

ABSTRACTS of SESSION 5

Paper n°8

Which resistivity? The relationship of ground potential rise to soil resistivity in conditions of variable resistivity

Abstract: The aim of this paper is to establish both the spatial and temporal relationship of soil resistivity to ground potential rise (g.p.r.) during a lightning strike or a power fault current.. Firstly, theoretical models are used to establish some principles. Then the implications of this for practical assessment of g.p.r. to conform to specific safety levels is considered . Thirdly, measurements of soil resistivity over 5 years are reported, in order to show possible time variations of soil resistivity to be experienced in practice.

Keywords: Lightning, ground potential rise, soil resistivity.

Paper n°21

An analytical evaluation of ground current distribution due to lightning strike

Abstract: This paper focuses on the calculation method in frequency domain of current and its distribution into the ground when a lightning strike occurs. The goal is that this calculation may be determined by using complex calculus, although it is assumed that the high voltage is represented by a rectangular impulse. Also, it is noteworthy that the lightning channel can be treated as an equivalent linear conductor and thus be described with simple parameters used in electrical theory. Calculation results are shown to match closely the data from field tests, so this suggested method should be used in practice.

Keywords: Lightning strike, lightning current distribution, lightning channel

Paper n°23

Evaluation of touch and step voltages distributions at vicinity of grounding systems using a frequency domain methodology

Abstract: The frequency-dependent behavior of two typical grounding systems is analyzed. From the results, including step and touch voltage profiles, an important difference is verified for both slow and fast phenomena.

Keywords: Grounding, Lightning, Soil Modeling, Frequency domain, Touch and Step Voltages

Paper n°26

Models of grounding systems under lightning discharges. Simple electrode configuration

Abstract. The aim of this paper is to obtain the transient response of different electrode configurations, and how this response is influenced by factors like the soil resistivity, the dielectric constant of the soil and the electrode length. In this work, a model based on lumped RLC Pi circuits is proposed; the parameters of the circuit are obtained using a program based in finite elements method (FEM). This circuit is implemented in the ATP to obtain the transient response of the grounding system. Additionally, the model is validated with field measurements.

Keywords: Grounding systems, Lightning discharges, Electromagnetic Transients, ATP/EMTP.

Paper n°43

Method of GSM broadcasting station grounding system analysis - measurements and calculations.

Abstract: This paper was undertaken in order to verify configuration of the existing GSM broadcasting station grounding system. Real measurements were made. Presented method was supported by computer simulation. This method is useful to approximate touch and step voltage during lightning strikes for personnel within the GSM broadcasting station area. Method base on up-to-date system data, appropriate measurement techniques and instrumentation, and state-of-the-art computer modeling methods.

Keywords: GSM, grounding system, measurements

Paper n°56

Controlling separation distances with insulated down-conductors

Abstract: Lightning protection of buildings and electrical installations includes also the controlling of separation distances to avoid uncontrolled side flashes between the different systems. A new solution for an insulated down-conductor will be proposed. The requirements on this insulated down-conductor are shown and an appropriate test method is applied to determine an equivalent separation distance.

Keywords : Lightning protection, Separation distance, Insulated down-conductor, HV-testing

Paper n°57

Lighning current distribution to ground at HV tower with mobile phone base station

Abstract: Mobile phone base stations are often mounted on towers of power transmission lines. They are usually powered from the LV network. The isolating transformer that separates HV and LV networks ensures security at other customers' premises especially in case of lightning stroke, which is a frequent cause of a subsequent phase to ground fault. This paper presents results from a computer simulation for the lightning current distribution between the sky wires, grounding systems and power cable network. Of special concern is the part of the lightning current that might be led into the metal-shielded distribution cable network. The analysis is applied to a practical case.

Keywords: Lightning, Grounding, Power cables, Power transmission lines, Mobile phone base stations.

Paper n°61

Electromagnetic field radiation due to energized conductors buried in multi-layer soils

Abstract: An electromagnetic field theory model is used to study the frequency-domain performance of a grounding system comprising single conductor buried inside a multi-layer soil. In this model, the conductor is subjected to the thin-wire approximation, and the governing electric field integral equation (EFIE) is solved using the method of moments (MoM). Also, the modified image theory is used to include the soil stratification. It is shown that the soil stratification and the location of conductor in each layer can affect the distribution of predicted electromagnetic field quantities at the ground surface.

Keywords: Electric field integral equation, grounding, method of moments, stratified media

Paper n°75*Interconnection of different earthing systems of a given installation*

Abstract: Despite of the recommendation of many reputed standards the interconnection of all earthing systems of a given installation to have a single earth reference, is not practiced in many parts of the world. According to a survey done in Sri Lanka on earthing systems of 52 installations only 16 places have interconnected the earthing systems of power and lightning protection. The survey reveals that the lightning related equipment damages have significantly increased at 11 places after the service earths have been bonded to the LPS earth. At 3 places the installation engineers are not confident of an increment in lightning accidents after the connection. At all 14 installations the engineers have removed the connection after few months. Even at the two installations where the interconnection of earthing systems has not increased the lightning damages, the bonding has been removed after some time by the order of the service providers. It has been found that there are many parameters other than the DC resistance is responsible for the dangerous potential rises at the common earth bar, thus the upper limit 10 Ω , given by many standards, is not suitable for recommending the interconnection of service earths to the LPS earth. Thus, the standards should be revised to provide proper recommendations in this regard.

