP-induced Faults on Ikeja 11 kV DN.

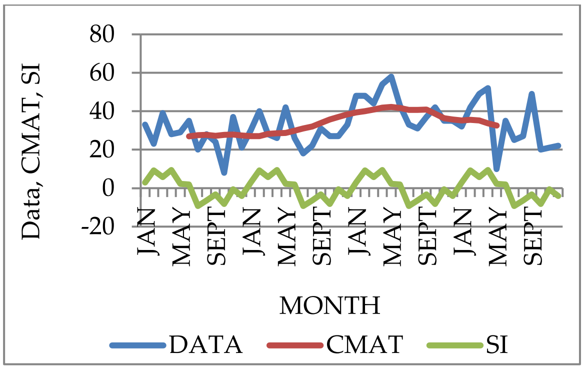

Fig. 4: Plots of data, CMAT and SI of NP-induced Faults on Ikeja 33 kV DN.

Table 3. Probability of nature-induced electrical faults in DNs of Lagos State

DN	$\sum_{np}^{m} F_{np}$	F_{gen}	$P_{m,}$ (%)
11kV Eko	2516	27837	9.04
11kV Ikeja	3289	29092	11.31
33kV Eko	894	14681	6.09
33kV Ikeja	1567	10418	15.04

Table 4. Nature-induced electrical faults per year per feeder in the DNs of Lagos State

DN	N	$F_{p.a,m}$				
		VEG	BIRD	LIGHTNING	FLOOD	TOTAL
11kV EKO	280	7.25	1.17	0.48	0	8.9
33kV EKO	100	5.73	2.12	0.9	0.08	8.83
11kV IKJ	283	7.4	2.9	1.29	0.01	11.59
33kV IKJ	93	9.29	6.34	1.22	0	16.85

Tables 1 and 2 show that at all voltage levels of the DNs of Lagos State, vegetation is the highest cause (67%) of NP-induced electrical faults. This is followed by bird/snake incursions (24%), followed by lightning (9%). The least cause is flooding (about 0.1%), despite the region being coastal.

Figs. 1 to 4 show the following. Firstly, there is no month of the year that NP-induced faults do not occur. Only that the intensity varies. Secondly, NP-induced electrical faults are cyclical (about the MA trends) for all the DNs and voltage levels. For Eko11 kV DN, it is above average from February to June, and from August to November every year; for Eko 33 kV DN, it is above average from January to July every year; for Ikeja 11 kV DN, it is above average only from February to June every year; and for Ikeja 33 kV DN, it is only above average from January to June every year.

Table 3 shows that 11 kV and 33 kV of the Ikeja DNs have the highest probability of NP-induced electrical faults in the State. This result established that natural phenomena affected the mainland part of the State more than the Island part in the data period. This may be due to the availability of a large landmass and vegetation on the mainland than the island part of the State that has a large water body. Table 4 shows that annual NP-induced faults in the studied DNs were quite considerable and was as high as 283 times on 11 kV DN, and 100 times in 33kV DNs. Vegetation is the highest contributor to nature-induced electrical faults per year per distribution feeder, followed by bird/snake fault causes. Annual NP-induced electrical faults per feeder is approximately 9 for Eko DN (island part), and approximately 12 to 17 for Ikeja (Mainland part). For both cases, the contribution of vegetation is highest and followed by birds/ snakes'

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incursions, as earlier stated. NP-induced electrical faults are more prevalent in the mainland area DN (Ikeja).

4 Conclusions

From the analysis of the results above, the following were established on NP-induced electrical faults for the studied distribution networks and coastal area. Firstly, vegetation and birds/snakes are the two most predominant natural phenomena that cause electrical faults in the distribution system of Lagos State. Secondly, although Lagos State is a coastal megacity that experiences floodwater, floods rarely cause electrical faults in its distribution networks. Thirdly, electrical faults caused by natural phenomena vary periodically about a moving mean throughout the year. Finally, NP-induced electrical faults are prevalent in the distribution systems of Lagos State, and it is more on the Ikeja DN than the island part that is closer to the coastline.

From these conclusions, the following recommendations are necessary. Planned maintenance policy must be enhanced to control vegetation, birds, and reptile incursions into Lagos DNs. Standard clearances of vegetation from DN elements (at least 2m on either side) need to be maintained effectively. Development and application of modern software-based sensor technologies for monitoring vegetation growth in the network should be explored. Existing protection scheme should be evaluated for effectiveness in view of ensuing short circuit events from intrusion incidents of these NPs at various hotspots.

