Session 9a, 9b, 9c, 9p

Practical and Specific Lightning Protection Problems

Moderator's Report

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INTRODUCTION

Twenty Six papers were accepted for Session 9:

- 7 papers for oral session 9a,
- 8 papers for oral session 9b,
- 8 papers for oral session 9c,
- 3 papers for poster session.

The first oral session is about the study of lightning to wind turbines. The topic of the second oral session is lightning to antennas and EMC. The third oral session covers papers about lightning to railways and field observations.

LIGHTNING TO WIND TURBINES

Session 9(a)

"Calculation of Electric Fields in a Windmill due to a Lightning Discharge Using Finite Elements Method"

Monica Aguado Alonso, Inigo Arostegui Larrion.

Lightning being the main threat to wind mills, the risk assessment becomes essential. This can be done with the evaluation of the electric field. The main objective of this paper is to analyze the electric field around a wind turbine and the stepped leader process during thunderstorm conditions. The possible risk points of being struck by lightning stroke are discussed.

"Application of Charge Simulation Method for Wind Turbine Lightning Protection"

B. Vahidi, A.R. Shaddel S., S.A. Kashi.

A wind plant model is developed for the charge simulation method (CSM) computation. The electric field over the windmill in the presence of a protection tower is computed. For different values of H (Height of the tower) and D (distance between the tower and protection system) the mean value of the distributed potential on the upper blade is computed and compared with that of the potential without a protection system. By changing the H and D with respect to the windmill dimensions during the design process, the proper height and position of a protection tower can be determined.

"A Study of Transfer Surge from a Low Voltage Side of a Transformer When a Lightning Strikes a Wind Turbine Generator System"

Kazuo Yamamoto, Taiji Nishii, Akihiro Ametani.

This paper describes the lightning transfer surge phenomena between the primary side of the transformer to the secondary of the transformer using EMTP simulations. The transformer used for the testing is a 10-kVA, 3-phase transformer. The simulations have been carried out on three different cases: a) with secondary circuit open, b) resistive load connected to the secondary, c) the secondary circuit of transformer has type line models. The simulations matched the measured values of input currents and output voltages. The transfer surge becomes large with no load connected to the secondary terminals, and the transfer surge is reduced when loads such as distribution lines are connected to the secondary terminals.

"Lightning Protection for Wind Turbines and its Test With a High Performance Lightning Current Generator"

Prof. Dr. –Ing. K. Scheibe, Dipl. –Ing. J. Schimanski, Dr.-Ing. M. Wetter.

Around 30% of lightning damage is caused by the direct lightning strokes and 70% are caused due to the electromagnetic interference. These electromagnetic pulses affect the electrical and electronic equipment. Risk assessment is necessary before designing the protection equipment. Rolling sphere method is used for demonstration of lightning currents up to 200 kA. Lightning protection modules must be tested in laboratory in advance. The generators used for the laboratory tests must be capable of delivering the prospective lightning current.

"Manner of Lightning Attachment to Non-conductive Wind Turbine Blades"

S. Yokoyama, N.J. Vasa, T. Naka, A. Wada, H. Honda, A. Asakawa.

Experimental data are presented on the influence of lightning discharges on a scaled blade-model made from non-conducting (polymer) and conducting (aluminum) materials. Results in these experiments show that the surface discharge effect was enhanced with positive polarity as compared to negative polarity voltages. The wind turbine blades, which are made of non-conducting material, serve as a preferential path for the lightning current under some conditions. This is due to the lower electrical breakdown strength of blade surfaces compared to the air around them.

"Tracking Tests of Glass Fiber Reinforced Polymers (GRP) as Part of Improved Lightning Protection of Wind Turbine Blades"

S.F. Madsen, J. Holboell, M. Henriksen, N. Bjaert.

