Topic VII: Lightning Protection of Electronic Systems Moderator's Report

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Abstract— **A total of 24 papers is accepted in 2006 for presentation in the session allotted to ICPL Topic VII "Lightning Protection of Electronic Systems". This is more than the 14 papers presented at the ICLP 2004 Conference in Avignon, France. The papers are assigned to two oral sessions and in a poster session:**

- **7 papers for oral session VII-A**
- **7 papers for oral session VII-B**
- **10 papers for poster session VII-P**

The first oral session VII-A is about the surges and their effects on electrical installations. The topic of the second oral session VII-B is assigned to surge protective devices (SPD).

I. Oral Session VII-A

VII-1 "*Measurement results of lightning surge current on AC mains line connected to access network equipment*", H. Yamane, T. Tominaga, J. Kato, K. Murakawa, K. Tajima

The paper deals with the unwanted tripping of over-current circuit breakers (MCB) due to surges induced by lightning on AC power lines. The investigated AC power lines supply distant access network equipment for telecommunication services. By using Rogowski coils many measurements were performed on different sites.

It is stated that the normal (differential) mode current may cause malfunction of the MCB, too. A lightning surge immunity test is demanded. The report does not say anything about time delay options for such MCBs.

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VII-2 "*Numerical electromagnetic analysis on lightning current distribution inside of directly stricken Building*", S. Miyazaki, M. Ishii

The lightning current distribution at a directly struck building is calculated using the computer code NEC-4. This computer code is based on the Method of Moments solving the Maxwell's equation in the frequency domain. The investigated structure is 8 floors high and has a base area of 20x20m^2. The conductors are assumed to be cylindrical wires located over perfectly conducting ground. The total structure was much simplified as far as the down conductors and the horizontal equipotentialisation is concerned. Six types of internal mains wiring systems are considered. It was stated that the influence of incoming services to the current distribution inside the structure is small. The authors conclude high rated SPDs are required for installations on the top and on the bottom floor.

VII-3 "*Experimental investigations of lightning overvoltages in circuits protected by selected measures*", D. Krasowski, B. Kuca, Z. Flisowski, F. Fiamingo, C. Mazzetti

The experimental tests focus to the case when lightning strikes a down conductor. The circuit under test is protected by primary and secondary SPDs. Optionally the two stage protection SPDs are interconnected by a shielded line. However, the report does nothing say about the permeability of the shield. Since the inductance of the impulse current generator is reported to be 23 nH this represents a very small electromagnetic loop. On the other hand, the resistance of 13,5 Ω used for the impulse current generator is rather high. How realistic are therefore the surges coupled into the circuits to be tested? The impulse current peak was limited to 0,5 kA!

The authors conclude that energy coordination of SPDs needs to be established as well as voltage coordination.

VII-4 "*Damages at electrical/electronic equipment caused by a lightning stroke in a great distance*", K. Scheibe, H. Altmaier, J. Schimanski, M. Wetter

The paper addresses lightning current surge distribution between several buildings mainly by their interconnections established by the TN-C power supply network. The investigations are based on different theoretical models using the program code PSPICE. The authors conclude that considerable high fractions of the lightning current (tail part) will flow through the mains producing flash over or breakdowns on isolations at distant terminations if those are unprotected.

VII-5 "*Overvoltage hazard for internal installations and equipment due to direct lightning strikes to the LPS of structures*", M. Loboda, D. Krasowski, K. Sobolewski, Z. Flisowski

Different configuration of two stages SPDs applications were exposed to tests. It shows that more attention has to be addressed to the coupling of impulse current coming from the common bonding network. Up to now SPD coordination was usually based on surges coming from the live conductors entering the structure.

VII-6 "*Surge protection of low-voltage systems connected to overhead line*", I. Uglesic, V. Milardic

Mainly based on calculations, the paper shows that class II SPDs may be successfully used on overhead LV power lines at the entrance of ordinary buildings. It says that on the transformer station site such SPDs may fail more often.

Is this due to an interaction between the capacitors for compensation of the reactive power and the line impedance?

VII-7 "*A review of the requirements governing the installation of surge protective devices on the US electrical distribution network*", A. J. Surtees, M. Caie, V. Murko

The paper gives a review about the electrical networks installed inside the USA. It shows the significant differences of the mains distribution networks applied in the USA and those mainly considered for the SPD application in the IEC standard for lightning protection.

II. Oral Session VII-B

VII-8 "*High energy lightning impulse discharge capability metal oxide varistors*", A. Stagoj, V. Murko, A. Pirih

The paper introduces a new type of Metal Oxide Varistor (MOV). Tests performed on up to 3 unmatched parallel MOVs show the possibility to fulfill the requirements for lightning current arrestors (class I SPD). However, the paper does not show measuring results for the suggested device (2xP75/4) to meet an impulse current of 100 kA with the waveform 10/350μs. The results obtained on the device 1xP75/3 consisting of 3 parallel MOVs seem to be extrapolated.

