28th International Conference on Lightning Protection

Topic IX: Practical and Specific Lightning Protection Problems Moderator's Report

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***Abstract*— A total of 29 papers have been accepted for Topic IX "Practical and Specific Lightning Protection Problems". Of these papers 14 could be presented in two oral sessions. The remaining 15 papers were assigned to poster presentation.**

As usual, Topic IX on practical and specific lightning protection problems comprised a large diversity of subjects. These could be allotted to the following main topics:

- **Railway systems**
- **Home appliances and home IT**
- **Renewable energy**
- **Lightning protection systems**
- **Telecommunication**
- **Miscellaneous**

The first Oral Session IX-A addressed the topics railway systems, home appliances/IT and renewable energy. The other topics were dealt within Oral Session IX-B.

I. Railway Systems

IX-1 "*Real-time decision support against lightning hazard in railways*", H. Takeuchi, T. Shozawa, M. Okai

This paper investigates the prediction of severe lightning discharges that might cause a serious disturbance in train operation, by using computers based on the Japanese Lightning Detection Network (JLDN), in order to support dispatchers to make an effective decision about arranging maintenance engineers, emergency electrical power generators and extra electrical devices for quick recovery.

IX-2 "*Development of Lightning Surge Sensor for Railway Signal Control System*", T. Hattori, R. Ishima, T. Kunifuji, Y. Hirano, H. Sugahara

A new railway signal control system is under development, which controls railway signals, switches and track circuits based on IP protocol. In such a system, many electronic devices are installed along harsh railway environment. As a countermeasure for the lightning surge, protective devices (cable arrester) are used. In this paper a lightning surge sensor to detect the degradation of a protective device is presented. As a method to acquire a waveform of a lightning surge, "the double threshold algorithm" is newly applied.

IX-3 "*Lightning and overvoltage protection concept for urban transportation systems*", B. Richter, S. Schäfer

MO-surge arresters with polymeric housings and low voltage limiters based on the same technology have been introduced in the past. The elements open the possibility of new protection concepts especially in DC railway systems. The advantage of the mentioned products and resulting concepts is that protection of equipment against overvoltages and protection of people against touch voltages can be combined, and implemented in some cases in one product.

IX-4 "*Estimation of Occurrence Frequency of Lightning Damages on Railway Level Crossing System in Japan*", H. Arai, K. Sato, Y. Hirano, H. Sugahara

It is required to build up effective and economical countermeasures for preventing lightning damages on the railway signalling system. Such countermeasures, up to now, were often based on trial and error. Therefore, the lightning overvoltages caused by invading lightning surges into the railway level crossing system in the event of real lightning stroke were measured in order to grasp the lightning overvoltages quantitatively. From the results of field test, the occurrence frequency of lightning overvoltages on the railway level crossing system in a real lightning

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environment could be determined.

IX-15 "*Study of artificial lightning test to Maglev Vehicle*", M. Okai, H. Tsunoda, H. Oshima, H. Matsubara

During the developing process of the Superconducting Magnetically Levitated Railway System several experiments were carried out aiming at an evaluation of the system under unusual natural conditions. The aim of these tests was to observe the behavior, such as a surge of the car body, the bogie, the superconducting magnet or the other electric devices equipped on the car by the artificial lightning test.

IX-16 "*Development of Lightning Protection in Electric Railway*", M. Okai, T. Syozawa, K. Sasaki

Lightning is still a natural threat to the electric railway system. Japan Railway has been executing various lightning protection countermeasures built around experiences or analysis of many lightning incidents. This paper introduces lightning protection measures that have been adapted in Japan high speed railway (Shinkansen Railway) and in conventional railway systems.

II. HOME APPLIANCES AND HOME IT

IX-5 "*Damages on Home Electric Appliances Due to Lightning in Japan*", T. Hosokawa, S. Yokoyama, T. Yokota, Y. Tsutsumiuchi, M. Soeda, K. Sacoda

In order to determine the protective methods for the household electric appliances (HEAs) the manner of lightning damages should be understood first of all. Statistics of HEAs lightning damages have been investigated for 3,800 monitors for three periods between 1987 and 2004. The rate of damage is 0.65%/household/year for an area of 20-35 thunderstorm days per year. The outage rate shows that the damages rate is large for the HEAs with an antenna and communication facilities such as telephones and fax machines.

IX-6 "*Experimental Study on Effect of Lightning Surge Invasion into Electrical Appliances*", M. Soeda, T. Hosokawa, M. Ikuta, S. Yokoyama

A lightning damage survey of electrical appliances conducted in the period from 2003 to 2004 reported that lightning damaged the appliances and also caused malfunction, or the freeze phenomenon, of micro-chip components in electronic equipment. This paper focuses on the freeze phenomenon of electrical appliances survey. The authors examined the impact of the wave front steepness of the lightning surge current on an electric water heater by applying lightning impulse currents, having different levels of wave front steepness, and by reproducing the freeze phenomenon in an AC superposition test. Steep impulse currents are more likely to cause the freeze phenomenon or damage electrical appliances.

