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Journal of Nepal Physical Society

Volume 8, Issue 3, December 2022

ISSN: 2392-473X (Print), 2738-9537 (Online)

JNPS, **8** (3): 59-65 (2022)

DOI: https://doi.org/10.3126/jnphyssoc.v8i3.50728

Published by:

Nepal Physical Society
P.O. Box: 2934
Tri-Chandra Campus
Kathmandu, Nepal
Email: nps.editor@gmail.com

JNPS 8 (3): 59-65 (2022)
ISSN: 2392-473X (Print), 2738-9537 (Online)

Research Article *© Nepal Physical Society*
DOI: https://doi.org/10.3126/jnphyssoc.v8i3.50728

Discharging Phenomena in different types of Lightning

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Received: *31st July, 2022;* ***Revised:*** *31st Oct., 2022;* ***Accepted:*** *3rd Dec., 2022*

ABSTRACT

There are two charge regions and charges can transfer from one region to another region. For lightning discharging process, the centers of two charges are separated by different distances and air as an insulator between them. The methods of the process of charge formation in different types of lightning are different. In volcanic lightning, it form closer to the ground and discharging process occurs between the two charge regions as the normal thunderstorm lightning does. The steeped leader starts at the structure and propagates upward in nuclear lightning. Their direction of branching is also upward and the return strokes do not initiate from upward moving leaders. It is similar to upward initiated thunderstorm lightning flashes from tall structures and forms in several kilometers. In Earthquake lightning, a shifting of the positive and negative charge centers in the material, which then results in an external electric field. Even the different lightning signatures have been observed in our scientific community, the thunderstorm lightning is frequently observed and measured by the different methods such as electric field measurement, magnetic field measurement, photography and so on. Here, the method of electric field measurement is used to measure the thunderstorm lightning. In all cases of lightning, the discharge phenomena take place between two different charged regions. The two regions of positive charges and negative charges are separated by a certain distance and the air between them is an insulator. When the sufficient charges store in the two charge regions, voltage is developed between them. If the potential developed is sufficient for the electric breakdown of the air, then lightning phenomena occur. Hence, the discharging phenomena occur between the positive and negative charge regions for the different types of lightning.

Keywords: Different types of lightning discharges; Thunderstorm lightning; Volcanic lightning; Nuclear lightning; Earthquake lightning.

INTRODUCTION

Lightning discharge is an electrical discharge phenomenon that takes place between two charged regions. Among the various types of lightning discharges, the observation, and measurement of thunderstorm lightning are prominent. In thunderstorm lightning, many properties of lightning processes have been discovered; however, some processes remain poorly understood. To find the discovered properties, researchers used different instruments with the help of fast optical and electromagnetic instruments. Some previously unrecognized lightning signatures have been identified later on, such as, Compact Intra-Cloud Discharges (CIDs)[1, 2]; Narrow Bipolar Pulses (NBPs)[3]; Isolated Breakdown Pulses (IBPs)[4, 5]; Transient luminous signatures observed in the middle and upper atmosphere[6, 7]; Unusual lightning[8]; Different features of cloud flashes[9,10,11]; Preliminary breakdown pulses[12, 13]; Different features of positive CG lightning[14, 15] and so on.

A sudden occurrence of a violent discharge of steam and volcanic material from certain regions of land, mountains, or water bodies is known as a volcanic eruption. Anderson and coworkers have illustrated lightning in the dust clouds above some active volcanoes and described that lightning illuminated the volcanic clouds during the volcanic eruptions almost continuously [16]. They further studied that the electric field intensity near volcanoes and found that the electric field intensified during vigorous eruptions of black clouds of dust and conclude that lightning was observed only during eruptions. Lightning and electrification at volcanoes are important because they represent a hazard in their own right; they are a component of a global electrical circuit and to ash particle aggregation and modification within ash plumes in the surrounding [17]. Williams suggest that lighting may also be used as a real-time predictor of ash particle density and again added that the electrical charge separation is known to occur in other meteorological processes that are distinct from thunderclouds like the dusty gas fronts [18].