The present paper describes the testing of the tracking phenomena in glass fiber reinforced polymers (GRP). The penetration of lightning current is critical and usually implies a delamination, while the arc moves along the surface leaving physical erosion, called tracking. The area subjected to tracking may further attract lightning because the carbonized track connected to the receptor exposes the earth potential. The tests consider various types of properties of both homogeneous and inhomogeneous surfaces that have to be considered before choosing the material for the manufacturing of the wind turbine blades. Results have shown a great deal of damage done to different types of resin materials by the lightning arc current.

"Lightning Damages of Wind Turbine Blades in Winter in Japan – Lightning Observation on the Nikaho-Kogen Wind Farm"

Atsushi Wada, Sigeru Yokoyama.

The paper presents the types of lightning discharges during winter thunderstorms in Japan, which were causing serious problems to the tall windmill blades in a windmill farm. Discussion follows on lightning protection for wind turbine blades during winter lightning events. The paper mainly aims at understanding the mechanism of lightning stroke attachment to the windmill. A positive lightning bolt composed of two strokes was observed at a windmill on the Nikaho-Kogen farm in Japan. The lightning discharge seems likely to be a downward lightning composed of a downward leader and an upward return stroke. Using Rogowski coil they have successfully recorded the lightning current. Many pulse currents of upward leader discharges without return strokes were also often measured.

LIGHTNING TO ANTENNAS AND EMC

Session 9(b)

"Protection of Antennas of Mobile Phone Relay Stations against Direct Strokes"

T. Horvath.

The author describes lightning protection of antennas in relay stations for mobile phones. He introduces an interesting computational method for expected frequency of shielding failure (number of lightning hits to the antenna) and the average stroke-free period. He concludes that the probability of shielding failure offers a basis to consider the risk of failure. Most convenient sizes of the lightning protection rods can be determined by appropriate selection of the rod height and location with respect to the antenna height. Comparison of results was nicely done with varying parameters of the protection system.

"A New Algorithm for Antenna Theory Modelling of a Lightning Return Stroke"

K. Aniserowicz.

Lightning return strokes are modeled through an antenna monopole approach, the AT3 model. Antenna parameters, including frequency, impedance, and dimension are selected for equivalent lightning stroke simulation. Fast Fourier analysis reveals a time-domain dispersion effect in the computations. This dispersion effect is noted in other references. The presented results of analysis are determined to be consistent with other methods of lightning stroke analysis.

"Investigation of Lightning Electromagnetic Pulse Effects in GSM Base Station"

R. Markowska.

Analysis of the return current is presented in this paper. Full and simplified computational modeling using a Method of Moments analysis were compared to actual on-site measurements using a surge generator. Computational results were converted into time domain with the Fast Fourier method for comparison. Results compare closest at points nearest the origin of the induced current of several different impulse shapes. Comparisons are used to evaluate the lightning threat very effectively. Field investigations help in determining which factors and elements should be considered in a real object. The author concludes that protective earth (PE) is the main source of current flow from the surge generator.

"Lightning Protection of Air Traffic Control RADAR Systems"

D. Kokkinos, M. Xenakis, S. Vassalos, N. Kokkinos, I. Cotton.

This paper presents some new design concepts for an internal lightning protection system on radar used at very

high altitudes subjected to frequent lightning strokes. Surge protection devices installed in the unit remained 100%

perfect even after 2 years under usage when hit by many lightning strokes. Problems in the protection system existed due to the high earth resistance at the installation. The elaborate new lightning protection design improved the reliability of radar operation and air traffic control.

"Application of Aircraft Lightning Protection to Radar Stations"

C. Bruel, D. Barilleau, A. Rousseau.

Traditional lightning protection systems cause interference in some antenna systems. The paper presents approaches to resolve the interference problems. The new lightning protection system is developed to be "transparent" to electromagnetic waves. The new protection system includes an appropriately named the "transrad" lightning rod, made of lightning diverter strips attached to a fiberglass rod. This method has been tested fully with high voltage impulse and the high-energy lightning stroke used by aircraft industry. The complete protection includes transrad lightning rods, equipotentiality, shielding and surge protection. The field results have shown that solid strips performed better than traditional radar lightning protection systems.