IX-17 "*Experimental Study on Effect of Lightning Surge Invading into a Fax Machine*", Y. Tsutsumiuchi, T. Hosokawa, M. Soeda, M. Ikuta, V. Nilesh, S. Yokoyama

Household communication equipments, which consist of a high-density integrated circuit driven by a low voltage, are connected through a complicated network of communication lines, power supply lines and antenna wires. These equipments can be upset or damaged by even low magnitude lightning surges. The aim of this study is to examine a breakdown or a freeze point of these household communication equipments due to high-voltage surge propagation. It is experimentally shown that impulse waveforms affect the damage manner of the fax machines. Finally, a protection circuits for a fax machine is presented.

IX-18 "*Lightning Protection System for Earth Simulator super computer*", K. Fujito, A. Sato, Y. Murano, H. Okamura, T. Tsuchida

The concern on Earth Simulator Project was to provide the ideal environment for the super computers, including the lightning protection system. An isolated horizontal air termination system was designed, based on the rolling sphere method, to keep the clearance from the building. In order to reduce the over-voltages induced by lightning currents, the safety distance of the super computers to the down conductors were studied. The lightning currents in down conductors and the maximum induced voltage were calculated using an Electro-Magnetic Transients Program. The use a standard EHV power cable as down conductors was studied.

III. RENEWABLE ENERGY

IX-7 "*Lightning and Surge Protection for Photo-voltaic Applications – Performance Tests of PV-modules and DC-AC-converters*", J. Birkl, B. Schulz

Surge currents and surge voltages constitute a severe threat for photo-voltaic systems. The efficiency of protective measures can be verified by laboratory tests at complete installations or system components. Different examples are presented, where lightning and surge protective measures for PV-applications on system level have been successfully tested in the laboratory in extensive test runs. Practical realisation and field experience in numerous PV-systems confirm the effectiveness of the tested lightning protection measures and surge protective devices.

IV. LIGHTNING PROTECTION SYSTEMS

IX-8 "*Lightning Protection of metal roofs*", J. Meppelink, M. Benzin

The probability of a puncture due to the charge of a long duration current has been evaluated in order to quantify the risk of a puncture. Furthermore the consequences of a puncture are studied and accompanied by laboratory tests. It was found that a fire does not occur as long as fire-proof materials are used. Performance tests on sections of metal roofs consisting of panels have shown that even under 200 kA 10/350 impulse currents the puncture was very small and that there was no mechanical destruction. Additional air

termination and/or down conductors can only reduce, but not generally avoid, current flow through the metal sheet.

IX-9 "*Effect of Direct Lightning Strike in the Down Conductors Embedded into the Reinforcement*", D. Kokkinos, N. Kokkinos, J. Koutsoubis, M. Klabana, A. Triantafillides, C. Charalambous

The foundation earthing is generally accepted as the best lightning protection earthing system. Also down conductors may be embedded into reinforced columns of a structure. However the installation of LPS conductors into the reinforcement must be very carefully implemented, since a poor bonding between the LPS conductor and the reinforcement bars can easily cause serious cracking of the concrete. In order to illustrate the consequence of a poor bonding, the effects of direct lightning strikes with various magnitudes and waveshapes were experimentally simulated on a variety of specimens designed according to civil engineering standards. The only specimen, which did not show visual damage of the concrete block, was one that had the appropriate connector.

IX-10 "*Investigation on the Performance of Different Lightning Protection System Designs*", N. Kokkinos, I. Cotton

In this paper different lightning protection systems (LPS) are modelled so that the scalar potentials on the LPS components and the magnetic fields that are generated due to the flow of the lightning current on the LPS conductors can be recorded. Furthermore an investigation regarding the induced voltages and currents due to the magnetic fields on cables inside the LPS is presented. It is shown that by using a meshed air termination system a better distribution of the lightning current on the down conductors can result. By using more down conductors and a meshed air termination system, the generated magnetic fields and the induced overvoltages and overcurrents on cables inside the LPS can be reduced.

IX-19 "*Lightning and Surge Protection of Cellular Transmit Sites*", D. Kokkinos, N. Kokkinos, I. Vlaseros, K. Dimas, M. Koulizos, P. Garoufalis, J. Sotiriadis

This paper aims to analyze the design, installation and the components/devices used in a lightning protection system of a cellular transmitter base station. Additionally, difficulties that were faced during the implementation of the above are presented. The experience of more than 200 installations all over Hellas and statistical data recorded during 10 years emphasize the important and sensitive parts of a station and show various techniques and devices that can be used to successfully minimize the damage. Various case studies are presented, e.g. isolated stations, high earth resistance, high lightning activity etc.

