ABSTRACTS of SESSION 1

Paper n°44

Influence of elevated stricken object on lightning return-stroke current and associated fields

Abstract: Influence of elevated stricken object on lightning return-stroke current and associated fields are studied using Numerical Electromagnetic Code (NEC-2). The peak amplitude of electric field is much decreased in close range and is increased in distant range due to the presence of the elevated stricken object. However, in distant range, the increase of the peak amplitude is less than 8 % when the slow rising current is injected into the elevated stricken object whose height is less than 120m. The influence of stricken object on the peak amplitude of current at the top is negligible even in the case of fast rising current injection, judging from the calculation by NEC-2 and the discussion of an engineering model.

Keywords: lightning to elevated object, lightning electromagnetic pulse, Peak of lightning current, electromagnetic model

Paper n°60

A return stroke model based on a hybrid field-circuit approach

Abstract: This work presents the basis of a new return stroke model, based in a hybrid field-circuit approach. Its basic ideas and concepts are presented and its formulation is expressed. The influence of physical features of channel, such as core losses, corona sheath and tortuosities, on lightning current distribution is discussed. The model is applied to evaluate current wave velocity profile along the channel and to illustrate the current wave dynamics. Comparisons with experimental data (measured electric and magnetic fields) are also presented.

Keywords: Return stroke models, lightning channel, lightning current dynamics.

Paper n°67

Incidence analysis of positive lightning flashes in Minas Gerais State, Brazil

Abstract: On a worldwide scale there is an increasing interest about positive lightning knowledge. In this paper, global and local evaluations about positive lightning incidence in Minas Gerais State, Brazil, are presented. These analyses are based on five-year period database reported by the local Lightning Location System (LLS).
The referred data set was obtained for a specific network configuration in order to assure uniformity of lightning database, once successive LLS upgrades were done along the years.

Keywords: Positive Lightning, Lightning Location System, Lightning Incidence

Paper n°81

Some aspects of numerical modeling of ligthning return stroke current based on antenna theory

Abstract: The paper presents selected limitations of the antenna theory applied for lightning return stroke channel representation. The value of corona sheath conductivity was estimated and the effect of this parameter on the upward-propagating front speed was reviewed. The vertical electric field was determined close to the lossy antenna while intentionally avoiding any additional assumptions that would decrease the return-stroke speed.

Key words: lightning, return stroke model, vertical electric field.

Paper n°92

Characteristics of upward leaders triggered by CO2 laser

Abstract: Characteristics of upward leaders triggered by CO2 laser have been studied for the development of the laser-triggered lightning system. In this experiment, the sphere - rod gap was used as the model of a tower under the thunderclouds. From the experimental results, we concluded that CO2 laser-produced plasma channel could trigger and guide the upward leader from the grounded rod. Furthermore, the electric fields of the upward leaders in air gaps have been measured with Pockels sensors. On the basis of the critical radius, the condition for inception of the upward leader was estimated.

Keywords: Laser-triggered lightning, Upward leader, Electric field, Pockels sensor

Paper n°94

Representation of the return stroke as a transmission line – the apparent return stroke velocity

Abstract: Assuming that the representation of the lightning return stroke as a current pulse propagating along a transmission line is valid, the effects of lossy transmission line parameters (i.e per unit channel resistance and channel conductance) on the channel currents are investigated. The lossy transmission line parameters that are incorporated into the study are varying spatially and temporally along the channel. The results show that the introduction of the time varying channel resistance and conductance will change the predictions of the model in such a direction that they will come closer to the experimental observations of the remote electric fields. The main emphasis of this paper is to show that the neutralization of the corona sheath around the stroke by the streamers emanating from the central core is responsible for the reduction in the apparent velocity of the stroke as it propagates up the channel, even though the actual velocity of the stroke is speed of light.

Keywords: Lightning, transmission line, return stroke.

Paper n°95

Observation of upward lightning in winter at The coast of Japan Sea with a high-speed video camera

Abstract: Observation of the upward lightning flash from the 200 m chimney in winter at the coastal area of the Sea of Japan, has been conducted with a high-speed video camera and shunt registers. The high-speed video camera can take the images of 256x256 dots at the recording speed of 4500 frames per second. From this observation, we found that there are many bipolar lightning flashes in winter. In the bipolar flash, first, the luminous lightning channel appeared with an initial continuous current. After that, the lightning channel brightens with current pulses of different polarities, again. The video images show that the positive current flows along only a channel. The results support the model of the bipolar lightning proposed by Goto and Narita.