In addition, region-specific bird/snake-repellent technology (e.g., frequency and noise-based), with favourable cost-benefit parameters, could be developed for application on the Lagos DNs to mitigate intrusions of such factors. The sensors could be installed at specific points along feeder lines, such as cross-arms, etc.

References

Akintola, A. (2017). Reliability Evaluation of Secondary Distribution System in Nigeria: A Case Study of Ayetoro 1 Substation, Aguda, Lagos State. *Unpublished Master's Theses, Covenant University, Ota, Ogun State, Nigeria.*

Awosope, C. (2014). Nigeria Electricity Industry: Issues, Challenges and Solutions. *Covenant University 38th public lecture. Public lecture series, Vol 3, No 2* (p. 11). Ota, Ogun State: Covenant University.

Csanyi, E. (2015, Mar 18). *11 major causes of power system failures*. Retrieved Dec 13, 2021, from electrical-engineering-portal.com.

Gunduz, N., Kufeoglu, S., & Lehtonen, M. (2017). Impacts of Natural Disasters on Swedish Power Policy: A Case Study. *Sustainability 9(2):230, DOI: 10.3390/su9020230* , 1-11.

Kjolle, G. (2011). What do Fault Statistics tell us regarding causes resulting in Power Outages? *SINTEF Energy Research Workshop DNV – NTNU Risk and Vulnerabilities in Power Systems in light* (pp. 1 -32). Norway: NTNU.

Melodi, A., & Oyeleye, M. (2017). Modeling of Lightning Strike Events, and it's Correlational with Power Outages in South-West Coast, Nigeria. *International Journal of Electrical and Computer Engineering (IJECE), 7(6), DOI: 10.11591/ijece.v7i6* , 3262-3270.

Melodi, A., & Temikotan, K. (2017). A Model Unavailability Perspective of Existing Nigeria Township Electricity Distribution. *International Journal of Electrical and Computer Engineering (IJECE), 7(1), DOI: 10.11591/ijece.v7i1* , 77-85.

Okunade, B. (2009). *Descriptive Statistics (STA111), University of Ibadan, Distance learning centre, Open and distance learning course series development.* Retrieved January 25, 2021, from http://dlc.ui.edu.ng/oer.dlc.ui.edu.ng/app/upload/STA%20111_1505825983.pdf.

Omonfoman, O. (2016, January 4). *Electricity Distribution Companies - The Challenges and Way Forward.* Retrieved January 25, 2021, from https://opinion.premiumtimesng.com/2016/01/04/electricity-distribution-companies-the-challenges-and-way-forward-by-odion-omonfoman/.

Oshin, O., Onile, A., Adanikin, A., & Fakorede, E. (2019). Reliability of Distribution Networks in Nigeria, Ikorodu, Lagos State as a Case Study. *Journal of Physical Science and Innovation* , Volume 11, No. 2, 57 - 70.

Quiroga, O., Meledez, J., & Herraiz, S. (2011). Fault Causes Analysis in Feeders of Power Distribution Networks. *International Conference on Renewable Energies and Power Quality, DOI: 10.24084/repqj09.619*, (pp. 1269 - 1272). Las Palmas, Spain.

Ross, S. (2009). *Introduction To Probability and Statistics For Engineers and Scientists.* London: Elsevier Academic Press.

Rudnick, H. (2011). Impact of Natural Disasters on Electricity Supply. *IEEE Power and Energy Magazine, DOI: 10.1109/MPE.2010.939922* , 22 -26.

Umoh, E., & Alaka, S. (2007). Natural Hazards and Sustainable Power Infrastructure in Zamfara, Nigeria: Emerging Lessons for Power Sector Stakeholders. *International Conference and Exhibition on Power and Telecommunication (ICEPT 2007).* Lagos: The Nigerian Institute of Electrical and Electronics Engineers (NIEEE).

Wang, L. (2016). The Fault Causes of Overhead Lines in Distribution Network. *MATEC Web of Conferences, 61, 02017, DOI: 10.1051/matecconf/2016610* (p. 1). France: EDP Sciences - Web of Conferences.