A nuclear explosion occurs as a result of the rapid release of energy from a high-speed nuclear reaction. The driving reactions may be nuclear fission, nuclear fusion, or combination of the two. Atmospheric nuclear explosions are associated with mushroom clouds. Anderson, et al., explained that the nuclear clouds also host lightning within them making these nuclear mushroom surreal with lightning discharges. The theory of lightning in nuclear explosions is still a naive and not well-understood subject [16]. Nuclear lightning occurs due to the detonation of thermonuclear devices (H- bombs) at ground level, negative charge is developed in the atmosphere which results in kilometer-length discharges. Several large-yield nuclear explosions have resulted in a lightning like discharges in the atmosphere [19, 20]. In this nuclear lightning discharge, as the conductive discharge, propagates the initial electric field structure changes very quickly and remains consistent with Coulomb's law, it is the space charge in closest proximity to the discharge which is most influential on its subsequent development [21].

An earthquake lightning also referred to as earthquake light is an unusual luminous areal phenomenon that rapidly appears near areas of tectonic stress and seismic activities etc. The transient luminous phenomena that may occur due to electrical discharges have long been reported during earthquakes and more recently attributed to the electric fields generated by seismic strains [22]. Earthquake lights and steady atmospheric glows associated with earthquakes are more commonly reported phenomena. These lights are reported to appear while an earthquake is appearing and have shapes similar to a bluish-white; Appearances of the earthquake light seem to occur when the quakes have a high magnitude, generally 5 or higher on the Richter scale [23].

The main goal of this paper is to present different lightning signatures that are characterized. There are different lightning phenomena that take place between two different charged regions. The two charges positive and negative were separated by a certain distance and the air between them as an insulator. In each types of the lightning discharge, the sufficient charges store in the two different regions, the voltage developed and sufficient to electric breakdown of the air. The basic principle in different lightning discharge occurs in different process in the natural hazard is the motivation of this article.

Instrumentation for measurement of thunderstorm lightning: Our measurement of lightning electric fields signatures in Kathmandu, Nepal, at a height 1300 m above the sea level. The parallel plate antenna measures the vertical electric field signatures was installed on the top of a building 13.5 m high. The parallel plate antenna has capacitance of 60 pF and the Pico-scopeD 6404 were connected through RG-58 co-axial cable as shown in Figure 1. The antenna and electronic system were carefully calibrated and the details of the calibration have been explained by Galvan and Fernando [24].The same measuring system also explained in the Himalayan country Nepal, and observed different types of lightning [25].

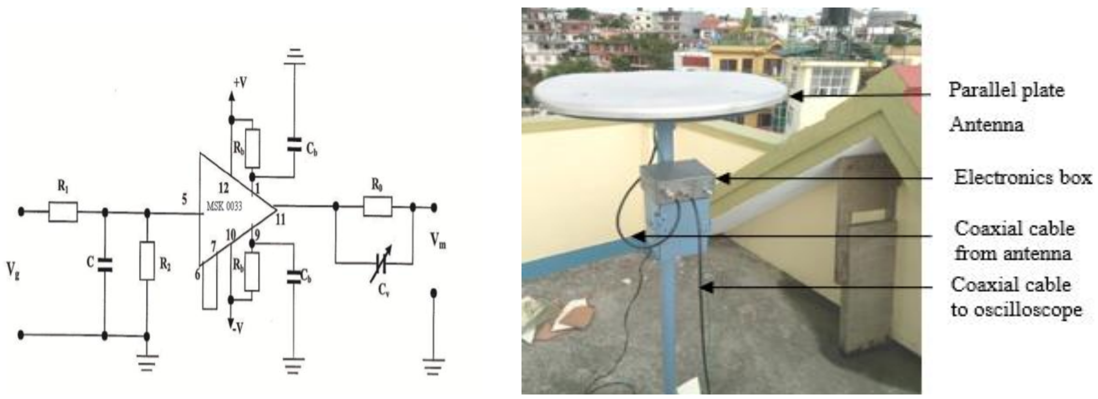

Fig. 1: The electronic buffer circuit and the elevated parallel-plate antenna installed in Kathmandu.

RESULTS AND DISCUSSIONS

Volcanic Lightning: A volcanic eruption which occurrence of a violent discharge of steam and volcanic material are thrown out of a volcano. Some of these ejects include lava, rocks, dust, ash, and other gas components. These gas and ash discharges are very hazardous to the surrounding environment. Lightning is a common phenomenon in volcanic eruptions. Lightning is the electrical flow between the positive and negative charges, that results when charge separation becomes too great for the air to resist the flow of electricity. As mentioned by the Anderson and coworkers, lightning occurs in the dust clouds above some active volcanoes during the volcanic eruptions. The electric field intensity near volcanoes found highly intensified during vigorous eruptions and the lightning was observed only during eruptions. From the charge structure, a static electrical charge to hold with the top of the cloud having a positive charge and the bottom having a negative one forms the lightning. During the formation of volcanoes, there is a mix of warm and cold air causes the early stage of the development of charges. The air acts as an insulator between the positive and negative charges in the clouds. When enough opposite charges formed, breaking the insulating capacity of the air and there is a rapid discharge of electricity, commonly known as lightning.