"Lightning Strike to Helicopters During Winter Thunderstorms Over North Sea"

A. Delannoy, A. Broc, E. Montreuil, P. Lalande, P. Laroche.

To optimize the lightning protection zones on aircraft, atmospheric cell electrification is evaluated. A tool for modeling meso-scale and small-scale atmospheric behaviors was run to describe the atmospheric electrical configuration. Electrification study is done using meso-scale non-hydrostatic model. A meso-scale non-hydrostatic model delivers a 3D description of the convective cell. A microphysical and dynamical 1.5D model then does the vertical electrification within the cell. Later ONERA model is used to compute zones on helicopters from where lightning discharge can develop. Results verify that electrification depends on temperature of the air.

"A Varying Surge Impedance Transmission Line Model to Evaluate Lightning Current Contamination at Tall Structures"

D. Rondon, F. H. Silveira, S. Visacro.

In order to determine the influence of instrumented towers and grounding systems in lightning currents, the transmission line model with variable surge impedances have been used. The lightning channel is represented by surge impedances of varying height for the evaluation of current profile throughout the lightning channel and the instrumented tower. The EMTP/ATP program was used to compute the time domain simulations. The present simulation, which is carried out in time domain can be compared with the electromagnetic model in the frequency domain with reduced computational time of simulation.

"Lightning Protection of Intrinsically Safe Zones"

Eduardo Mariani, Claudia Piaggio.

Protection of intrinsically safe zones is considered in greater detail with the issue of protection high energy strokes by more complete shielding. Intrinsically safe zones may include containment of low voltage equipment or hazardous and explosive materials and real ground is not necessarily a natural "lightning energy diverting device." This paper takes the approach of a Faraday cage with a ground window to solve the potential safety hazard problems. Many field installations prove the efficiency of this approach.

LIGHTNING TO RAILWAYS AND FIELD OBSERVATIONS

Session 9(c)

"Global Engineering Methodology and Designer Studies Examples"

Prof. Monica AGUADO, Raymond GOIFFON, R. MOUTIER/ Alain VORON, J. DEKONINCK.

Sophisticated design of protection due to lightning incidents caused by environmental conditions is considered. Lightning prevention and protection should be taken into account because of unprecedented damages that could undermine the very foundation of sustainable technology development. Engineering methods for lightning protection designs are presented for different environmental conditions.

"Experimental Study of Effective Lightning Protection Measures for Railway Level Crossing System in Japan"

Hideki Arai, Ikuo Watannabe, Hiroji Matsuabara, Shigeru Yokoyama.

Field experiments were carried out by injection of lightning surge currents to rails and wayside ground. These experiments help in gathering basic data for the design of the lightning protection of low voltage electronic and signaling equipment for rail crossings. Countermeasures were introduced for suppressing the lightning over-voltages on the level crossing at the test site. As presented from the experiments, the ground potential distribution near the rail is much different from that of a buried conductor.

"Lightning Protection for Track Circuits in Railway Applications"

J. Birkl, P. Zahlmann.

A new device is presented for lightning protection of track circuits in electrical traction and railway applications. The fuse link is intended to ensure protection against direct contact, providing a safe environment for operator personnel and passengers. The paper describes the design of the fuse link, i.e. the way to take special system parameters.

A brief overview of the complete method of evaluation and application is presented.

"Overvoltage Protection Concept for DC Railway Systems"

Bernhard Richter.

A Hybrid Voltage Limiter (HVL) is developed and used in protecting against dangerous touch voltages along rails and in substations. Types of HVL devices and application in a DC railway system are presented. Use of the HVL is more significant, as recently added low voltage electronic components in substations are to be protected against over voltages due to lightning strokes.

