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Lightning a Fundamental of Atmospheric Electricity

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Abstract

This paper discussed briefly the basic connection between lightning phenomena and atmospheric electricity. Characteristics pertaining to lightning discharges were reviewed in order to elucidate some elementary mystics that are still associated with lightning events in some parts of the world and that lightning strike when and where it will. Various lightning protection principles were discussed. The essence of lightning protection device is to prevent lightning strikes from taking place over or around an installation or structure.

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Keywords: Lightning; Static electricity; Electrostatic discharges

1. Introduction

Electrostatic discharge is due to static charge build-up, which occurs as a result of tribo-charging or by electrostatic induction. The theory of electrostatic discharge (ESD) which is the momentary flow of electrical energy between electrically charged bodies when in contact with each other is the base for understanding of lightning.

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The sudden flow of electrical energy can result in electric sparks accompanied by some sound. It is the larger scale of such ESD occurrence in the atmosphere that is referred to as lightning and thunder (Anderson and Eriksson, 1980; Kasemir, 1960, Thomson, 1985).

In simple terms, lightning is the process of spontaneous momentary high-current electrostatic discharge, which often is initiated in the cloud and the path usually stretch over kilometers in length (Uman, 1987). In the time of upward draft, tiny ice particles in the cloud rub against each other setting up polarization process. Positive charges generated in the process drift upward in the cloud while negative charges drift downward, the reason for this is still under investigation by researchers (Rakov and Uman 2003). As the cloud size increases, there is increase in electric potential difference between the upper positive and lower negative parts, which unavoidably lead to ESD reaction between the regions. When these discharges are limited to the same cloud, it is called intra-cloud discharges, while those that involve two or more clouds are called inter-clouds or cloud-to-cloud discharges, (Fig. 1). These types of discharges account for about 75% of global lightning occurrences and do not involve the earth surface (Rakov, 2007). Cloud to ground (CG) discharges are the most relevant of all the lightning discharges to human and other life existence on earth surface (Fig. 1).

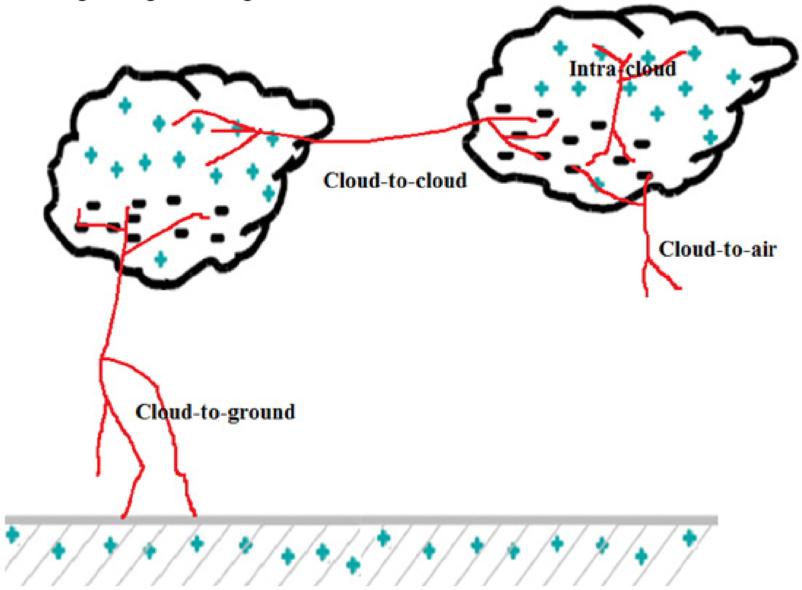

Fig.1 Different types of lightning discharge (Rakov, 2007)

1.1 Types of Cloud-to-Ground (CG) Lightning Discharges

The CG discharges are categorized into four major types namely; (i) downward negative lightning (ii) downward positive lightning (iii) upward negative lightning and (iv) upward positive lightning as shown in figures 2(a-d).

