28th International Conference on Lightning Protection

Topic I: Lightning Discharge
I-D: Modelling
I-E: Observation Techniques
Moderator's Report

Chairman: V. A. Rakov *University of Florida, USA*
Moderator: T. Shindo *Central Research Institute of Electric Power Industry (CRIEPI), Japan*

***Abstract*-- A total of 23 papers have been accepted, to be presented in 2 oral and one poster sessions. The oral sessions of oral presentation are (A) Modelling (7 papers) and (B) Observation Techniques (7 papers). The remainder 9 papers are assigned to the poster session.**

***Index Terms*--Lightning, Modelling, Observation Technique.**

I. Introduction

A total of 12 papers are accepted for the topic of modelling and 11 papers are accepted for the topic of observation techniques. In each topic, 7 papers are accepted for oral presentation.

II. Modelling

Theme on the modelling has several sub-categories. One of them is modelling of the leader itself (I-21, I-22, I-26, I-27, I-57) and the other is the modelling of the return stroke (I-23, I-24, I-25, I-59, I-60). Estimation of the charge in thunderclouds is also an important subject (I-56, I-58).

A. Oral presentation

I-22 "*Lightning leader channel modeling*", M. Vargas et al.,

The authors propose a numerical model of the bi-directional leader, initiating a negative cloud-to-ground discharge. Using this model, they computed electric fields on the ground level due to the dart leader and compared model predictions with measurements. Effects of tortuosity and branches on the charge distribution and close electric fields are investigated.

I-23 "*Computer simulation of lightning strokes*", V. P. Charalambakos et al.,

The authors review three types of leader propagation models: physical models, stochastic models, and "electrical equivalent" (circuit) models. Advantages and disadvantages are discussed. Physical models are useful to understand the physics of lightning, while stochastic models are capable of reproducing the random nature of lightning channels.

I-24 "*Reproducing lightning electromagnetic field signatures with a new current return-stroke model based on a distributed-circuit approach*", A. De Conti, S. Visacro

The authors have proposed a new return stroke model called Dynamic Non-Uniform Transmission Line Model (DNUTL), where the lightning channel is modeled as a cascade of lossy transmission lines whose parameters are both height and time dependent. Using the model, the authors calculated electromagnetic fields at different distances and compared them with observations. A good agreement was found.

I-25 "*New insights into dynamic and properties of the lightning-channel corona sheath*", G. Maslowski, V. A. Rakov

Using the concept of equivalent corona current, the authors demonstrate how to convert distributed-source (DS) return-stroke models to equivalent lumped-source (LS) models. Additionally, dynamics of lightning channel corona sheath is examined based on three transmission-line-type (LS) return-stroke models.

Contact Address:
Takatoshi Shindo
Central Research Institute of Electric Power Industry (CRIEPI)
2-6-1 Nagasaka, Kanagawa 240-0196, JAPAN
E-mail: shindo@criepi.denken.or.jp

I-26 "*On the need to include ground reflection in lightning return strike models of current generation type*", V. Cooray, V. Rakov

Ground reflections in return stroke models of current generation type are usually neglected. In the paper, the authors introduce a new, reflection term in the original model formulation. It is shown that the reflection term is necessary for adequate reproduction of close electric fields of subsequent return strokes.

I-27 "*Reverse discharges near grounded objects during the return stroke of branched lightning flashes*", E. M. Bazelyan et al.,

The reverse discharges have sometimes been observed in laboratory experiments when the applied voltage is removed suddenly. The authors, via numerical simulations, show that similar phenomena may occur when an upward leader develops from an earthed object in response to a nearby branched flash. Calculation shows that the current of the reverse discharge is limited to 1 kA by a high resistance of the unconnected upward leader channel.

I-28 "*Chemically non-equilibrium model of pulsed arc discharges in air at atmospheric pressure*", Y. Tanaka et al.,

The authors have developed a time-dependent one-dimensional chemically non-equilibrium hydrodynamic model of pulsed arc discharges in air, considering 84 reactions in air plasma. Influences of current waveforms on the temperature and particle composition are investigated. The calculations show that a rapid current increase results in an increase of temperature and electron density. Results may be applicable to lightning return strokes.

B. Poster presentation

I-56 "*An algorithm using the prior information for estimation of thundercloud electric charge distribution*", K Honda et al.,

In order to estimate the charge distribution in a thundercloud using the measured values of electric field on the ground level, an algorism to solve the severely ill conditioned inverse problem is proposed in the paper. From the numerical simulation, it is found that the regularization techniques such as Marquardt scheme are important to reach convergence.

I-57 "*On the electric field at the top of dart leaders in lightning flashes*", V. Cooray et al.,

The electric field at the tip of dart leaders is calculated as a function of time and height. The calculations show that as the dart leader tip passes a given point on the defunct return stroke channel, the electric field may increase within a fraction of a microsecond to values several times higher than the breakdown fields of the low-density air in the channel. The results may explain the observed emission of x-ray bursts by dart leaders.

I-58 "*Evaluation of thundercloud structure and lightning progression process by electric field observations*", K. Masugata et al.,

The lightning observation system developed by the authors is described, which includes field mills, VHF receivers, and optical observation equipment. The movement of thunderclouds is estimated from electric fields on the ground level recorded simultaneously at several sites. The results agree with radar observations. Upward leader development was also observed by the VHF TOA lightning mapping system.

I-59 "*A current generation type return stroke model that predicts the return stroke velocity*", V. Cooray, V. Rakov

The authors evaluate the return stroke velocity using a current generation type return stroke model. The predicted return stroke velocity shows height dependence; it increases with height at first, then reaches a peak and decreases after that. Such a velocity profile agrees with recent speed measurements for rocket-triggered lightning strokes.

