ELF / VLF LIGHTNING NETWORK TO MONITOR CHARGE DISTRIBUTION AND CONTINUING CURRENT

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Abstract – Changes of the vertical electric field due to individual strokes of multiple-stroke flashes to ground have been used to determinate sources of charge and the occurrence of continuous current in a thunderstorm cloud. This paper presents a technical description of the development and installation of a multiple station ELF/VLF electric field network to study the occurrence of continuing current in cloud-to-ground lightning flashes. Through the data recorded by the multiple stations ELF/VLF sensors the charge destroyed in the strokes and the signals related to continuing current in a region of about 1000 km*2 will be obtained. The data from the sensors network will be analyzed using the RINDAT (Integrated Lightning Detection Network) support. The network will be developed by the Atmospheric Electricity Group (ELAT) of the National Institute of Space Research (INPE). The Optical Ground Wires (OPGW) technology is used for data communications in power transmission lines. The studies using this network can also be used to a better understanding of the damages produced by lightning discharges on OPGW cable, providing information for simulation in laboratory of the continuing current effect on these cables.

Introduction

Lightning give us a very convenient means to explore the electrical structure of a thunderstorm. It discharges highly charged regions of the storm in a very short period, proximately 0.5 s, during which other charges in and around the storm remain essentially stationary. ELF/VLF electric field changes can be used to examine relatively short durations events such as individual strokes separate from slower intracloud processes.
Wilson [1916] first suggested that simultaneous measurements of the electrostatic field change caused by lightning could be used to obtain a measure of the charges involved in the process. He describes the equations relating the field change at the ground to the height and distance of single and two charge center models. The first multiple-station lighting study was made in New Mexico by Workman et al. [1942] using eight ground station over an area 6 km in diameter.

In the present paper, we will present a network with eight stations for ELF/VLF lightning electric field measurements using the GPS system in order to compare the data with RINDAT (Integrated Lightning Detection Network).

Basic considerations

In order to found the center of charge inside in thunderstorm, two models will be used in the analysis of the electric field measurements. The point charge (or monopole) model introduced by Wilson [1916], which is used to model charge lowered to ground by individual cloud-to-ground strokes. In this model it is assumed a spherically symmetric charge above an ideal ground plane. The electric field is calculated by:

$$\Delta E_i = \frac{1}{4\pi\varepsilon_0}\frac{2QZ}{R_i^3} = \frac{1}{4\pi\varepsilon_0}\frac{2QZ}{[(x-x_i)^2+(y-y_i)^2+(z)^2]^{3/2}}$$

where x, y, z are the coordinates of the charge Q, and x_i, y_i is the location of the sensor and R_i is the straight line from the sensor to the charge point Krehbiel et ali. [1979], as showed in Fig 1.

Measurements of ΔE_i at four locations are sufficient for determining the variables x, y, z and Q.
When the number of measurements exceeds the number of unknowns, then the values of the unknowns can be found using the standard least squares optimization procedure [Jacobson and Krider, 1976].

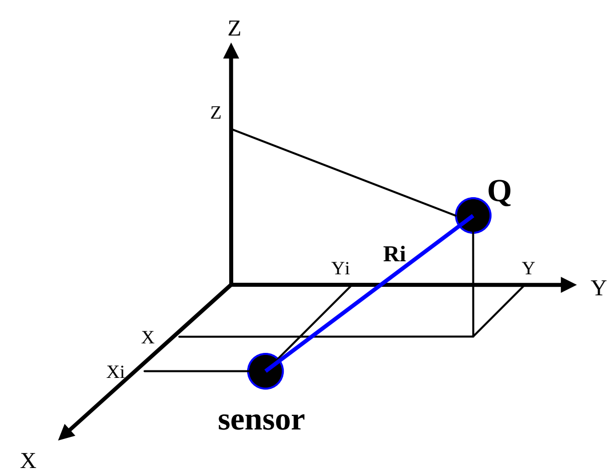

Fig.1: The coordinate system used to relate a spatial charge and the sensor for a point charge model.

Neutralization of charge by intracloud processes is modeled by means of dipolar models, utilizing either two point charges of equal intensity and opposite polarity [Fitzgerald, 1957]. For the two-point charge model, the field change is simply the superposition of the individual point charge contributions, or:

$$\Delta E_i = \frac{1}{4\pi\varepsilon_0}\left[\frac{2ZQ_+}{R_{i+}^3} - \frac{2ZQ_-}{R_{i-}^3}\right]$$

Seven variables are necessary to describe the charges and their position: x_+, y_+, z_+, x_-, y_-, z_- and Q, so that measurements ΔE_i are required from at least seven locations.

Equipment

Sensors for the ELF/VLF vertical electric field measurements will be composed by two aluminum circular parallel plates with 0.8 m and 1.0 m in diameter. The electric field will be measured by measuring changes in the charge induced upon the top plate. The top plate is mounted elevated 0.03m above bigger plate, as show in Fig. 2.

Fig.2: Electric field Sensor.

The bottom plate is grounded using a wire mash ground screen. The sensor plate is centered within a curvet-type steel enclosure with 4m diameter and 1m high, that will shield the sensor from external boundary variations and to protect it from animals. We intend to put the electronics housed below ground to stabilize their temperature. Another point very important to observe is to accommodate the large range of ΔE values that occur as a function of distance from lightning. This will be solved by using four different gain integrator circuits (with four A/D converters) to digitize and store the data. The sensor plate will be connected to four integrating amplifier which measure voltage changes on the plate by the atmospheric electric field. For a change ΔE in the ambient field above the station, the induced charge changes by an amount $\Delta Q = \varepsilon_0 A.\Delta E$, were A denotes the area of top plate and ε_0 is 8.854x10 $^{-12}$ F/m is the permittivity of free space. A schematic diagram of the field change sensor is show in Fig. 3.

