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Lightning protection systems and safety considerations: Federal Polytechnic Kaltungo and Kaltungo environs as a case study

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Abstract
The evaluation of Lightning Protection System (LPS) necessitates the identification and lightning risk assessment on facilities in accordance with the international standards. This research aimed at assessing the risk of lightning strike and the probability of damages it may pose on safety of living beings and equipment within the Federal Polytechnic Kaltungo, Gombe State of Nigeria. The second phase of the study dealt with qualitative data collection and analysis, gathering information from within the Polytechnic community and its environs, through verbal interviews and surveys, aimed at exploring societal awareness on lightning protection and their ability or otherwise to afford basic lightning protection system. The results obtained shows that out of the 88% completed structures, less than 5% have functional and effective LPS installation. Findings of the research showed that, for all identified structures, the lightning strike frequency N_d is greater than the tolerable lightning frequency N_c, hence the necessity of LPS installations on the structures. The qualitative data results gave rise to recommendations and guidelines on simple lightning protection and safety measures that can be easily adopted in accordance with the community's peculiarities.

Keywords: Lightning protection system (lps), lightning strike frequency N_d, tolerable lightning frequency N_c, lightning strike

Introduction

Lightning is one of the most dramatic and most common natural activities that occur in the atmosphere. Lightning strikes may cause severe damage to physical structures and claim human and animal lives. It may ignite fires that may bring an entire structure down to ashes or create cracks, and at a lower degree of damage, it may destroy electrical, electronic and communication equipment beyond repair. Transmission lines, communication towers and tall physical structures including residential houses and monuments are more vulnerable to lightning activities. However, one of the most significant losses that it may cause as far as the industries are concerned is the downtime. A couple of hours of obstruction of normal operation or a loss of some important data stored in a computer may cause a company a huge economic loss (Masri, *et al*., 2022) [4].

Nowadays, due to global warming caused by infrastructural activities of man, the number of lightning strikes has increased. As much as 1% of temperature rise will increase the number of lightning strikes by 6% per annum. Parameters of strikes are also increasing (e.g., lightning density, peak value). This demands and determines the creation and utilization of increasingly accurate calculation models (Kasza & Kovacs, 2019) [3].

Kaltungo local government area, located in southern area of Gombe State of Nigeria, having a lightning stroke density of 16 strokes per km^2 per year (Vaisala GLD360, 2025) [5], is associated with occasional lightning strikes during the rainy season. Similarly, Federal Polytechnic Kaltungo, located at the outskirt of the town, is characterized by high-rise building structures and large population of both staff and students, which makes it a more vulnerable location for lightning strike. For instance, in 2020, an unreported lightning strike case hit the First Bank branch office, located in Kaltungo town, leaving internet and other communication facilities and host of networked desktop computers completely damaged, causing huge economic losses. Figure 1 depicts the different sources of damage in relation to the point of lightning strike on a building.

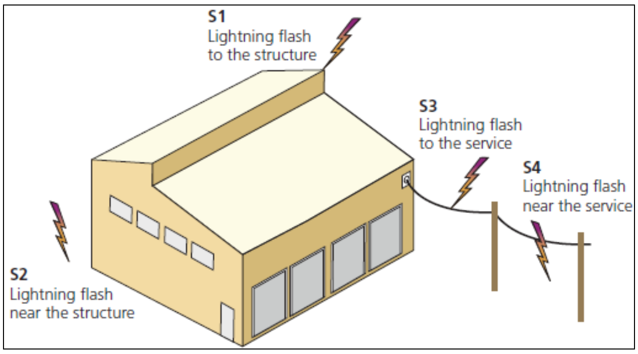

Fig 1: Sources of Damage Depending on Point of Lightning Strike on a Structure

Methods

A mix-mode research method comprising a mixture of experimental and qualitative measurements was adopted. It is based on the evaluation of lightning protection system on structures within the Institution and data gathering on societal behavior and beliefs towards lightning, and basic LPS installation affordability of the community for lightning safety considerations. Data gathered indicated that, Kaltungo local government area has an estimated thunderstorm day (T_D) of 90 days and a lightning stroke density (F_D) of 16 $stroke/km^2/year$. Lightning risk assessment analysis was conducted on the existing completed structures within the Polytechnic by determining whether an LPS is required on the particular building by comparing the actual lightning strike frequency (N_d) to a tolerable lightning frequency (N_c). If the calculated N_d exceeds the N_c, then an LPS is recommended. The assessment employed various other factors related to the building and its contents to calculate N_d and N_c. A flow chart for the risk assessment adopted for the LPS design is depicted in Figure 2.

