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Lightning Activities and Ground Flash Density in Niger Delta Coast

John Tarilanyo Afa
Department of Electrical Engineering, Rivers State University of Science and Technology,
P.M.B. 5080, Nkpolu, Port Harcourt, Nigeria

Abstract: The lightning activities in Brass, Bonny, Opobo and the Calabar axis are very high. The mechanism for the formation of thunderstorm is strong convective processes. The sea breeze, the different temperature and the humidity changes may lead to such processes, therefore the lightning activities (Keraunic level) in these areas are high. The study is aimed at establishing the average ground flash density in the area. This was done by taken records of the lightning days for a period of 2 years in three different sites. This figure was compared to some data taken from meteorological stations. The cloud to ground flashes recorded within the working period was much fewer compared to the total flashes. When the ground to clouds was taken as 5:1, the number of days was between 120-150 days year^{-1} that is the ground flash density was 12-16 flashes/km^2/year. The need to know the lightning activities cannot be over emphasized when considering protection of electrical, electronic and telecommunication designs and constructions. This research was done to sensitize the government, companies operating in the area and line designers to provide better lightning detectors for more accurate figures in the area.

Key words: Keraunic level, ground flash density stepped leader, thunderstorm day, return stroke, sea breeze, Nigeria

INTRODUCTION

Lightning is an electrical discharge. It is the high current discharge of an electrostatic electricity accumulation between cloud and earth or between clouds. The initiation of lightning takes place in cloud region with sufficiently strong electrical fields.

Lightning is discharged as stepped leaders that propagate towards the earth in discrete steps of about 50 m each (Bhavika, 2007). The ionization path taken by these leaders depends on various variables such as the shape of the electric field, dust and other particles in atmosphere. As the leader grows, it creates an ionized path depositing charge along the channel and as it nears the earth, a large potential difference is generated between the tip of the leader and the earth. The earth acquires a net positive charge and a positive streamer is launched from the earth intercepting the descending stepped leader initiating a return stroke that transport charge between ground and cloud. The current surge along the conducting channel results in an explosive expansion of air heated to temperature in excess of 30,000°C producing an incandescent flash and shock wages known as thunder.

The tip of the leader has a speed between 10^5 and 2×10^5 m sec^{-1} and the initial speed of the return stroke is 10^8 m sec^{-1}. The current involved in the stroke has a peak value from 1-200 KA lasting about 100 μ sec (Bhavika, 2007; Pinto *et al*., 2006; Soriano and de Pablo, 2002).

Following the initial electric discharge, subsequent surges of electrons called dart leaders follows. The total discharge of energy resulting in lightning is called a flash and involves one or more subsequent current flows each of which is termed a stroke (Christian, 2003; Mowete and Adelapu, 2009).

A flash which is made up of one or more strokes may take place between two clouds known as Cloud-to-Cloud (CC) flashes within the same cloud known as Inter Cloud (IC) or from cloud to ground flashes. The CC flashes are characterized by lower amplitude and some researchers (Bhavika, 2007; Pinto and Pinto, 2003) place the ratio as 6:1.

It has been generally agreed that negative flashes, account for at least 90% of global lightning and 10% are positive lightning flashes. Also, positive flashes carry at least 6 times more current than negative flashes. The Keraunic level can be defined as the average number of days per year on which thunder is heard can be assessed either from Isokeraunic maps or from daily weather records being obtained from ground base observations. A thunderstorm day is a local calendar day during which thunder is heard at least once in a given location. With the use of Keraunic level, the ground flash density N_g can be calculated as:

$$N_g = 0.04T^{1.25}\left(\text{flashes}/\text{km}^2/\text{year}\right) \quad (1)$$

where, T is yearly Keraunic level.

MATERIALS AND METHODS

Characteristics of lightning discharge: The lightening discharge current is defined by its shape and characteristic parameters. Given the random nature of lightening, the parameter identifying each stroke follows probabilistic laws.

IEEE guidelines consider (Ekonomou *et al*., 2003; Shafaei *et al*., 2011) a triangle sharp and the characteristic times of lightning currents are considered constant (2 μ sec/50 μ sec). The amplitude follows a probabilistic law given by the cumulative probability of exceeding the amplitude I:

$$p_\lambda = \frac{1}{1+\left(\frac{I}{31}\right)^{2.6}} \quad (2)$$

where, I is in KA. CIGRE guide lines consider a concave front current (Ekonomou *et al*., 2003). The characteristic parameters of lightning currents follow a log-normal distribution which probability density is given by:

$$f(x) = \frac{1}{(2\pi)^{1/2\beta x}} e^{-(z^2/2)} \quad (3)$$

Table 1: Parameters of log-normal distribution for the lighting current, according to CIGRE (Ekonomou *et al*., 2003)

