

ABSTRACTS of SESSION 4

Paper n°7

A quantitative study of lightning striking distance factors

Abstract: In this paper, the results of a sensitivity analysis of an upward leader initiation from ground structures in response to an approaching lightning downward leader are presented. A theoretical analysis for the processes involved in natural lightning attachment to earth structures is presented. This analysis is based on physical criteria for upward leader inception and propagation during the approach of the downward lightning leader. The paper also makes some comparisons with the predictions of the simple EGM often used to determine the protection zone of lightning rods. From the obtained results, it is suggested that any model for lightning interception must take into account both earth structure geometry and lightning parameters.

Keywords: stepped leader, EGM, lightning attachment.

Paper n°15

Computer simulation of the effect of dimensions on the efficacy of a lightning rod

Abstract: A numerical simulation is used to clarify a physical mechanism of the effect of dimensions on lightning attachment to a lightning rod. The effect is studied by considering a sequence of discharge processes, from a corona ignited in a slowly rising thundercloud electric field to the development of an upward leader in the electric field of an approaching downward leader. It is shown that the efficacy of a lightning rod is almost independent of the rod radius in the range 0.05 - 5 cm, whereas lightning attachment to a rod of a given length depends on whether the rod is mounted on the ground or on the roof of an object.

Keywords: Corona, space charge, downward leader, upward connecting leader

Paper n°18

Numerical investigations of lightning proofness of UHV overhead lines

Abstract: In the present paper a new approach to the estimation of lightning proofness of ultrahigh-voltage overhead lines is suggested. This approach is based on the "lightning leader orientation" model. This model describes the lightning leader propagation as a random process taking into account stochastic deviations of its trajectory and the development of upward leaders from overhead line conductors. The results of numeric (computer) investigations of lightning proofness of ultrahigh-voltage overhead lines of various designs for the voltage of 110; 345; 500; 750 and 1150 kV are given. The results of the numeric modelling are compared with the experimental data.

Keywords: lightning proofness, ultrahigh-voltage overhead lines, numerical simulation

Paper n°28

Corona discharge in lightning rods under impulse voltage: an analysis tool for the investigation of charge emission

Abstract: Corona discharge current under a rod to plane discharge in air at atmospheric pressure has been widely studied for short and long gaps usually under DC or AC voltage. Usually research on corona discharge under an impulse voltage has been mainly focused on

air breakdown more than in obtaining a characterization of charge emission before breakdown. However, charge emission is supposed to be important on air breakdown since it modifies the electric field distribution in the air. But the transient nature and the statistical variations of the measurement make difficult a representation of the relation between voltage and emitted charge. The aim of this paper is to present a simple method to represent statistical charge emission under impulse voltage for different types of rods. This method shows the influence of experimental parameters. An experimental setup and some results are described leading to physical interpretations.

Paper n°36

A Method to calculate the number of lightning strikes to a high object taking into account gas discharge processes near its tip

Abstract: A computer model is developed to simulate the initiation and progression of an upward leader from a ground object in the joint electric field of a thundercloud and approaching downward leader. Taking into account corona space charge, the model is used to calculate the radius of attraction of downward and upward lightning discharges to a high ground object. It is shown that a multi-point corona-producing system mounted on a high object can reduce drastically (or even practically eliminate) the number of lightning strikes to it due to the suppression of streamer flashes.

Keywords: Corona, space charge, downward leader, upward connecting leader

Paper n°47

The striking distance of lightning flashes and the Early Streamer Emission (ESE) hypothesis

Abstract: The attachment of a lightning flash to a lightning conductor (or to any other structure) takes place through a connecting leader that rises from the structure towards the descending stepped leader of a lightning flash. The spatial separation between the tip of the stepped leader and the lightning conductor (or the grounded structure) at the initiation of the connecting leader is known as the striking distance. In this paper the striking distance of stepped leaders is derived as a function of conductor height, conductor radii and the prospective return stroke current. Based on these results the validity of the Early Streamer Emission (ESE) hypothesis is discussed. According to ESE hypothesis, the striking distance of a lightning conductor can be increased by the artificial initiation of streamers from a lightning conductor. The results cast doubt on the validity of the ESE hypothesis. This in turn calls for more experimental data and field validations before using the ESE hypothesis in standard lightning protection practice.

Keywords: Lightning, Lightning protection, striking distance, Early Streamer Emission.

Paper n°48

On attempts to protect a structure from lightning strikes by enhanced space charge generation

Abstract: Research conducted in laboratory on long sparks show that the breakdown voltage of spark gaps increases in the presence of corona emission from one or both of the electrodes. This observation together with other reasoning based on intuition has led some scientists to suggest the possibility of avoiding a lightning strike to a building by introducing sufficient quantities of space charge around it. In this paper the way in which the striking distance of a slim structure changes as a result of it being equipped with a network of corona generating needles is investigated. Based on the results presented in this paper one can make the following conclusions. (a) The connection of a corona element of radius on top of a tower of

radius () will lead to a decrease in the striking distance of the tower. This decrease is purely a geometrical effect and the space charge generated by the corona needles may play only a minor role in reducing the striking distance. (b) Neither the geometrical effect nor the space charge generated by the corona element can reduce the striking distance of a given tower below a certain critical value which depends only on the charge on the stepped leader. Thus, the corona element will not be able to prevent a lightning flash terminating on the tower.