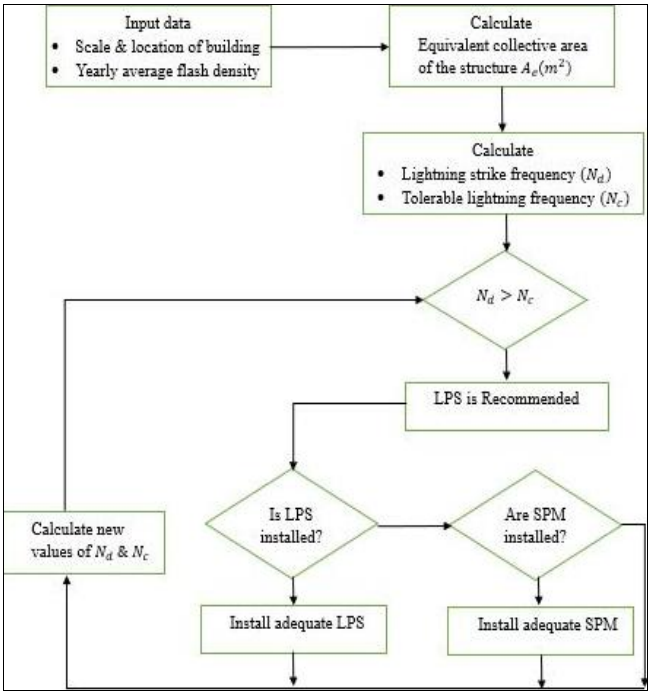

Fig 2: LPS Design Procedure

Design Considerations 1

A total of twenty-two (22) completed structures out of the twenty-six (26) existing buildings at the permanent site of the Polytechnic were identified and assessed, in compliance with the lightning risk assessment standards.

The lightning strike frequency was calculated as (Halilu, 2023) [2]:

$$N_d = (N_g)(Ae)(C_1)(10^{-6})$$

Where

N_g: The yearly average flash density in the region where the structure is located

Ae: The equivalent collective area of the structure

C_1: The environmental coefficient

$$\text{Ae} = L \times W + 6H(L + W) + \pi 9H2$$

Where L, W and H are the length, width and height of the structure respectively.

While the tolerable lightning frequency was determined using Equation (3):

Tolerable Lightning Frequency $(N_c) = \frac{(1.5\times10^{-3})}{C}$

$$C = (C_2)(C_3)(C_4)(C_5)$$

C_2: The structural coefficient

C_3: The structure contents coefficient

C_4: The structure occupancy coefficient

C_5: The lightning consequence coefficient

Design Considerations 2

a. Sampling Technique

The population was gathered, considering the three dominant tribe groups (Tangale, Hausa, Fulani), resident within Kaltungo and its environs. The selection was based on a stratified random sampling technique.

b. Data collection

Qualitative research was conducted by gathering data from the host communities. A total of 100 participants were issued with structured questionnaires, designed to capture:

1. Demographic information – age, gender, educational qualification, employment status and monthly income.
2. Belief and awareness on lightning activity, lightning protection and safety measures, first-aid measures, and lightning experience or history.

Results and Discussion

Lightning Risk Assessment

The results from the lightning risk assessment analysis conducted on the twenty-two (22) buildings are depicted in Table 1.

Table 1: Lightning Risk Assessment Analysis

S/N	$A_e(km^2)$	N_C	N_d	LPS Requirement
1	0.01114	0.0015	0.08916	LPS Installation is Required
2	0.01327	0.00075	0.05307	LPS Installation is Required
3	0.00239	0.0015	0.01915	LPS Installation is Required
4	0.00440	0.0015	0.01761	LPS Installation is Required
5	0.00468	0.0015	0.01873	LPS Installation is Required
6	0.00661	0.0015	0.02643	LPS Installation is Required
7	0.00444	0.0015	0.01775	LPS Installation is Required
8	0.00193	0.0015	0.00772	LPS Installation is Required
9	0.00196	0.0015	0.00786	LPS Installation is Required
10	0.00577	0.0015	0.02309	LPS Installation is Required
11	0.00524	0.0015	0.02098	LPS Installation is Required
12	0.00463	0.0015	0.03701	LPS Installation is Required
13	0.00403	0.0015	0.01613	LPS Installation is Required
14	0.01260	0.0015	0.05038	LPS Installation is Required
15	0.00691	0.0015	0.02762	LPS Installation is Required
16	0.00455	0.0015	0.01819	LPS Installation is Required
17	0.00408	0.0015	0.01632	LPS Installation is Required
18	0.00393	0.0015	0.01570	LPS Installation is Required