Parameters	First (M)	Stroke (β)	Subsequent (M)	Strokes (β)
Front (u sec)				
$t_{d30} = T_{30}/0.6$	3.830	0.553	0.6700	1.013
Steepness (KA/μ sec)				
S_m, maximum	24.300	0.599	39.9000	0.852
$S_{30/90}$, 30-90%	7.200	0.622	20.1000	0.967
Crest current (KA)				
I_I, initial	27.700	0.461	11.8000	0.530
I_F, final	31.100	0.484	12.3000	0.530
Initial/final	0.900	0.230	0.9000	0.207
Tail (μ sec)				
t_h	77.500	0.577	30.2000	0.933
Charge (c)				
Q_I	4.650	0.882	0.9380	0.933
$\int i^2\,dt$ (KA^2.sec)	0.057	1.373	0.0055	1.366
Interval between strokes (m sec)	-	-	35.0000	1.066

Where:

$$Z = \ln\frac{(x/M)}{B}$$

Data collection: Data for lightning days were collected for 2 years (2010 and 2011) in three different sites, Onne and Port Harcourt in Rivers state, Brass in Bayelsa state. Also data were collected from the Niger Delta University and the Federal Ministry of Aviation. These data were compared to the data taken in the various centres. From the available records, the necessary data were tabulated as shown in Table 1.

RESULTS AND DISCUSSION

The lightning days for 2010 and 2011 for Onne, Port Harcourt and Brass are shown in Table 2-4.

Onne-site: The lightning days for 2010 and 2011 for Onne site are shown in Table 2. While:

- The ground flash density = N_s= 0.04T$^{1.25}$
- For 2010, the total thunder storm days = 376
- For 2011, the total thunder storm days = 422

If the CC to CG is 4:1 then:

- The number of lightning days = 400/5 = 80
- The ground flash density = 0.04×80$^{1.25}$ = 10 flashes/km^2/yearly

Port Harcourt site: The lightning days for 2010 and 2011 for Port Harcourt sites are shown in Table 3. While:

- The number of lightning days = 314/5 = 63
- The ground flash density = 7 flashes/km^2/year

Brass site: The lightning days for 2010 and 2011 for Brass sites are shown in Table 4. While:

Table 2: Lightning days for 2010 and 2011 for Onne site

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Years	Yearly total
5	20	43	49	68	35	31	6	40	54	18	7	2010	376
7	24	45	71	72	40	29	10	42	61	15	6	2011	422

Table 3: Lightning days for 2010 and 2011 for Port Harcourt site

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Years	Yearly total
2	15	38	42	57	35	28	15	25	40	6	5	2010	308
1	18	35	58	61	28	18	18	25	48	8	2	2011	320

Table 4: Lightning days for 2010 and 2011 for Brass site

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Years	Yearly total
15	30	71	89	76	67	35	28	51	78	20	9	2010	569
10	20	60	97	66	57	38	30	60	82	15	6	2011	541

- The number of lightning days 555/5 = 111
- The ground flash density = 14.4 flashes/km^2/year

The electric field required in a lightning discharge for the breakdown between cloud and earth at standard temperature and pressure is 30 kv cm^{-1} peak. In a cloud where moisture content in the air is high with a high altitude (pressure) the field required could be as low as 10 kv cm^{-1}.

This explains why the Brass site has lower breakdown with more lightning flashes (thunderstorm) than the Port Harcourt site. It has been established that the highest flash densities occurred in coastal areas and mountainous regions (Christian, 2003; Telesca *et al*., 2008). It was also said that lightning occurred mainly over land masses with an average land: ocean ratio of 10:1 that is the influence of ocean current on lightning activity is visible with high incidences occurring along coastlines. It is necessary that the coastland areas may experiences more lightning flashes than the inland areas which is evident in the three tests. Several observations have shown that in the coastal areas of Bonny, Brass etc., mild flashes are observed even in fair weather. The ratio of the cloud-to-cloud and the cloud-to-ground flash was taken as 4:1. In most practical case, the figure is realistic in this part of the country but in the coastal areas, the ratio may increase.

Between the months of July to September during the peak of the rainy seasons, the thunderstorm days are fewer but they are mainly cloud to ground flashes with prolonged durations. From Table 1, the thunderstorm days are more during the transitional periods of rainy and dry seasons with much smaller amplitude which also confirms that other researchers observed (Mowete and Adelapu, 2009).

CONCLUSION

The reasons for the high flash density in the coastal areas are:

- The high humidity (moisture) and pressure of the area
- The influence of the ocean current on lightning activities
- The trajectory nature of discharges on coastline

LIMITATIONS

One of the limitations in estimating lightning frequency is that lightning activity is highly variable on both a temporal and a spatial scale. Lightning activities varies from year to year and between individual thunderstorm events. The climatic and weather changes that are obvious yearly that is why a long term average values are necessary for a good estimation of lightning activities. In order to obtain a reliable average data, good lightning detectors are necessary for a long term (10 years) investigations.

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