The downward negative lightning discharge is believed to be the most common, accounting for about 90% of the CG discharges globally, while less than 10% are downward positive lightning. According to Uman, 1987 and Rakov, 2007, on the average, negative cloud-to-ground lightning discharge is composed of 3 to 5 leader/return stroke sequences, but occasionally, two leader/return stroke sequences occur in the same lightning channel with a time interval between them as short as 1 ms or less. According to them, positive CG discharges are associated with the after effects of prolonged cloud-to-cloud discharges which finally result in downward positive discharges. The upward negative and upward positive lightning discharge types are observed to occur mainly from tall objects of height of about100 m or from objects of moderate height located on mountain tops, (Anderson and Eriksson, 1980; Uman, 1987 and Rakov, 2007). Observations showed that the lightning process was initiated from the top of such objects upward to seek a conducting pathway with opposite charges in the cloud above. This is in line with the saying that "lightning do not strike tall objects", but instead tall objects induce lightning conduction path towards itself (Cooray and Jayaratne, 1994).

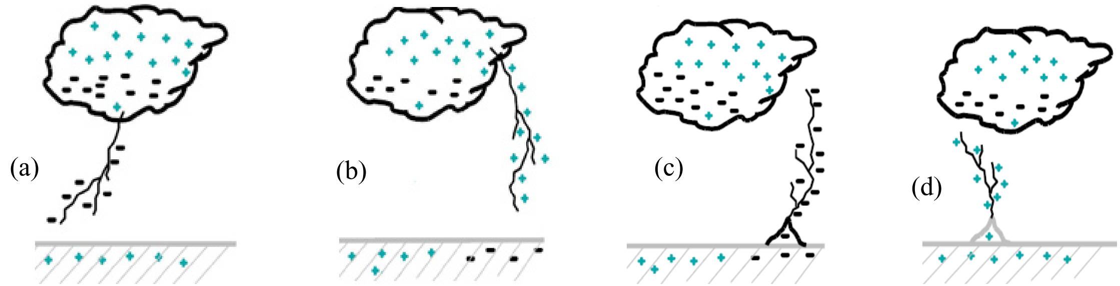

Fig.2 (a-d): Downward negative discharges, downward positive discharges, upward negative and upward positive discharges respectively (Rachidi and Rubinstein, 2009).

1.2 Lightning Connection and Attachment Process

Understanding the principles behind the lightning event helps in proper design of the lightning system protection, heated air migrates upward into a freezing region, creating constant collisions among the ice particles in the thundercloud driven by rising and falling air columns, which cause the building up of static charges leading to preliminary discharge, a phenomenon that occurs at the lowest portion of the cloud (Figs.3a and b), (Mazur *et al.,* 1995, Rakov and Uman, 1990).

As the static charges become sufficiently large enough, an initial small charge called a step leader breaks out, seeking an ideal cloud-to-cloud or cloud-to-ground path. Once this path is established, the main series of strokes follow Fig3 (c-e). (Baum, 1999; Rakov, 2007; Rakov and Uman, 2003)

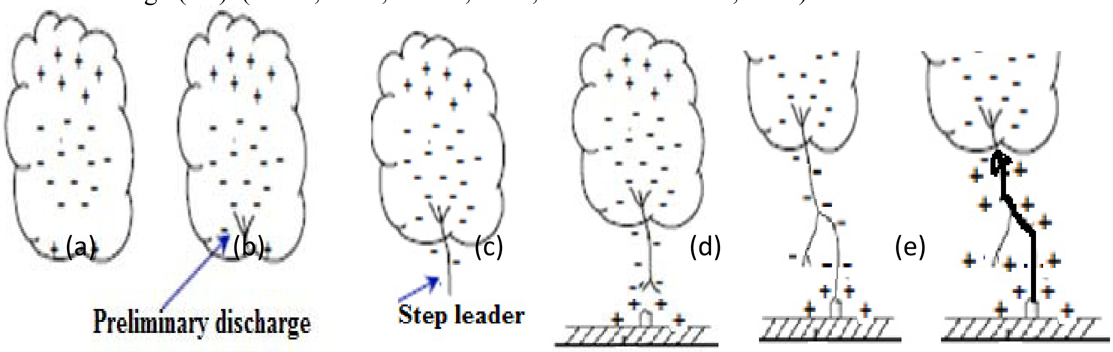

Fig.3(a-f) Different stages of Lightning Connection and Attachment (Adapted from Rachidi and Rubinstein, 2009)

The step leader polarity indicates whether the strike will have positive or negative characteristics. The step leader proceeds downward towards the ground seeking connection with static charges of opposite polarity. Once this is accomplished, a lightning conducting path is created and this results in the first return stroke as shown in figure 3f.