IX-20 **"***Lightning Protection of Cable Bridges***",** D. Kokkinos, G. Valirakis, N. Kokkinos, C. Charalambous, I. Cotton

The aim of this paper is to present a lightning protection system for a cable bridge, which was implemented 11 years ago and no damage was ever reported. This cable bridge is manufactured to link the mainland of Hellas with the island of Evia, which is the second largest island of Hellas. In addition a similar design for a smaller scale cable bridge will also be presented. The design was based on the Hellenic standard ELOT 1197 and IEC 61024, which are now replaced by the new IEC 62305 series. Protection against side flashes was considered, by using natural components of the bridge. Surge protective devises protect sensors and sensitive electronic equipment, which are now installed in modern bridges.

V. TELECOMMUNICATION

IX-11 "*Lightning Protection of Mobile Services Switching Centres*", N. Szedenik, I. Kiss, L. Babits, I. Berta

The Core Network Sites (e.g. Mobile Switching Centres) are important parts of the mobile telephone network. They are specially endangered by lightning strokes, because of their tall transmitting towers. They contain extensive electronic equipment, which is highly sensitive to the overvoltages caused by lightning. The authors give a review concerning both the general aspects of the lightning protection of such Core Network Sites (CNS) and typical problems of the practical operation. Basically dangerous situations, theoretical principles of the protection and possible typical faults of the installation are discussed in the paper. The studies prove that without a consequent overvoltage protection the sensitive electronic equipment is exposed to serious damages.

IX-23 "*Alternative method to measure lightning current distribution in telecommunication sites*", A. H. Samad, A. N. Johar, A. M. Ramli

To reduce damages in telecommunication sites, the lightning current distributed in the grounding and bonding system distribution need to be managed by diverting it away from sensitive electronics equipment or provide shielding against the magnetic field. The current distribution can be measured by injecting a surge current into the bonding system, but it will become a destructive test since the current is too large. Alternatively, using a signal generator, a much lower test current at any frequency can be applied to the existing bonding network. Both techniques are investigated in a laboratory setup and found in reasonable agreement. The alternative technique is able to give an assessment of the current distribution during lightning strikes at telecommunication stations and facilitate rectification of deficiencies.

IX-24 "*Lightning Protection for Mobile Base Stations*", M. Sato, T. Matsui, K. Sasaki, K. Amagasaki

Mobile base stations are often exposed to direct lightning strikes and the telecommunications equipment in the stations can at times be severely damaged. In order to protect the equipment against these lightning surges, a lightning protection program has been established and

implemented in 2001 which consists of a zone defence system, an equipotential grounding, and protectors for the vulnerable interface circuits. This paper outlines the typical lightning damage that occurs to conventional base stations and the countermeasures that have taken to reduce future damage from lightning surges.

IX-25 "*An Example of Investigation in Lightning Damage on micro-radio steel tower station and Proposal of Countermeasures*", T. Sato, S. Yanagawa, H. Kurita

A lot of lightning damage is observed within micro-radio steel tower stations, because they are frequently located at the top of a mountain. A wireless micro-radio steel tower station damaged by lightning was investigated and the causes of damage were examined by experiments and EMTP analysis. The lightning protection measures are discussed with voltage rise and current flow based on the EMTP analysis applying the direct lightning waveforms (10/350μs, 100kA). Potential differences generated by the earthing line inductance are addressed. The voltage generated within apparatus by the direct lightning current and the required current withstand of SPDs are described.

VI. MISCELLANEOUS

IX-12 "*On Reducing the Internal Voltages and Currents Due to Lightning Transients in Buried Shielded Cables*", N. Theethayi, R. Thottappillil

This paper investigates the importance of a follow on buried bare earth wire for the lightning protection of buried shielded cables. When lightning transients couple to the shields of the cables larger induced voltages are developed between the inner conductors and the shield. It is shown by theoretical simulations that if a follow on bare earth conductor is placed in parallel with the shielded cable with the bare earth wire connected to the shield at the current injection end then the shield current and thereby the internal transient voltages and currents of the cable are reduced considerably. The observations presented have implications in EMI studies of large distributed outdoor systems, such as the telecommunication, power and railway systems subjected to lightning strikes.