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Keywords: Upward lightning, High-speed video, bipolar lightning, Upward lightning

Paper n°100

The relationship between the leader charge and the return stroke current – Berger's data revisited

Abstract: First return stroke current waveforms measured by Berger and Berger and Vogelsanger are used to estimate the charge stored in the lightning stepped leader channel. As opposed to previous charge estimates based on the entire current waveform, only the initial portion of measured current waveforms (100 μs in duration) was used in order to avoid the inclusion of any charges not involved in the effective neutralization of charges originally stored on the leader channel. The charge on the stepped leader channel, Q_{sl} (in C), is related to the first return stroke peak current, I_{pf} (in kA), as $Q_{sl} = 0.061\ I_{pf}$. This relationship is used to derive the distribution of the charge along the leader channel as a function of return stroke peak current. The advantage of the new equation for the charge distribution along the channel is that it can be used in evaluating the striking distance of lightning stepped leaders as a function of the prospective return stroke current.

Keywords: Lightning, leader, return stroke.

Paper n°114

Analytical representation of lightning current waveforms using genetic algorithms

Abstract: In this paper, we propose a method based on genetic algorithms to extract primary lightning return stroke current parameters from currents measured using instrumented towers or triggered lightning. The proposed algorithm infers automatically the parameters to represent a lightning return stroke current using two Heidler functions. For lightning return stroke currents measured using instrumented towers, the algorithm allows additionally the evaluation of reflection coefficients at the top and at the bottom of the tower. The proposed method is validated using experimental data of lightning return stroke current measured at on the Peissenberg tower in Germany and at Camp Blanding in Florida.

Keywords: Lightning return stroke currents, genetic algorithms, triggered lightning, instrumented towers.

Paper n°137

Modelling attempt of negative discharge in long air gaps using equivalent electrical network

Abstract : In this paper, we present a model enabling to describe the propagation of the negative discharge obtained in laboratory. It uses a RLC electrical network which vary with time according to the channel characteristics ; the model enables to determine the current evolution of the discharge, the corresponding charge, the trajectory of the discharge and its velocity. The obtained results are found to be in a good accordance with the experimental data available.

Keywords: negative discharge, propagation, current, charge

Paper n°158

Types of upwardlightning discharges observed at the 200-m Fukui Chimney

Abstract: Lightning discharges initiated by an upward leader were observed at the 200-m Fukui chimney in winter in Japan. The lightning initiated by an upward positive leader was categorized in four types by the simultaneous measurements of lightning current, lightning progressing feature, and electric field changes. The upward lightning of 74 % was observed only the upward positive leader development. About one quarter of the upward lightning produced the subsequent discharges following the upward positive leader development.

Keywords: Lightning in winter, upward lightning discharge, triggered lightning, Japan

Paper n°168

Return stroke current profiles and electromagnetic fields associated with lightning strikes to tall towers: Comparison of engineering models

Abstract: In this paper, we compare five engineering return stroke models, extended to include the presence of an elevated strike object, namely the Bruce-Golde (BG) model, the transmission line (TL) model, the traveling current source (TCS) model, and the two modified transmission line models (MTLL and MTLE). The current profile along the channel and along the strike object, as well as radiated electric and magnetic fields at different distances, predicted by these models, are presented and discussed. The comparison is made assuming the same undisturbed current and the same return-stroke speed. Except for the case of very close (50 m) electric field, it is found that the computed electromagnetic fields associated with a strike to a 168-m tall tower are less modeldependent than those corresponding to a strike to ground.

Keywords: Lightning, strike object, tall towers, return stroke models, electromagnetic fields, return stroke current, reflections.

Paper n°175

Study of some ligthning current's parameters using cloud-to-ground ligthning data

Abstract: The paper presents some of the results issued from the statistical analysis conducted upon a large sample of lightning data. Two of the lightning current's parameters, namely the number of strokes in a flash and the crest value, are analysed by means of statistical methods, in order to provide reliable estimation for the
associated distribution functions. Comparisons are made, with the corresponding \"classic\" parameters related to the lightning ground flashes incidence and current.

Keywords: Lightning, current, statistics

Paper n°180

Optical signatures of laboratory sparks with currents comparable to return strokes in ligthning flashes

Abstract: Temporal variation of several spectral lines generated by high current discharges with similar features as the lightning channel current was measured simultaneously with the discharge current. Certain spectral lines closely followed the temporal variation of the rising portion of the current pulse, suggesting the possibility of accurately inferring rise time of the currents of discharges without having to measure directly. Results also indicates that certain optical frequencies has a shorter rise time than current and hence attain its maximum before the discharge current.

Keywords: High current discharges, optical radiation, time resolved spectrum

Paper n°189

Ligthning return stroke speed: a review of experimental data

Abstract: The available experimental data on return stroke speed for both negative and positive lightning are reviewed. The often assumed relationship between the return-stroke speed and peak current is shown to be generally not supported by experimental data.