The volcanic lightning observed the volcanic eruption of Mount Sakurajima in Japan, one of the most active volcanoes on the planet by a team Ludwig-Maximilian University of Munich, and found that volcanic lighting typically occurs in the lower section of the ash cloud [17]. This is because the magma inside the rim of the volcano causes the ash cloud right above to become electrified. Eventually, this charge builds up similar to the way it does in a normal cloud and produces lightning. A study in the journal Science indicated that electrical charges are generated when rock fragments, ash, and ice particles in the volcanic plume collide and produce static charges just as the ice particles collide in regular thunderstorms and due to the production of static charges flashes of lightning are observed in volcanic eruptions. From different observation of the volcanic lightning, it forms only after several minutes when the volcanic explosion occur from the storm clouds in the sky and is generated within the ash cloud spewing from the volcano and the formation of black gases.

The charge separation process in volcanic lightning is still not completely understood. There are various theories describing the charge separation process in volcanic lightning. As volcanoes can occur in the mountains, in those places surrounded by water, and on dry land, the process of lightning also varies accordingly. The atmosphere is thermally unstable, the heat input from the volcano could initiate strong convective activity approaching thunderstorm proportions and under such conditions, the electrification mechanism of thunderstorms would act in addition to the electrification produced by the volcano.

The time interval between the start of eruption and the discharge of lightning from each new cloud was so short that it was difficult to explain the accumulation of necessary charge in terms of the charge separation process that took place in the atmosphere after the cloud have been formed. Also, the potential gradient was most intense near the crater and it rapidly diminished with distance. The conventional thinking about volcanic lightning has been that the interactions between dry silicate ash particles such as collisions and fractures have been dominant processes causing electrification while the role of water is thought to be secondary. The existence and role of ice particles in ash plumes are now recognized as a fundamental aspect of thundercloud electrification. In this process, the expansion of steam and its subsequent condensation and freezing are emphasized as primary processes whose magnitude and effects have been understood concerning volcanic lightning. The volcanic thunder cloud is assumed to be formed due to the formation of ice at the top of thinning ash cloud which was also carrying water vapor producing lightning. Thus the effect of water (steam) in the formation of lightning during a volcanic eruption is significant.

Nuclear Lightning: Unlike the situation of thundercloud lightning, the most common source of lightning, the charge separation mechanism in the nuclear lightning case is uncontroversial and is generally attributed to Compton scattering of electrons by the prolific source of gamma rays. Thus knowledge of the electric field and current behavior is important to a clear understanding of the physical mechanism responsible for nuclear explosion-induced lightning, its physical characteristics, and how it differs from natural lightning. Most of the cloud-to-ground lightning flashes are initiated in the cloud by a downward propagating discharge known as the steeped leader. The leader branches in a downward direction, when it reaches the ground the return stroke propagates from the ground up to the leader channel and out of the leader branches as mentioned by Uman et al., (1972). Most lightning flashes between very tall structures and clouds take place in a very different manner. The steeped leader starts at the structure and propagates upward. Their direction of branching is also upward. Upward moving leaders do not initiate return stroke when they reach the clouds. Typically the leader current merges smoothly into a continuous current that flows between the cloud and the structure. The lightning discharges induced by surface thermo nuclear detonations are very similar to upward initiated lightning flashes from tall structures. The initiation is apparently at heights that concentrate the electric field lines. Uman et al., (1972) also described that in nuclear lightning, the upward propagation velocities are of the order of 10^5 m/s, the branching is upward and the channel grows brighter as they grow upward. The lightning in a nuclear explosion occurs when the potential discontinuity between a structure and the ambient atmosphere exceeds about 10^8 m/s. If lightning is to be initiated at structures of the order of meters above sea level, the general electric field at sea level in the vicinity of the structure must be about 10^5 V/m. thus, in the case of a nuclear detonation, the electric field on the ground must be about 10^5 V/m for the lightning break down to occur. We also need to understand the charge that gets created in the air around the fireball for lightning discharge to occur during nuclear detonation. The deposition of charge around the nuclear detonation is due to the interaction of gamma radiation produced by nuclear detonations with the surrounding air by the process of Compton scattering producing Compton electrons. Also, the Compton electrons further produce secondary electrons due to the interaction of high-energy Compton electrons with the air molecules. Hence, the separation of charge produces a field which is nearly constant in amplitude over a distance of the order of several kilometers from the detonations and is directed radially [19].