Key words: Earthing, bonding, transient, impedance

Paper n°76*Influences of low-resistivity-materials on lightning impulse properties of grounding devices*

Abstract: The low-resistivity-materials (LRMs) are widely used to decrease the power frequency grounding resistances of grounding systems in the regions with high soil resistivity. The research about the influence of the LRM on impulse properties of grounding systems can not be found in literature. Simulating experimental results of lightning impulse property of grounding devices covered with LRM was presented in this paper. The influential properties of impulse current, geometrical dimension of grounding system and soil resistivity to impulse grounding resistance and impulse coefficient of grounding devices with the LRM are still the same with those without the LRM. The impulse grounding resistance decreases 25-45% when the LRM is used. The fitting formulae to calculate the reducing ratio of impulse grounding resistance of different grounding devices are provided.

Keywords: grounding device, low-resistivity-material, impulse grounding resistance, impulse coefficient, power frequency grounding resistance, impulse characteristic

Paper n°78*Lightning impulse effective area of earthing grid*

Abstract: The transient characteristic of an earthing grid under lightning current is analyzed in detail in this paper, which especially considers the dynamic and non-linear effect of soil ionization around earthing conductors and the inductance between earthing conductors. The analysis results are calculated by a distributed time-variable parameter circuit model. The influences of soil parameters, location of feed point, and shape of the lightning impulse current on the transient characteristic of earthing grid are discussed. The effective impulse range of earthing grids is analyzed, which will be helpful for technical staff to design earthing grid in the protection against lightning.

Keywords: Transient characteristic, earthing grid, impulse earthing resistance, transient ground potential rise, lightning impulse current

Paper n°90

Analysis of Soil Relief Influence on Lightning Incidence and Current Amplitude in Minas Gerais State, Brazil

Abstract: This paper describes some analyses that consider the influence of soil relief on lightning incidence and current amplitude. Such analyses were performed, considering the stroke density for a large number of sites where telecommunication sites were installed and their surroundings. A four-year stroke database provided by a Lightning Location System and maps describing the local relief were employed, in order to analyze the influence of local features on lightning density. Some observed trends are commented.

Keywords: Lightning incidence, Soil relief influence on lightning incidence, Lightning Location Systems.

Paper n°102

Frequency dependence of grounding impedances in lightning protection systems

Abstract: This paper presents a systematic approach of measurement and analysis of grounding system impedances for lightning protection in high technology branches or intelligent building. A novel method for measuring the grounding impedance as a function of frequency was proposed. The measurement device consists of a V/F inverter, data acquisition and processing unit and probe systems. Computations were made by using the equivalent circuit approach based on the resistivity and dielectric constant of the soil and the inductance of grounding electrodes. Frequency dependence of grounding system impedance was mainly caused by the inductive current flowing through grounding conductors over the frequency of some tens kHz.

Keywords: Grounding impedance, lightning protection, grounding grids, frequency dependence of grounding impedance

Paper n°107

Theoretical and Experimental Study of a Grounding Grid in High Frequency (Up to 1 MHz)

Abstract. This paper shows a comparative study of a grounding grid when it is affected for a current impulse. An experimental was done with the aim of compare it with theoretical results based on electromagnetic theory and antennas theory using the moments method to solve the equations. The soil was modeled as homogeneous half space with plane boundary, characterized by conductivity (σ), permittivity (ϵ) and permeability (μ) constants.

Keywords: Electromagnetic fields, grounding, transient performance, moments method.

Paper n°125

Evaluation of stress parameters of lightning current arresters in case of subsequent strokes under consideration of travelling wave models for down conductors and earthing.

Abstract: Subsequent stroke currents 0,25/100 μ s stress the LPS. The stress of the equipment in a building is of importance when the strength of the equipment has to be considered in development of new components. Therefore a model of a building with the main components was developed and calculated using a network analysis programme. Especially the high di/dt value in case of subsequent strokes requires a insulation coordination under consideration of the induced voltages in loops between a surge arrester and the secondary equipment to be protected. For this purpose a model is described and the conclusions for both conventional

connected and V-shape connected class I lightning current arresters are compared by calculation of the current distribution and voltages at secondary equipment.

Keywords: Arrester, subsequent stroke, modelling

Paper n°128

Modelling of soil electromagnetic behaviour in frequency domain

Abstract: - In this work some procedures to measure and model soil electromagnetic behaviour in frequency domain are presented. The proposed model takes into account the earth conductivity and permittivity frequency dependence, which normally are not considered. Also, the importance of properly considering the earth's electromagnetic behaviour is enhanced when calculating transmission line parameters. For an actual 440 kV single three-phase transmission line the soil behaviour is represented through a unique real value of conductance (the normal approach) and through the proposed model.