19	0.01070	0.0005	0.04281	LPS Installation is Required
20	0.01284	0.0005	0.05136	LPS Installation is Required
21	0.00285	0.003	0.01140	LPS Installation is Required
22	0.00311	0.003	0.01244	LPS Installation is Required

The analysis of the results obtained in Table 1 is plotted and displayed in Figure 3. The result shows that the tolerable lightning frequency, N_c remains relatively steady for corresponding variations in the equivalent collective area, Ae and lightning strike frequency, N_d except in some few instances. This is largely due to the changes in the values of environmental coefficient C_1, which is relative to location of the structure, and structure contents coefficient, C_3. Some of the buildings investigated are surrounded by smaller structures while others are isolated with no other structures located within certain specified distance, such as the central administrative block and school of engineering, respectively. The variation in the values of C_3 is as a result of structures containing high value and moderate flammability contents, like school of science and technology building.

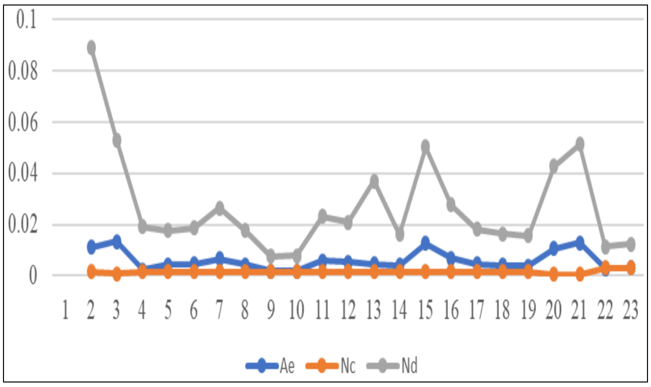

Fig 3: Relationship between A_e, N_c, and N_d

Similarly, the results further indicate a direct proportionality link between the equivalent collective area, Ae and lightning strike frequency, N_d, as shown in Figure 4. This portrays the fact that buildings occupying larger areas, not necessarily high-rise structures, are more prone to lightning strikes.

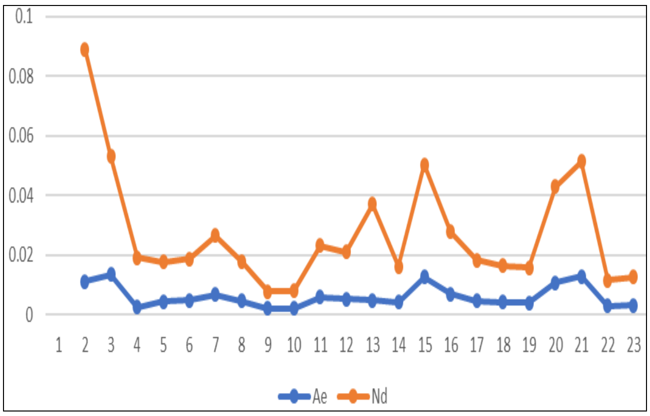

Fig 4: Relationship between A_e and N_d

Survey

The results obtained from the survey is expressed using quantitative data analysis in form of pie chart, as shown in Figure 5. The result captured people within the age range between 26 to 50 years and above. Among these groups, 90% have certain knowledge on dangers incurred by lightning, while 30% attach some cultural beliefs to lightning and are aware of known deaths as a result of lightning strike. 30% testified on the frequent occurrence of lightning in their areas while 40% acknowledge 1 or 2 lightning incidents, and 10% are aware of between 3 to 5 lightning incidents.