Key words : striking distance, space charge, dissipation arrays

Paper n°49

An experimental study of leaders initiated by single and advanced (ESE) lightning rods: Triggering site of Cachoeira Paulista (SP) Brazil.

Abstract: Specifically designed to allow testing to be conducted on both naturally occurring and triggered lightning strikes, the Cachoeira Paulista facility was built in 1998 on the initiative of INDELEC, the University of Toulouse in France, Hydro-Quebec (IREQ) in Canada and the Brazilian universities of Campinas and San José Dos Campos in Sao Paulo state. The main on-going test involves comparing single rod and advanced lightning conductors, so-called Early Streamer Emission (ESE) rod. An apparatus carrying the measuring instruments and lightning devices under test is subjected to strikes triggered at altitude, the final point of impact being determined by the discharge itself. The investigation techniques, together with the main results of the previous campaigns are set out herein.

Paper n°50

Comparison of partially and fully-probabilistic models of lightning attachment and a proposed laboratory test

Abstract: This paper presents results from recent studies carried out in the area of modelling the process of lightning attachment to structures. The more traditional model (“partially-probabilistic”) uses purely vertical downward and upward leaders and determines leader inception and propagation conditions, whilst the more recent “fullyprobabilistic” studies involve the additional step of using fractal theory to model the tortuosity and branching of the leaders. The paper describes some of the main results from these studies and then illustrates how both approaches can be combined into a novel experimental configuration that can be used to carry out comparative testing of air terminals.

Keywords: Lightning attachment, modelling, fractals, probabilistic, leaders, laboratory testing.

Paper n°58

Guidelines for the placement of air terminations near vulnerable points on structures

Abstract: An important consideration in the design of an air termination system is the maximum distance at which the terminations can be placed from the “vulnerable points” on structures, i.e., typically those points that create the highest degree of electric field intensification. Surprisingly, many codes and standards provide very little, if any, guidance in this regard. This paper presents a preliminary analysis of the problem using numerical electric field computations and two different criteria for determining whether the given parameters are acceptable. The parameters include the type, height and distance of the air terminations, as well as the height of the structure on which they are installed. A quantitative guideline is provided for the maximum distance at which air terminations should be installed from the vulnerable points of structures.

Keywords: Lightning protection, air terminations, placement, vulnerable points, electric field, shielding criteria, computer modelling.

Paper n°98

Characteristics of lightning flashes striking the CN Tower below its tip

Abstract: It has been observed that tall structures are sometimes struck by lightning below their tops. This phenomenon necessitates the use of special procedure for protection of tall structures from lightning hazards. This paper focuses on the analysis of lightning flashes that struck the CN Tower below its tip over the period of one decade (1991-2000). Through the use of video images recorded during the reporting period, it was found that out of 371 flashes to the tower, only 13 hit the tower below its tip (3.5%). The strike distance from the tip (the distance between the tip and the point of impact) varied between 4 m and 56 m. Statistical analysis of the flash characteristics of strikes below the tower's tip generally shows that the number of strokes in a flash as well as the flash duration are lower in comparison to those for the majority of cases when the tower is struck at its tip. It is hoped that this paper will not only assist in lightning protection of tall structures but also trigger more investigations of strikes below the top of other tall structures. This work and the anticipated future work are expected to lead to the developments of more sophisticated measures for lightning protection of elevated objects and would possibly shed more light on the understanding of tall structure lightning.

Keywords: Tall structure lightning, lightning flash characteristics, lightning protection.

Paper n°123

Comparative testing of ionizing and non-ionizing air terminals under quasi static electric fields

Abstract: The objective of this work is to analyze the capability of nine air terminals (lightning rods) to produce corona currents when electrostatic fields are applied, considering several parameters, as the voltage polarity, short length gaps, high voltage electrode geometry (rod, plate and sphere), type and tip geometry of the air terminal. Three types of ionizing air terminals and six types of non-ionizing air terminals with different configuration at their tips were tested in order to observe important differences between them. The results show that It is very difficult to make final conclusions, but it can be established that, in general, the behavior of ionizing air terminals is similar, in terms of emission currents, to nonionizing terminals for most of the experimental arrangements. For the ionizing air termnals, their behavior is better at higher gaps. In general, positive polarity generated higher emission current levels. Even though the corona inception levels were quite different for the ionizing and non-ionizing terminals , the dispersion on the breakdown voltages was only about 10%, which means that the breakdown voltage is practically not dependent on the operation criterion of the air terminals, at least not more than the dependence of the geometry.

Keywords : Lightning, Lightning protection, Air terminal, emission currents, breakdown voltage.

