

## ABSTRACTS of SESSION 3

### Paper n°2

*Induced Voltages in AC Overhead Power Lines and Shared-Corridor Pipelines during Normal Operation and Lightning Strikes*

Abstract: A pipeline running in parallel to overhead power lines is simulated using "CONCEPT II" computer program package. The program is based on the method of moment combined with the transmission-line model. A 1- km long, 132-kV, 3-phase, double-circuit overhead line, and a 2-km long pipeline, 1 m above ground and with 40 cm (~16 inch) diameter are modelled. Extra shielding wires under the phase conductors are investigated. Different current waveforms are simulated to cover the whole range of the anticipated lightning currents.

Keywords: Pipeline, lightning, electromagnetic fields, shielding, induced voltages

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### Paper n°3

*Magnetic fields and induced voltages in case of a direct strike – comparison of results obtained from measurements at a scaled building to those of IEC 62305-4*

Abstract: In the paper the results obtained from experiments at a modelled reinforced building in case of a direct lightning strike are compared with calculations. The comparison includes peak values of the magnetic field  $H_{max}$ , its derivative  $(dH/dt)_{max}$  and of induced voltages  $u_{max}$  in typical cable routings. The experiments are performed at a 1:6 scaled building and the results are extrapolated using the similarity relations theory. The calculations are based on the approximate formulae given in IEC 62305-4 and have to be supplemented by a rough estimation of the additional shielding effect of a second reinforcement layer. The comparison shows, that the measured peak values of the magnetic field and its derivative are mostly lower than the calculated. The induced voltages are in good agreement. Hence, calculations of the induced voltages based on IEC 62305-4 are a good method for lightning protection studies of buildings, where the reinforcement is used as a grid-like electromagnetic shield.

Keywords: Direct lightning strike, electromagnetic shield, magnetic fields, induced voltages, calculations.

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### Paper n°12

*A System for simultaneous measurements of lightning induced voltages on lines with and without arresters*

Abstract: The growing importance of improving the power quality and the high number of lightning-caused faults on distribution lines have motivated a research project with the aim of evaluating experimentally the effect of surge arresters on the improvement of the indirect lightning performance of MV lines. This paper describes the most important features of a system designed for this purpose, which has been implemented at the campus of the University of São Paulo and started to operate at the end of the 2001/2002 thunderstorms season. Some of the recorded induced voltage waveforms are also presented.

Keywords: lightning, induced voltages, distribution lines, experimental investigation.

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### Paper n°62

*Electromagnetic field radiation due to lightning strokes in the presence of tall buildings: modeling and measurement*

Abstract: this paper, discusses the effect of tall buildings on measured electromagnetic field data in a lightning detection station. The measurement results obtained at the two elevation levels (25 m and 40 m) of a seven-story building are presented. It is shown that the magnitudes of the two measurements differ from each other, emphasizing the effect of the building on measurements. To enhance the measurement accuracy, an appropriate correction coefficient for electromagnetic field sensors is thus required, encountering the scattering effect of the building. To support the experimental observations, theoretical results, based on a wire grid model of the building metal structure, are also presented.

Keywords: Lightning Detection System, Moment Method in Time Domain, Antenna Enhancement Factor.

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**Paper n°83**

*Electromagnetic field coupling to non-symmetrical transmission lines inside an LPS*

Abstract: This work presents an analysis of the behavior of the currents and voltages induced on a non-symmetrical transmission line (with components on  $x,y,z$ ), excited by an external electromagnetic field through a computer simulation in time domain. In the simulation process, each component of the non-symmetrical transmission line is discretized on dipole elements ( $dx'$ ,  $dy'$  or  $dz'$ ). These dipoles are short enough that current can be considered constant along the length of each one. The parameters of the transmission line are calculated at each dipole element. The induced voltage on a non-symmetrical transmission line is simulated when the component of the external electric field is taken into account that is tangent to the line as the distributed voltage source along the line.