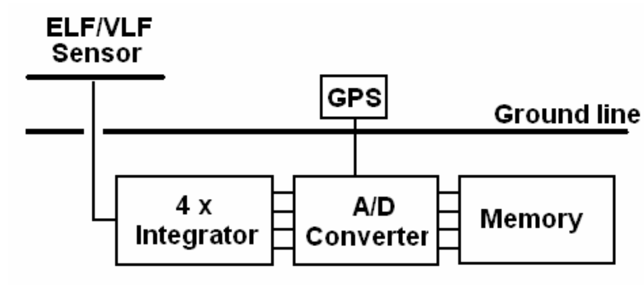

Fig.3: Schematic diagram of the field change sensor.

Application

Many users like Furnas, Light, Eletrosul, Copel, Chesf, Eletronorte and others are using the Optical Ground Wire Cable (OPGW) technology in its power line transmission like shown in Fig.4

Fig.4: A TL of 69kV (Tartarugalzinho – Calçoene/ Eletronorte) with 126km of long using guard cable OPGW 14.5mm

The OPGW series provide an entirely new form of telecommunication line that acts as a ground line for aerial power lines, which contain optical fibers inside. The OPGW was developed for use the viable support in long routes of power line transmission. OPGW combines a ground wire for shielding overhead power transmission lines together with optical fibers for transmission of communication signals. The product is designed to resist strong winds, lightning and short circuit current. The OPGW has been designed to meet both the Electrical and Mechanical equivalent of conventional ground wire. The electrical Brazilian system has used this cables since 1980, and at present has thousands km of OPGW cable installed [Loewentthal, 2001]. The Brazilian telecommunication system is using this technology to keep high quality and velocity of communications between very long distances. The Fig. 5 present a picture of OPGW cable with its formations parts. 1- Dielectric central member, 2- Optical fibers, 3- Jelly filled loose tubes, 4- Wrapping tapes, 5- Aluminum tube, 6- Metallic wires. The Fig. 6 presents a transversal section of this cable.

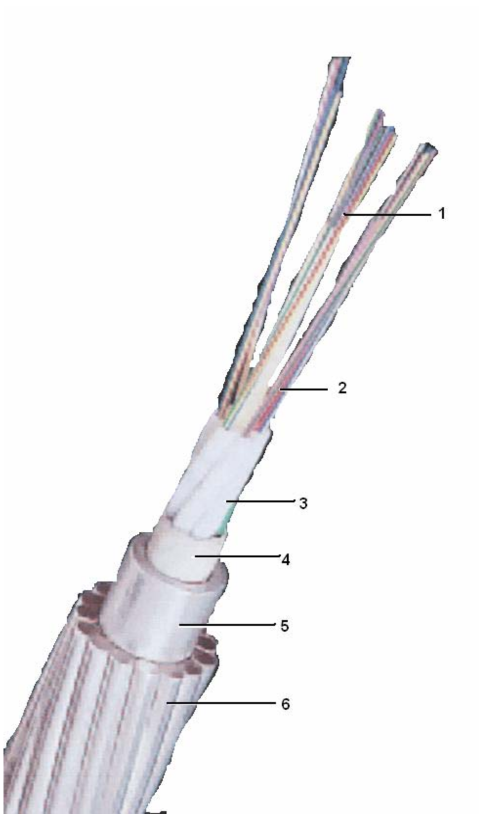

Fig.5: OPGW cable. 1- Dielectric central member, 2- Optical fibers, 3- Jelly filled loose tubes, 4- Wrapping tapes, 5- Aluminum tube, 6- Metallic wires.

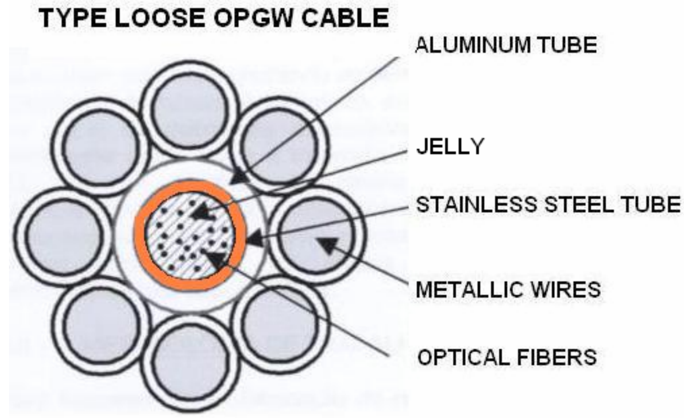

Fig.6: Transversal section of type loose OPGW cable.

It is well known that return strokes can reach very high intensities in excess of 200kA, during a time period of several milliseconds. However, due to this short time period the conductors can be not affected significantly [Wiesinger, 1996]. On the other hand, the heating caused by the continuing current, that has typical values of hundreds of amperes and hundreds of milliseconds [Brook et ali.,1962], can caused severe damaged to OPGW cables [Alvin et ali., 2002]. Damage due to lightning discharges in OPGW cables in Europe has not been common. However, in Brazil where the lightning activity is much higher, damages have been reported frequently. In consequence, due to the large use of OPGW cables, it is very important to know the continuing current characteristics in a given region, as well as to have time accuracy data to verify damage events.

Conclusions

The ELF/VLF network will be used for lightning research, in particular, to find out the continuing current characteristics. The data can be compared with the data provided by the Brazilian Lightning Detection Network RINDAT. Also, the data can be used to minimize the damages on OPGW cable due to continuing current effects. For this purpose, a network of sensors can be installed in the region of interest, providing data of destroyed charge and time duration of continuing current. Such information can be used to test the OPGWs cables, and develop new manufacturing technology.

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