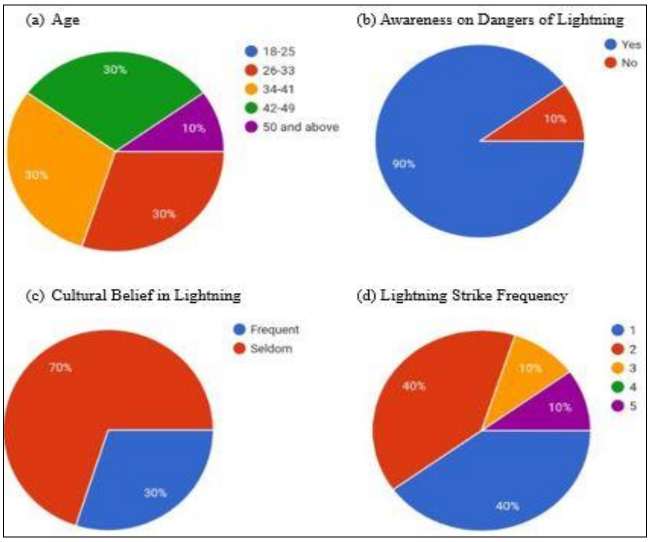

Fig 5: Quantitative Analysis on Lightning Surveys

Conclusion

Lightning risk assessment on 22 structures within Federal Polytechnic Kaltungo, Gombe State of Nigeria has been conducted in this paper. Out of these buildings, only one has a functional LPS installation, while another one has external LPS, but no internal LPS installed. The second phase involves a qualitative data gathering from around Kaltungo environs, aimed at proffering guidelines and safety measures against lightning storms. The survey considered the locality's peculiarities such as, beliefs, socio-economic aspect, nature of dwellings, awareness, etc. Consequently, the study came up with the following recommendations:

Lightning Protection System (LPS)

There are two main forms of lightning protections deemed necessary for the Polytechnic structures:

1. **External lightning protection**
   - Lightning rods and air terminals
   - Down conductors
   - Good electrical grounding system

2. **Internal lightning protection**
   - Surge protection devices (SPDs), most especially for structures housing sensitive electronic equipment.

Furthermore, periodical inspection and testing of the lightning installations are also recommended, taking into consideration the following:

1. Deterioration of air termination elements, conductors and connections
2. Corrosion of earth electrodes
3. Earthing resistance value for the earth termination system
4. Conditions of connections, equipotential bonding, separation distances and fixings.

In contrast, the study recommends basic lightning protection installations for the communities around Kaltungo environs due to factors such as, belief, affordability, awareness, culture and nature of dwellings.

It has been observed that most of the indigenous shelters are made of clay and bio-materials such as thatched, zinc or other plant-based material roofed and clay walled houses. Others are shanties (informal small dwellings made of a combination of various materials such as wood, polyethene, PVC, metal sheets, thatch, clothes).

Such structures could be upgraded to safe structure levels, SSL IV or SSL III to either protect the occupants only from a direct strike, side flash, step potential, touch potential and upward leader or protect them from all primary injury mechanisms but not from the effects through service lines, respectively.

As a rule of thumb

1. An air termination with a single-mast lightning protection system could be installed having a 1-m minimum separation distance between the mast and the thatched/polyethene roof edge (Gomes, 2022) [1].
2. The base of the air termination is grounded with a single deeply driven rod, with the pit filled with charcoal and animal dung for effective grounding.

Lightning Safety Considerations

Some of the responses from the survey when asked to describe any known lightning event are;

"I have 3 persons' death as a result of lightning, the sound is scary. Some believe that swearing by thunder attracts in lightning". Another reads;

"Touching a metal object during lightning, and was electrocuted".

Consequently, the following recommendations could be helpful in saving lives during lightning storms:

1. Avoid touching any form of conductor or electrical installations connected to the National grid during thunderstorms
2. Disconnect mobile phone chargers and other electronic appliances from the sockets during lightning storms
3. Avoid taking shelter under a tall tree during lightning storms. Another respondent among those interviewed says; "A case of lightning which struck a tree, after few minutes the tree was set ablaze, and that was the end of that tree".
4. Adopt the popular slogan; "When thunder roars, go indoors". But ensure to take shelter in lightning-safe structures. In the environment under study, such shelters could be:

- A building with roof and floor made of concrete, having no covering walls but large in internal space, with or without external LPS. The internal space is large enough to avoid occupants being subjected to side flashes or step potentials if there is no LPS installed. The International Electrotechnical Commission (IEC) specifies a separation distance of at least 1 m from possible lightning current paths (possibly concrete pillars and walls) and between the occupants. The size of the internal space should be sufficient for such spaced occupancy. Among the responses from the survey, a respondent cited "cracks in buildings" as a lightning incident encountered in the area.

- A building with a metal roof that is firmly connected (both mechanically and electrically) to metal struts, having no covering walls but large enough in internal space to allow the abovementioned spaced occupancy, with metal struts properly grounded (typically, workshop buildings).

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