Keywords: Induced voltage, LPS, TLM

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**Paper n°106**

*The lightning shielding effect of buildings: A reduced model study*

Abstract: The paper presents the experimental setup need to study the shielding effect of buildings located near the lightning striking point. The soil was modelled as a perfect ground plane, and the lightning channel as a vertical transmission line with a current source injected at the ground level. The building was made of copper wires. Electric and magnetic field sensors were positioned near the channel. Shield factors were determined in 4 (four) different situations for the electric and magnetic fields separately. The results show that for electric field, the highest reduction value (68%) was obtained with the building between channel and sensor. Magnetic fields can be amplified (10%) or reduced (74%) depending on the relative position of the building and the sensor.

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**Paper n°115**

*Lightning coupling to overhead and buried conductors as frequency response function of the system*

Abstract: The paper analyses errors resulting from discrete time-domain and frequency-domain representation of continuous LEMP disturbances in continuous systems. FFT procedure was used to obtain frequency-domain expression for the lightning return stroke current while transient responses were calculated via IFFT. The system is represented by its frequency response function for which the lightning channel-base current constitutes an input signal, while the overvoltages along the overhead transmission line, located at a given height, or a buried conductor located at a given depth, constitute its output signals.

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Key words: lightning return stroke current, LEMP, lightning overvoltages, frequency response function, discrete representation of continuous signals and systems.

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**Paper n°134**

*High loss horizontal transmission line investigation*

The lightning channel has fundamental importance in the study of the voltages and currents induced in the electrical installations located in the vicinity of the lightning stroke point. It is a high loss transmission line due its high estimated series axial resistance per meter [4].

The reduced scale models normally used in laboratory experiences to calculate the electromagnetic coupling between the lightning channel and the victim installation use a single spiral wire around a plastic cylindrical pipe to obtain a suitable front of wave speed obeying the scale factor used in the model. In spite of the reasonable results obtained by this method according to many published papers [3,4], the changing of the physical configuration of the electromagnetic field in the vicinity of the artificial channel due the current direction invite us to search for a more convenient model, decreasing the wave speed through the increment of its series axial resistance per meter.

The main goal of this paper is to investigate the electromagnetic performance of high loss horizontal transmission lines, verifying the application of the classic theory on this special type of line.

This paper presents the laboratory measurement and time and frequency domain simulation results regarding the high loss horizontal transmission line. The knowledge obtained in this experiment is being used in vertical high loss transmission line investigations.

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**Paper n°150**

*Lightning effects on the vicinity of elevated structures*

Abstract: This work presents preliminary results concerning an investigation of effects caused on low voltage distribution networks by lightning currents that strikes to close elevated structures of radio-base stations placed in urban areas. The studied case considered the presence of a distribution line close to the station. The results were obtained by simulation, employing a hybrid electromagnetic model. Assuming the incidence of typical lightning current waves, several levels of overvoltage were found on electrical system, mainly due to induced overvoltage.

Keywords: Lightning-induced voltages, radio-base station, low voltage networks, grounding, soil resistivity.

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**Paper n°164**

*On the calculation of electromagnetic fields radiated by lightning to tall structures*

Abstract: Recently, engineering return stroke models were extended to take into account the presence of an elevated strike object, which was modeled as an ideal, uniform transmission line. We show in this paper that the current distribution associated with these extended models exhibits a discontinuity at the return stroke wave front, which cannot be considered as physically plausible. This discontinuity arises from the fact that the current injected into the tower from its top is reflected back and forth at its ends, and portions of it are transmitted into the channel; these transmitted pulses, which are supposed to travel at the speed of light, catch up with the return stroke wave front traveling at a lower speed and no current is allowed to flow in the leader region above the front. This discontinuity needs to be carefully treated when calculating the radiated electromagnetic field through an additional term in the

electromagnetic field equations, the so-called “Turn-On” term. We derive additionally a general analytical formula describing the turn-on term associated with this discontinuity for various engineering models. We present simulation results illustrating the effect of the turn-on term on the radiated electric and magnetic fields for an elevated strike object of height  $h = 168\text{m}$ , corresponding to the Peissenberg tower in Germany. Finally, possible modifications to engineering models are suggested in order to eliminate this discontinuity.

Keywords: Lightning, tall towers, discontinuity, turn-on term, return stroke models.