I-60 "*Radiated lightning electromagnetic fields at different heights above ground*", J. M. Meledath, S. K. Nayak

Electromagnetic fields associated with return strokes at different height (from 10 m to 10 km) and at different distances (from 20 m to 10 km) are calculated using the modified transmission line model with exponential current decay with height. The vertical electric field shows polarity reversal with height but horizontal electric field does not. The effect of several parameters such as ground conductivity, return stroke velocity, and current derivative are investigated.

III. OBSERVATION TECHNIQUES

Observation of electromagnetic fields associated with lightning discharges is one of the most interesting subjects and a lot of studies related to this area has been carried out (I-28, I-30, I-32, I-63, I-64). In interpreting current observations at tall objects, we must take the effect of the strike object into consideration (I-31). Not only the lightning current peaks but also charges involved are important for protection from damages caused by lightning. Some studies to measure the charge without measuring the currents have been conducted (I-33, I-34). Recent progress in developing opto-electronic techniques enables highly sophisticated observations of discharge phenomena. Novel measurement techniques developed for such observations will be presented. (I-29, I-61, I-62).

A. Oral Presentation

I-29 "*Measuring system specially designed for lightning electromagnetic fields*", M. Rubinstein et al.,

In this paper, the authors discuss the suggested standard calibration and evaluation criteria for measurement systems for electromagnetic fields radiated by lightning discharges. Based on the discussion, an observation system for electromagnetic fields is developed by the authors and the features of the system are described in detail.

I-30 "*Measurement of two orthogonal component of electric field based on second harmonic generation in nonlinear electro-optic crystal*", R. Tanaka et al.,

A novel approach for electric field observation is proposed in this paper. The authors describe a method to measure electric field using a second harmonic generation (SHG) with a pair of nonlinear optical crystals ($KTiOPO_4$: KTP). The experimental results show that the electric field measured using the proposed method agrees with theoretical estimates.

I-31 "*Investigation of the applicability of an anisotropic magnetoresistive sensor to lightning flash observation*", Y. Kishimoto et al.,

The authors have developed a system for the observation of lightning discharges with an anisotropic magnetoresistive field sensor, which has a wide frequency band from DC to several MHz. Using two of such systems, lightning observations have been carried out and the results are compared with data from the Japanese Lightning Detection Network (JLDN). The data obtained using the developed system agree with the data from the JLDN.

I-32 "*Estimation of lightning currents from measurements performed on elevated objects*", A. Piantini, M. Shigihara

When lightning currents are measured at elevated objects, the waveform is affected (contaminated) by reflections from the ground and other impedance discontinuities. Based on a return stroke model, the authors compare the "contaminated" current with the "undisturbed" current, assuming matched conditions at both ends of the object. Furthermore, comparison with the "reference" current, which is the current that would flow in the absence of the object, is also carried out. Calculations show that an object whose height is less than 70 m does not significantly affect the measured current characteristics.

I-33 "*Estimation of lightning current parameters based on measurement of electric field waveforms*", T. Harada, K. Michishita

The authors observed electric and magnetic field waveforms at multiple sites and tried to estimate return stroke velocity and parameters of lightning current waveforms, such as peak value, time to crest (rise time to peak), and time to half-peak value using the Diendorfer return stroke model. From the statistical point of view, the estimated values show relatively good agreement with actual current observations.

I-34 "*Study of the estimation of the amount of lightning electric charge by measurement of the electric field*", F. Suzuki et al.,

In order to identify lightning with a large amount of charge, a new observation system is proposed by the authors. The authors combined two-station measurements of electric field changes due to lightning and data reported by a lightning location system, to calculate charges of lightning. The resultant cumulative distribution of the charges has a 50 % value of about 2.5 C and a 10 % value of 10 C.

I-35 "*Measurement and estimation of charge transfer in lightning discharge using ELF transient*", T. Otsuyama et al.,

In order to evaluate the charge transfer associated with a lightning discharge, the authors proposed a novel method based on the use of ELF transients. In the paper, the basic theory is described and some observation results are shown. Comparison with direct measurements of lightning currents supports the proposed method.

B. Poster Presentation

I-61 "*Visualization of neutral density variations accompanying impulse discharge in air*", T. Fukuchi, K. Nemoto

In this paper, a laser shadowgraph system developed by the authors is described. Neutral density variations accompanying discharges are clearly visualized in spite of strong luminosity produced by the discharges. Furthermore, using the laser interferometry technique, the authors showed relationship between light emission from discharge and neutral density variations, as well as the effects of polarity on the discharge characteristics.

I-62 "*Design and implementation of the electro-optic sensor for lightning electric field measurement*", R. Zeng et al.,

An electric field sensor using the electro-optical effects is developed by the authors. The characteristics of the electric field sensor using an $LiNbO_3$ crystal is investigated experimentally, and it is shown that the sensor is useful for intense electric field observations.

I-63 "*Simple technique for detection of HF radiation from lightning*", J. Makela et al.,

The authors have developed a simple HF measuring system whose central frequency is about 1.2 MHz. With the system, radiated electromagnetic fields from natural lightning strokes are observed, and the HF radiation characteristics at different distances are presented.

I-64 "*Experimental analysis of a parallel plate antenna used in lightning electric field measurements*", F. Santamaria et al.,

With a parallel-plate antenna, the authors have measured lightning electromagnetic fields. The characteristics of the measuring system, such as its frequency response and its calibration method, are described.