Keywords: Soil model, Line parameters, Frequency dependence, Electromagnetic transients.

Paper n°132

Measurement of lightning surge characteristics of footing impedance on actual 500kV transmission tower

Abstract: This paper shows the measurement results of lightning surge characteristics for footing impedance on actual 500kV transmission towers. The results show that (a) the tower footing impedance is shown to be time-dependent in most measured cases, so they can be represented using parallel circuit of resistance and capacitance, (b) the tower footing impedance can be regarded as being close to the resistance frequency range of a lightning surge, and (c) there is mutual coupling impedance among four tower feet. These characteristics should be considered to make a calculation model for the tower footing impedance.

Keywords: Lightning, lightning surge, actual transmission tower, footing impedance, EMTP

Paper n°147

A non-uniform transmission line approach for transient analysis of grounding system under lightning impulse

Abstract: A non-uniform transmission line approach is adopted in this paper for modelling the transient behaviour of grounding systems under lightning strikes in time domain by solving Telegrapher's equations based on FDTD technique. Electromagnetic couplings between different parts of the grounding wires are included using effective per-unit length parameters (l, c, and g), which are space and time dependent. It is shown that the time and space varying mutual coupling phenomenon is the one that decides the effective length of the horizontal grounding electrode, while, an uniform transmission line approach [6-7] is appropriate only for electrodes shorter than the effective length. The simulation results for buried horizontal wires and grounding grid based on the present model are in good agreement with that of the circuit and electromagnetic field approaches [1-2].

Keywords: grounding, lightning, transient analysis, transmission line and FDTD methods

Paper n°149

An EMTP model for the grounding impedance of overhead transmission line. Sensitivity analysis

Abstract: This paper presents an analysis of the lightning performance of transmission lines. The main goal is to determine the flashover rate of a line as a function of the main parameters of the grounding impedance model and decide the accuracy with which these parameters should be specified. The document includes a comparative study of the lightning performance of transmission lines considering three different models of the tower grounding impedances. The study is based on the application of the ATP package and the development of a Monte Carlo procedure.

Keywords: Modeling, EMTP, Grounding Impedance, Lightning, Monte Carlo Method.

Paper n°152

Simplified expressions for tower surge Impedance based on application of a field-circuit modelling approach

Abstract: The authors analyze aspects related to the modeling of a typical 138 kV transmission tower configuration. A discussion concerning the application and accuracy of traditional modeling techniques represented by simplified analytical expressions for tower surge impedance is carried out. New expressions for this parameter are proposed based on the application of a Field-Circuit Modeling Approach (HEM). Such new expressions, although obtained through a refined model, keep the attractive characteristic of simplicity, adequate for engineering application.

Keywords: Transmission tower modeling, hybrid electromagnetic approach.

Paper n°167

Initial design of a system to determine the behaviour of an earth electrode subjected to real lightning discharges

Abstract: An initial design is proposed for a modular and scalable measurement system that can be used to study the dynamic impedance of an earth electrode subjected to real lightning current discharges. The measurement system will be used to instrument an existing cellular base station. A novel approach to obtaining absolute voltage measurements is introduced and investigated. The key components and functionality of the overall measurement system are discussed.

Keywords: earth electrode, soil ionisation, lightning current, dynamic impedance.

Paper n°179

Characterisation of tower base earthing systems under impulse conditions

Abstract: In this paper, we describe experimental results obtained with a portable impulse current generator on a purpose-built 275kV transmission tower base. Tests with increasing current magnitudes were used to investigate conduction phenomena in the soil. Numerical simulations of the configuration were used to predict the potential distribution around the tower base and an equivalent circuit model is proposed to represent tower base earthing systems under impulse conditions.

Keywords: Earthing, transmission towers, impulse tests, impulse resistance, soil ionisation.

Paper n°186

Experimental and analytical study on electromagnetic transient response of a buried bare wire and ground net

Abstract: This paper describes experimental and analytical studies on electromagnetic transient response of a buried bare wire and ground net. The measurement of electromagnetic transient response of a buried bare wire and ground net is carried out in various conditions. The measured results compare with the calculated results by Sunde's theoretical formulas, and the validity of the theoretical formulas is examined. Moreover, a calculation model based on the theoretical formulas and EMTP is proposed. From the above examinations, it clearly shows that the theoretical formulas and the calculated results by the proposed model can reproduce the experimental results.

Keywords: Electromagnetic transient phenomena, Buried bare wire, Ground net, Lightning, Lightning surge, EMC, EMTP

Paper n°206

A didactic general approach of grounding behavior for lightning currents

Abstract: This paper is intended to present a comprehensive and objective approach for the behavior of grounding electrodes submitted to lightning currents.

Keywords: Grounding behavior for lightning currents, Transient grounding behavior, Grounding.

Paper n°240

Impulse and High Frequency Tests of Lightning Earthing

Abstract: A safety earthing designed for short circuit currents is not always good enough to carry away lightning current. For lightning protection purposes impedance of earthing, instead of its resistance, should be taken into account. A comparison of impulse and high frequency test methods has been presented.