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**Paper n°183**

*Penetration of lightning induced transient from high voltage to low voltage power system across distribution transformers*

Abstract: The overvoltage transients in the power distribution systems have several pathways into the system. In this paper we will characterize the signature of voltage transients that penetrate into the distribution system through the distribution transformer. In our analysis we considered the transients caused by the interaction of electromagnetic fields of nearby lightning flashes in the transmission line system. In the study the transformer was represented by a circuit model based on the experimental data gathered by analyzing the response in the low voltage side of the transformers when the high voltage side of the transformer is injected with step current impulses. Moreover, we also considered the effect of surge protective devices connected across the transformer. The simulation shows that the transformer changed the signature of the overvoltage observed in the low voltage network. Also, the protection level achieved by connecting a surge protector on the low voltage side of the transformer was not sufficient. The main reason is that, the major contribution on the load side is due to the induction of the electric field couple to the distribution line.

Keywords: Transformer models, Lightning Induced Over Voltages (LIOV).

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**Paper n°225**

*Experiments with Voltages Induced in Installation Circuits by Discharges Simulating those of Lightning*

Abstract: The paper deals with the results of experimental investigations, performed in laboratory scale, related to measurements of induced voltages in the loop created by model of low voltage installation placed in the proximity of air spark gap simulating lightning discharge.

To assess effectiveness of some protective measures reducing the induced voltage influence on low voltage equipment the measurements have been done using metal shielding cage and different type of SPD's in modelled installation.

The description of test arrangements, methodology of investigations, and tests results with conclusions are presented in the paper.

Keywords: lightning, induced voltages, electromagnetic disturbances.

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**Paper n°235**

*Magnetic fields and induced voltages inside LPZI measured at a 1:6 scale model building*

Abstract: For the application of the concept of Lightning Protection Zones (LPZ), the knowledge of the magnetic fields and induced voltages inside a structure is necessary. Laboratory experiments have been conducted at a down-scaled model of a building (scale factor 1:6) to determine these electromagnetic quantities in case of a direct strike to the structure. The model (3 m x 2 m x 2 m) represented a small industrial building using the rein-

force-ment of the concrete as electromagnetic shield. The magnetic fields and magnetic field derivatives were measured at several location inside the scaled model. Further, the voltages induced on three typical cable routes inside the model was determined. The influence of the lightning current wave-shape, point-of-strike, bonding of the cable routes, and bridging of an expansion joint in the middle of the build-ing on these quantities was studied.

Keywords: Lightning, electromagnetic shielding, rein-forced concrete, scaled model.

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#### **Paper n°241**

##### *Experimental analysis of lightning-induced currents in buried cables*

Abstract: This paper presents recent experimental results obtained in 2002 and 2003 at the International Center for Lightning Research & Testing (ICLRT), Camp Blanding, Florida, where currents induced by triggered and natural lightning events were measured at the ends of a shielded buried cable, both in the shield and in the inner cable conductors. The horizontal magnetic field and the lightning return stroke current were also measured. It is shown that the induced current in the cable shield can reach values of about 100 A for stroke locations within 200 m from the cable. The induced current in the cable shield is characterized by a significantly shorter pulse width than that of the corresponding return stroke current. Further, for the considered configurations, the induced current in the inner conductor is characterized by a relatively fast bipolar waveshape.

Keywords: Lightning, induced currents, buried cables, coaxial cables.

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#### **Paper n°245**

##### *Testing of the LIOV-EMTP96 code for computing lightning-induced currents on real distribution lines: triggered-lightning experiments*

Abstract: The analysis of the response of distribution networks illuminated by indirect lightning electromagnetic fields (LEMP) requires the availability of accurate models suitably translated into computer codes. These should be able to reproduce the real and complex configuration of distribution systems taking into account the presence of shielding wires and their groundings, as well as of surge arresters and distribution transformers. The paper presents an experimental validation of the LIOV-EMTP96 code using recorded data obtained at the ICLRT (International Center for Lightning Research and Testing) of the University of Florida on a real experimental overhead line, by means of the triggered lightning technique.

Keywords: Lightning-induced voltages, triggered lightning, EMTP, LIOV code.

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