"Measurements of Lightning Transients Entering A Swedish Railway Facility"

Nelson Theethayi, Yaqing Liu, Rajeev Thottapillil, Thomas Gotschl, Raul Montano, Per Anders Lindeberg, and Ulf Hellstrom.

Transient over voltages and currents entering the auxiliary power supply of a railway facility from actual lightning strokes are measured. During measurements, surges due to switching and other operational effects must be distiguished from the surges due to lightning stroke. Methods, dates, and location of measurements are presented with measurement data. These measurements help in the verification of numerical models of lightning interaction with railway systems.

"System Electromganetic Compatibility for the Lightning Protection of EDF Hydro-electric Power Plants in Corsica"

Alain Alcaras, Daniel Soleil , Gerard Bord.

Corsica hydroelectric power station and its outer structures are highly prone to lightning strikes because of the geology and the climate. Studies were conducted with a new EMC (Electromagnetic Compatibility) related Zero method. This method uses an accessible and easy process to control the industrial electromagnetic interference from various electromagnetic effects. In particular, protection against lightning current intrusion is considered.

"Lightning Protection for a Complex Isolated Renewable and Diesel Power Network – Micro Grid"

D. Kokkinos, G. Ladopoulos, N. Kokkinos.

This paper explains the design of LPS (lightning protection system) of a micro grid, which is located at higher altitudes and prone to many lightning strokes. The LPS provides protection of specific equipment located at a high altitude in a high ground flash density area, without using heavy duty and expensive surge protection devices. Efficiency of the LPS is shown by the statistics over a period of ten years, and no major damage has occurred during this period.

"Effect of a Direct Stroke into Reinforced Concrete"

Andreas Jan Meppelink.

Effects of a lightning stroke on a reinforced concrete are discussed. In some cases a large mass of concrete was found in front of a building. Events such as concrete falling due to lightning stroke damage can be dangerous to the people standing underneath. Hence, these tests are significant for safety. Switching and lightning impulse voltages at positive and negative polarity were tested on the most commonly used samples of reinforced concrete and buried metal plate. The impulse current after the pre discharge will follow the prepared track in a small expanding channel. This current channel expands to an order of a millimeter in a short time duration exerting pressure that forms cracks.

POSTER

"Lightning Analysis on Wind Farm – Sensitivity Analysis on Earthing"

YASUDA Yoh, FUNABASHI Toshihisa.

Interconnection issues and lightning surge propagation between wind power generation and the power system is discussed. Surge analysis using a wind farm model with 10 windmills connected to a power system is presented. Lightning strokes do not need a direct hit to a windmill to cause damage on that windmill. When lightning strikes the wind farm, windmills far from the power system receive a large surge compared to the surge at windmills near the power system. The paper tells about the importance of protecting every windmill in the farm.

"The Observation of Direct Lightning Stroke Current to the Wind Turbine Generator System"

Yasuhiro Shiraishi, Takahiro Otsuka, Hideki Matsuura.

The authors present an observation of lightning stroke current to the wind turbine generator system using a large diameter Rogowski coil. The high reliability of a large diameter Rogowski coil was proven effectively from these observations. Measured data was proven to be reliable and accurate from previous statistics. Latest technology such as a Global Positioning System (GPS) was used in order to get accurate data.

"Analysis for High Frequencies of Grounding Systems, for Wind Turbines"

O. Ukar, I. Zamora, R. Idiondo, A. Mugica.

Probability of lightning impact grows with the number of wind turbines installed and with the increase of height. This paper describes the importance of grounding and the different types of grounding. An important part of the lightning protection system is the ground that must disperse lightning current, flowing from the wind turbine to the earth termination system. Over voltages that can be dangerous to both humans and equipment must be limited. The grounding performs a function of drain, as evacuation of current toward the earth, or as a collector, gathering the currents spread from other points. The grounding system

plays a very important role in the dissipation of atmospheric discharge currents, in order to prevent damage to electrical and electronic equipment and prevent injuries to people.