IX-13 "*Understanding the point discharge DC current produced by corona needles*", L. Arevalo, M. Becerra, F. Roman

The corona behaviour in a coaxial cylindrical arrangement with needles in the internal cylinder has been investigated. This research has been performed in two different stages: the experimental one and the theoretical. The experimental results have shown a direct current with superimposed pulses. Streamer, Trichel and DC current formation are explained in terms of photo-ionization and secondary processes. Results are obtained for the spatial - temporal distributions of electrons, positive ions, negative ions, net charge and the space charge distorted electric field. A comparison between point to plane and point-to-cylinder arrangement is also included.

IX-14 "*Design of a re-usable rocket for triggered-lightning experiments*", M. D. Grant, K. J. Nixon

The design of a re-usable hybrid rocket for use in triggered-lightning experiments that conforms to South African explosive legislation is presented. The fuel tank and combustion chamber behaviour is analysed, as is a thrust model for rocket performance prediction. Ignition materials and process along with aerodynamic considerations are presented. A radio location system facilitates the recovery of the rocket. Finally a cost analysis is performed against available solid propellant rocket motors and it is found that the hybrid rocket is significantly cheaper to operate.

IX-21 "*New data about lightning damages in Portugal and Navarra (Spain)*", R. Rodrigues, C. Soares, M. Aguado

This paper presents provisional results of an evaluation of damages due to lightning on the continental territory of Portugal and the region of Navarra in the north of Spain. Damages were classified taking into account the new IEC 62305 standard. In order to achieve the necessary information, contacts were made with public and private companies, governmental institutions and newspapers. Data recorded by the two national Lightning Location Networks were also considered. All cases reported were joined in a commune database. The reduced number of cases found in Portugal seems to be in accordance with the low average value of strokes to ground. On the other hand in Navarra a larger number of cases were found.

IX-22 "*Application of a methodology for ranking sensitive equipment sites for pro-active modifications on Lightning Protection Systems*", A. P. Soares, A. R. Nobrega, R. C. Marcos

Some telecommunication facilities of FURNAS Centrais Eletricas, one of the largest power companies in Brazil, are susceptible to severe lightning conditions concerning the magnitude and the incidence rate of lightning strokes. Thus, a computational methodology has been developed for the ranking of susceptible telecom facilities based on (a) the number of interruptions on the electricity supply of telecom facilities probably caused by lightning, and (b) the correlation of sensor's records to lightning data available from the Brazilian Integrated National Lightning Detection network (RINDAT).

IX-26 "*Improvement of the Output Current Response of an Electrostatic Fast Impulse Current Generator*", O. Diaz, F. Roman

Lightning current impulses are usually diverted to ground by surge protective devices (SPD's). Most SPD's are tested with normalized current impulses 8/20 μs. However, the effect of high current derivative events such as 100 kA/μs or more are not often considered. A fast impulse current generator (FICG) based on the floating electrodes (FE) principle was designed and constructed. The generator is an electrostatic generator able to produce lightning-like current derivatives, with pulse amplitude in the order of some kA and a typical rise time of some tens of nanoseconds. The

focus of the present work was to improve the new generator's output current response by decreasing its internal equivalent inductance.

IX-27 "*6 channel lightning surge counter*", H. Kato, S. Yanagawa, H. Kurita

As communication lines and low voltage power lines are drawn into systems together, discussion of lightning current routes in low voltage lines and communication lines including waveguides is essential for effective measures of lightning surge protection. A "6 channel lightning surge counter" allows to evaluate the invasion and the branch route of lightning currents. The lightning current peak values of maximum 6 neighbouring lines can be measured at the same time. Peak values of lightning currents can be measured in the range from ± 100A to ± 20kA. The number of data that can be stored for each channel is 100, so that maximum storage memory amounts to 600. The life time of battery is seven years.

IX-28 "*Research of Lightning Surge Effects by Equipotential Grounding or Isolated Grounding*", T. Fukuda, K. Ichikawa, K. Nagata, N. Kuzuoka, H. Arai

The grounding system is an important part of a lightning protection system. The structure of buildings often includes reinforcing bars, steel frames and deck slabs as the main components. These components can also be used to form a low impedance grounding system. Lightning surges have been applied to a real-size test setup. The influence of lightning surges on different grounding methods, the effects of the size and length of grounding conductors, the characteristics of a surge protection device (SPD) and the protection coordination of the system with different types of SPDs is examined.

IX-29 "*Lightning protection of a cable-stayed bridge*", A. Rousseau, L. Boutillon, A. Huynh

One of the longest stay cable bridges in the world has been struck by lightning leading to the failure of one stay cable. This event has been studied in order to explain the failure mechanism and to find appropriate protection solutions. Many tests have been performed either on components or on the whole stay cable including metallurgical inspections, mechanical, high voltage and surge current tests. The scenario of the failure has been established and enhancement of the existing lightning protection system has been defined and implemented.