The whole essence of lightning protection device is to prevent these connection and attachment from taking place over or around an installation. Attachment process is what helps to establish an electric conduction pathway which leads to free flow of current resulting in lightning strokes. The presence of installed lightning protection device on the structure either helps to dissipate the electric charges into the ground to avoid any hazard instead of accumulation of charges on the structure, or it terminates the proceeding lightning step leader right in the air before it connects with the structure by connecting it to a conducting rod buried in the ground (Uman and Voshall, 1968; Cummin *et al.,* 1998; Rakov 2007).

2. Types of Lightning Protection Devices

2.1 Static Charges Dissipating Device

Lightning dissipators are devices used to protect the site by making it invisible to lightning; this is accomplished by dissipating charges from the structure into the ground, thus resisting static charges build-up to minimize lightning strikes. A fundamental principle of static electricity is that all objects emit charges through the process of ionization, and sharp objects emit charges faster than flat or rounded planes. This partly explains why lightning strokes hit corners and sharp points of a building more often than the flat sides. When the static charges are allowed to accumulate at the pointed edge, a level is reached that will attract lightning strokes towards such point. Ideal lightning dissipators has multiple fine electrically conductive strands of wires fitted into a hole in an electrically conductive base that allow the static dissipation of electrical ground charges and thereby minimize the electrical potential between the clouds and the structure (Sadler and Kaiser, 1990; Durret, 1977).

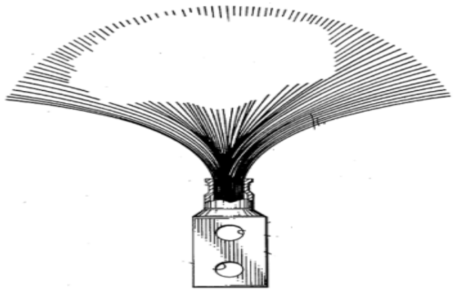

Fig. 4 A Typical lightning dissipator (Sadler and Kaiser, 1990)

These thousands of sharp small pointed wires though may create more ionization but they also induce faster dissipation of the charges created. Instead of having positive charges concentrated on the top of a single point and forming a streamer, the same amount of charges are formed through thousands of smaller points leading to the dissipation process. Dissipation process mostly stops or in some cases delays the formation of streamers and minimizes the risk of lightning occurrence at the point to be protected (Sadler and Kaiser, 1990). Thus protecting the metal structures such as telecommunication towers with lightning arresters or leaving them unprotected sometimes may end up having the same result, that is both collect the positive charges on the tower top, emit them in the form of positive streamers and once one of these streamers meets with one of the negative stepped leaders from the cloud, the lightning hits the tower top.

2.2 Strike Termination Device (STD)

Strike Termination Device is another lightning protection system component which reaches out to intercept lightning flashes in the air and connect them to proper path into the ground. In essence, lightning terminators attract lightning on themselves. The main aim of lightning terminator systems which are also referred to as "charge transfer systems", is to produce conditions under which lightning either does not occur or if it occurs, it does not strike the protected structure (Durrett, 1977 and FAA, 1990). Lightning elimination systems include one or more elevated arrays of sharp points, often similar to barbed wire, that are installed on or near the structure to be protected. These arrays are connected to grounding electrode rods via down conductors as in the case of conventional lightning protection systems (Uman, 1987). The principle of operation of lightning terminator systems, according to their developers, is generally that the charges released via corona discharge at the sharp points will either (i) discharge the overhead thundercloud, by eliminating any possibility of lightning (this is why such arrays are sometimes referred to as "dissipation arrays") or (ii) discourage a downward-moving leader from attaching itself to the array and to the structure to be protected by reducing the electric field near the array and, hence, suppress the initiation of an upward-connecting leader by attracting the lightning to themselves (Uman and Rakov, 2002).

3. Conclusion

In this paper various types of lightning discharges were reviewed which is a major phenomenon that affects the telecommunication installations and other infrastructures in Nigeria and environ. The basic protection devices discussed can be used by various organizations to combat existing problems due to lightning discharges. This review is a contribution to knowledge and provides further enlightenment to lightning studies for the society. The group is presently researching on the effect of lightning which is a major challenge in developing countries' telecommunication installations, using both ground and satellite data. Ongoing research studies are being carried out to find ways of combating these challenge

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