Paper n°130

Optimum design of lightning protection system in a clustered building environment

Abstract: A study of lightning struck isolated tall buildings show that the stricken points mainly occur on the corners and edges of the roof. A similar study of clustered tall buildings shows that the stricken points mainly occur on those buildings that are located on the perimeter of the cluster. This suggests that the protection requirements of clustered buildings

will depend on their location within the cluster and the spacing between the buildings. This can lead to a significant reduction in the number of air terminals to be used on the buildings while maintaining the same level of protection against direct lightning strikes.

Key words: Air terminals, stricken points, collection surface.

Paper n°159

Corona current Impedance, a Possible Relation between Applied Electric Field and Measured Current in Earthed Needles of Different Shape

Abstract: The lightning attachment process in earthed electrodes initiates with Corona discharges. In this paper we investigate the superposition of Corona currents in three hyperbolic electrodes in a coaxial cylindrical configuration. The purpose of this experimental work was to investigate if corona currents produced by needles of the same shape could be added. Another objective of this work was to quantify the corona current amplitude produced by one, two or three corona-electrodes. The performed experiment showed that Corona currents could be added. Additionally, the Corona current was a DC with superimposed pulses. The measured DC components of the corona current were correlated with the applied voltage, the electric field and the interelectrode gap distances. The relationship between applied voltage and measured current in the arrangement was also investigated. A "Corona impedance Z ", defined as the ratio of the applied voltage to the measured current (I), was obtained. The obtained equation that relates these two parameters was:

$Z = A \cdot I - B$, where A and B are constants.

Keywords: Trichel Pulses, Corona Impedance, Corona.

Paper n°163

A dynamic model of the lightning attachment process

Abstract: Preliminary results of a dynamic theoretical model shows that the model has the basic features which describe the lightning attachment process. The model relies on the notion that the lightning discharge to ground is actually an electrical breakdown of the air isolation between the cloud and ground. The dynamics is introduced by Electric-field dependent boundary conditions.

Keywords: lightning-attachment process, Laplac's equation, electrical breakdown.

Paper n°171

A 3-D numerical model of negative lightning leader interception - applications to the collection volume construction

Abstract: The proposed model is based on physical phenomena leading to the formation and the development of positive upward leader in the field produced by the negative downward leader charge distribution and by some other competing upward leaders. Its purpose is to develop a 3-D numerical model which calculates the lateral distances of protection under different conditions (rod geometry, lightning characteristics), with some assumptions on the charge distribution and the velocity of the leaders. We used our model to compute the collection volume for various ratio velocities values. The results are compared to those computed from another models.

Keywords: Lightning protection, lateral distance of protection, collection volume.

Paper n°178

Experimental study of rod height and impulse polarity impact on the protection zone

Abstract: Based on review of previous study on a electrogeometric model and recent theoretic exploration of the lightning striking distance, a physical geometric model is established to study the lightning protection zone of the Franklin Rod. New equations are deduced to calculate the striking distance to the Franklin Rod both under negative and positive polarity of the lightning strokes. The lightning protection zone of the Franklin Rod can be predicted by proposed elliptical model. Experimental data coincides to the calculated protection zone by proposed equations.

Keywords: Franklin Rod, lightning protection, protection zone, electrogeometric model, striking distance

Paper n°192*Lighnning striking frequency simulation and effects of lighthning rods considering inclined lighthning path*

Abstract: Concerning the degree of damages due to lightning, some of them are comparatively trivial and some of them are serious. Therefore, it is important to evaluate the risk of lightning damages and to take the proper countermeasures against them with reasonable costs. Lightning is a natural phenomenon and its characteristics have very wide dispersion. Considering the random aspect of lightning, a Monte-Carlo technique is used to simulate values of various lightning parameters. The technique is combined with the electrogeometrical model and a frequency distribution of lightning strokes for a simple structure model is estimated. Calculation results show that the effect of a lightning rod agrees well with a conventional lightning protection theory. The effect of lightning rod is less effective for inclined lightning paths than for vertical lightning ones.

Keywords: Lightning, lightning protection, striking distance, Monte-Carlo simulation, electrogeometrical model

Paper n°221*The use of Leader Progression Model to predict lightning incidence in power lines*

Abstract: The Leader Progression Model [1,2,3,7] represents an attempt to predict the lightning incidence to an earthed object, for instance, a transmission line, by making use of physical considerations. It can also be used to simulate structures located in orographic conditions different from flat territory, such as in valleys, hillsides and mountain tops with the presence, when significant, of other nearby structures. This paper proposes simplified formulas developed from regression analysis of LPM simulations to estimate the lateral distance of transmission lines [8], where the lateral distance is the maximum distance a lightning stroke can hit the structure, for different terrain shape (flat and hills) and different current intensity.

Keywords: Leader Progression Model, Lightning Incidence, Transmission Lines

Paper n°236*Critical analysis of the lightning attachment models and perspectives to realise a improved model*

Abstract: In this paper, we analyse initially the different models which have been developed to simulate the lightning attachment process. The advantages and the limitations of each model are presented. In the second part of this work, we will present the numerically model elaborated which simulate the spatial and temporal development of the space charge emitted

by both the lightning rod and the ground surface. This model constitutes a first step to improve the initiation and the propagation criterions of the upward leader.

Keywords: space charge, upward leader, lightning attachment.