Earthquake lightning: Powell et al., (1969) described that in some parts of the world, earthquakes are often accompanied by ball lightning, stroke lightning, and sheet lightning. Rakov and Uman (2003) described that earthquake lightning is a very poorly understood phenomenon. Earthquake lights, and steady atmospheric glows associated with earthquakes are a more commonly reported phenomenon; however, some observations of steady or transient luminosity associated with earthquakes in the twentieth century are likely to be due to faults (flashovers) in the local electric power system rather than from other causes associated more directly with the earthquake. The only causal connection that seems possible is that the seismic strains of the earthquake somehow cause an electric field in the air which in turn produces ball lightning and stroke and sheet lightning. Electrostatic generation by dust which is probably important in volcano lightning is not significant in these earthquakes.

Piezoelectricity is the electric charge that accumulates in certain solid materials in response to applied mechanical stress. Finkelstein purposed that the piezoelectric effect in the earth's crust causes the electric field. The only significant piezoelectric constituent of the crust seems to be quartz. The mere presence of quartz is not sufficient; there must be the right kind of large range crystal-line order or texture for the effect to occur. The piezoelectric effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress which in this case is applied by the earthquake. When piezoelectric material is placed under mechanical stress, a shifting of the positive and negative centers in the material takes place, which then results in an external electric field.

Thunderstorm Lightning: In thunderstorm lightning, the composition of water droplet and ice crystals forms clouds. The cloud at the height about 10 km above the earth's surface and the temperature reaches below -30º C. The temperature vary as height as the height of the air is uplifted, the temperature of the air decreases. Thundercloud generally contains two main charge centres, positive charge at the top of the cloud and the negative charge just below the positive charge. There is a small pocket of positive charge located just below of the negative charge centre of the cloud about the freezing temperature is shown in Figure 2. William considered the small pocket positive charge at the bottom of the cloud and explained the tri-pole charge structure [26]. Due to the number of pocket positive charge in the cloud, the different types of lightning occurs as mentioned by Nag and Rakov (2012) [27].

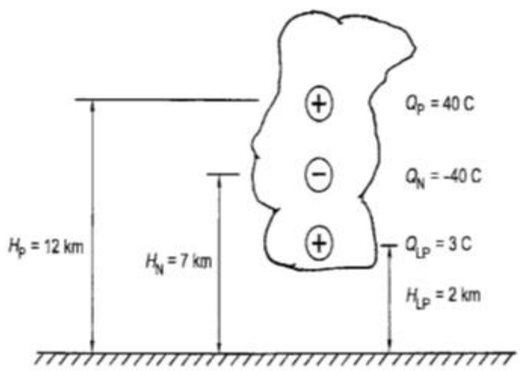

Fig. 2: An idealized vertical tri-pole charge structure of a thunderstorm.

The main negative charge centre lies at the centre of the cloud and the temperature in between -10º C and -25º C and the main positive charge centre lies at the top of the cloud and temperature below -25º C. There is the interaction between the charges and charges transfer from one to another called lightning discharge phenomena. If the charge not transfer to the ground called cloud discharge and the charge transfer to the ground called ground discharge. Again, the transfer of positive charge from cloud to ground called positive discharge and transfer of negative charge from cloud to ground is called negative discharge. For the discharge phenomena, the electric field should be greater than 30 KV/cm, and there is electric breakdown of the air. For the lightning phenomena, There are so many process occur among them the electrical breakdown process, preliminary breakdown (PB) pulses, stepped leader, Return strokes, intermediate stages, J process, M process, K process, continuing current process, subsequent return strokes, F process etc were observed in thunderstorm lightning. The examples of preliminary breakdown pulses, isolated breakdown pulses, stepped leaders with return strokes are given in Figure 3.