Keywords: Lightning return stroke, propagation speed, peak current

Paper n°191

Frequency spectrum of the electromagnetic fields of a positive return strokes

Abstract: The frequency spectrum of the electromagnetic fields generated by lightning flashes, especially the high frequency end is of much interest. In the present study the electromagnetic fields from positive lightning flashes striking the sea were recorded at 10ns resolution at a coastal station. The electromagnetic fields of twenty three return stroke generated electromagnetic fields recorded in this
manner are Fourier transformed and the frequency spectrum extending up to about 20MHz is obtained. It is found that the amplitude of the energy spectral density for the positive return strokes decreases with a slower rate of about 1/f up to 0.1MHz and with slightly greater rate from 0.1 to 6MHz.

Keywords: Lightning, Positive return strokes, Frequency spectrum, Fourier transform

Paper n°195

Ligthning radiation field spectra of cloud flashes

Abstract – Electric radiation fields produced by lightning cloud flashes have been Fourier analysed to obtain amplitude spectra for frequencies in the range of 20 kHz to 20 MHz. The spectra were generated by analysing the first 10ms time window of cloud flashes and they show f?1 frequency dependence up to 2 MHz followed by f?2 dependence and higher for frequencies above 2 MHz. By utilizing digital filters it has been shown that measurements taken with narrow band filters do agree with the results produced under wide band measurements.

Keywords: Lightning; Radiation field spectra; Cloud flashes

Paper n°199

Nonlinear Optical-Frequency Conversion Technique for Electric Field Measurements Due to Ligthning

Abstract: A novel approach of measurement of the electric field due to lightning is proposed by combining an optical second-harmonic generation (SHG) technique with an electro-optic effect. The feasibility of the technique for the measurement of impulse electric fields was studied by using a diode laser with a nonlinear, electro-optic crystal. The experimental measurements combined with the theoretical calculation show that even though the temperature control of the nonlinear crystal is a critical requirement, the SHG technique with electro-optic crystals, such as Mgo:LiNbO3 and KTiOPO4, can be effectively used for electric field measurements with a wide dynamic range of the order of a few kV/cm.

Keywords: Electric field sensor, optical sensor, second harmonic generation, electro-optic effect

Paper n°204

On the constraints imposed by the close electric field signature on the equivalent corona current in lightning return stroke models

Abstract: Engineering return stroke models can be categorized either as current generation models or current propagation models. The current generation models are described among other parameters by a corona current distributed along the
channel. Recent studies show that there is an equivalence between the models of current generation and current propagation types. Due to this equivalence, any return stroke model can be described in terms of an equivalent corona current.
The measurements conducted within 10 – 100 m from triggered lightning flashes show that the electric field of subsequent return strokes at these distances flattens within 15 μs or so. In

this paper, the constraints imposed by this feature on the temporal and spatial variation of the corona current are investigated. The
results show that in order for the close fields to flatten within 15 μs or so, the equivalent corona current, both in the current generation and current propagation models, should be bipolar and that the time signature of the corona current at late times is identical to that of the longitudinal current time derivative. This is in contrast to most of the engineering models that belong to the current generation type, in which the corona current is assumed to be unipolar.

Keywords: Lightning, Return stroke, Models, LEMP

Paper n°231

Statistical Description of Lightning Current Parameters

Abstract. We introduce a new set of parameters related to the lightning current waveshape (WSH), slightly different with regard to the previous CIGRE parameters, especially for time-components. Both computation of the descriptive statistics for the resulting random data and the univariate analysis lead to conclusions concerning the nature of each parameter's distribution function. The theoretical distributions fitting the sample cumulative frequency distributions are also inferred. The bivariate analysis allows us to establish new distributions for the front duration and steepness parameters, which take into account the strong correlation existing between the variables involved in their definition.

Keywords. Lightning current, Probability, Statistics, Correlation

Paper n°234

The influence of sensor position on contamination of lightning current waves for measurements taken at short towers

Abstract: An evaluation concerning the influence of the current sensor position along short instrumented towers on the contamination of measured lightning current waves is presented. The evaluation was performed by means of computational simulation, employing a hybrid electromagnetic model - HEM. Assuming certain simplifications, the dynamic behavior of lightning channel is considered, including core losses and corona sheath. The results showed that, for short towers and realistic values for wave front time, the current wave measured at tower top or at tower base should be practically the same. Their amplitude would be very similar for both first and subsequent strokes.

Keywords: Lightning current measurement, Lightning current contamination, Instrumented towers.

Paper n°251

Incorporation of distributed inductive loads in the antenna theory model of lightning return stroke channel

Abstract: Most of the electromagnetic models of lightning return stroke (i.e., AT model) make use of non-realistic non-unit relative permittivity for surrounding medium of the channel. It adjusts lower propagation velocities of the upward traveling current wave. To reasonably model lower propagation velocity, distributed inductance is used along the wire model of lightning channel. The lossy-wire model of lightning return stroke channel is governed by electric field integral equation in the time domain. To eliminate the preliminary steps of impedance calculations, the concept of current source is utilized. The calculated current distribution along the channel and predicted electromagnetic fields are compared with AT model and good consistency between the results is observed.