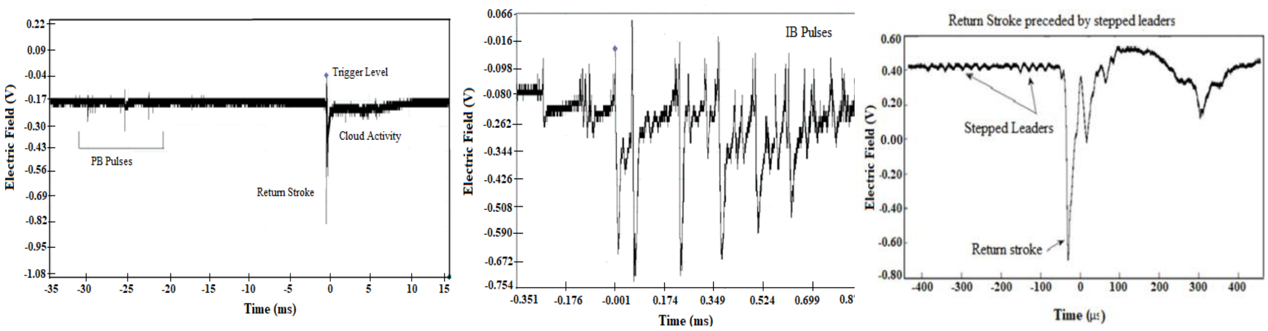

Fig. 3: The examples of preliminary breakdown pulses, isolated breakdown pulses, stepped leader with positive return stroke respectively.

The unusual electric field waveforms generated by thunderstorm lightning in the Himalayan Regions were recorded which is a new event in the field of lightning. The event just like a single-stroke positive flash consists of an opposite-polarity pulse and the main waveform was preceded by it. Hence the polarity of step pulses is opposite to that of the main event of return-stroke, which is also highly unusual. An example of unusual events found in this region is shown here in Figure 4.

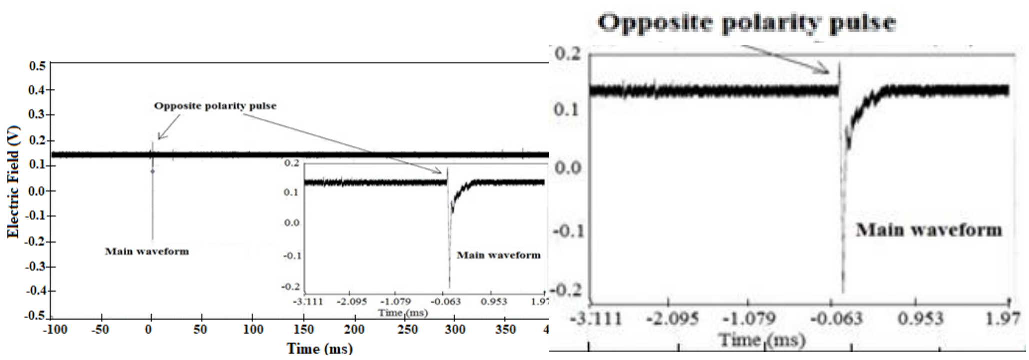

Fig. 4: Example of electric field signatures of unusual lightning events and the expanded form of the unusual lightning flash observed from Kathmandu, Nepal.

CONCLUSION

In volcanic lightning, it is caused due to charge separation as thunderstorm lightning but the method of charge separation is different. These volcanic lightning form closer to the ground and don't always move downwards in the same way that the normal thunderstorm lightning does. The steeped leader starts at the structure and propagates upward in nuclear lightning. Their direction of branching is also upward. Upward moving leaders do not initiate return stroke when they reach the clouds. The lightning discharges induced by surface thermo nuclear detonations are very similar to upward initiated thunderstorm lightning flashes from tall structures. Again, the separation of charge in nuclear lightning produces a field which is nearly constant over a distance of several kilometers and is directed radially. In Earthquake lightning, the piezoelectric material is placed under mechanical stress, a shifting of the positive and negative charge centers in the material takes place, which then results in an external electric field. Even the different lightning signatures have been observed in our scientific community thunderstorm lightning is frequently observed and measured. In all cases of Lightning, the discharge phenomena take place between two different charged regions. The two regions of positive charges and negative charges are separated by a certain distance and the air between them is an insulator. When the sufficient charges store in the two charge regions, voltage is developed between them. If the potential developed is sufficient for the electric breakdown of the air, then lightning phenomena occur. Despite the variations in lightning phenomena, the basic principle is the same.

ACKNOWLEDGMENT

First of all, I would like to express my sincere gratitude to the Division of Electricity, Angstrom Laboratory Uppsala Sweden for providing the instrument and for the Colombo University, Sri-Lanka for the excellent facility to carry out a research campaign during the summer of 2014. Also, I would like to thank Tri-Chandra College and Tribhuvan University for the research facility.

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