VII-9 "*Development of ZnO disks with high energy withstand capability for low voltage surge protective devices*", N. Tsukamoto, Y. Wakahata

A new MOV with higher energy withstand capability per unit volume has been developed and tested. The chemical composition and the manufacturing process had to be changed in order to improve the homogeneity and the electrode design of the newly developed ZnO disk. The authors claim that the new ZnO disk can withstand the energy density of 500 J/cm^3 being 2.5 times higher than the energy density of conventional disks.

However, no impulse current test results are presented in the paper.

VII-10 "*Proposal of rectification type decoupling element for current capacity coordination between surge protective devices*", H. Shimizu, H. Fujita, N. Watanabe

A decoupling element in series between SPD1 and SPD2 is presented. It consists of a rectifier circuit with an embedded inductance. The rectifier across the inductance reduces the voltage drop for non surge operation. The diodes need to be able to carry the high impulse current.

It could be interesting in getting some information on saturation effects of the inductance.

VII-11 "*The ability of different simulation models to describe the behaviour of metal oxide varistors*", B. Zitnik, M. Zitnik, M. Babuder

The paper describes the numerical modelling of MOV using different simulation models. The authors found that the existing varistor and surge arrester models do not reproduce the varistor behaviour accurately. Therefore, they propose a new varistor model combining the features of two investigated models. They state that this new model can quite accurately predict the varistor behaviour.

The simulations and measurements, however, are restricted to currents of 8/20 μs waveform with peak value up to about 2500 A.

VII-12 "*Monolithic balance-type surge protective device*", R. OKA, H. SATO

The paper presents a special type of monolithic surge protective device using six diodes in the protection circuit. The SPD is in a telecommunication device and directly installed on the printed circuit board.

This type of SPD is a new development and it seems that the presented device is a preliminary version. No information is given about the tests under lightning conditions.

VII-13 "*Performance of low voltage varistors under repetitive current impulse environment*", M. Edirisinghe, V. Jeyanthiran, M. Fernando, V. Cooray

Low voltage varistors with disc diameters up to 20 mm are tested by repetitive current impulses varied between 10 s and 60 s. The used combination wave generator produces the 1,2/50 μs impulse voltage waveform at open circuit and the 8/20 μs impulse current waveform at short circuit. The generator is further specified by the maximum charging voltage of about 6 kV and the effective output impedance of 2 Ω. The tested varistors limited the clamping voltage to a maximum of about 820 V and the current to less than 2 kA. The total test includes several test cycles with several hundreds of repetitive currents tests.

It is found that the repetitive current impulses highly influence the varistor behaviour and its degradation. It was found that the capacitance and the varistor voltage is altered during the tests. When it came to failure, the clamping voltage was changed to much lower values compared to the previous impulses.

VII-14 "*Dynamic performance of arresters*", J. Meppelink, J. Trinkwald

The performance of SPD is analysed taking into account several installation arrangements of class I SPD and class II SPD. For different cable routings, the installed SPD are tested with an oscillating impulse current. The peak value of the oscillating current is about 7 kA and the rise time is about 2 μs. The tests are supplemented by computer simulation using the standardized subsequent return current of 0.25/100 μs waveform.

The authors found that the impulse current may create high over-voltages inside the installation circuits. These over-voltages are mainly caused by the high current derivative producing high magnetic field derivative. The magnetic field derivative induces over-voltages in loop structures and produces the inductive voltage drop when the current flows through the bonding conductor. One of the most important countermeasures is make the length of the bonding conductors as short as possible.

III. Poster Session VII-P

VII-15 "*Calculation of lightning-induced voltages inside the structure using engineering return-stroke models*", G. Maslowski, R. Ziemba

The authors calculate the voltage induced into a square loop with an area of 5 m x 5m. The loop terminated with a 10 kΩ resistance is located directly over the ground taken into account with the conductivity of $\sigma = 0.01$ S/m and the relative permittivity of $\varepsilon_r = 10$. The distance to the lightning channel is chosen as 100 m and 500 m. The straight and perpendicular lightning channel is simulated with the MTLL and the MTLE return stroke models. The calculations are performed in the frequency domain using the computer code HFREQ. To this end, the MTLL and the MTLE return stroke models are transformed into the frequency domain.

During the current rise the magnetic and electric fields of both models are approximately given by the well-known far distant field formula of the TL-model. Therefore, the calculations reveal nearly no differences in the loop voltage produced with the MTLL and the MTLE model. Significant differences are found varying the return stroke velocity. These results are reasonable, because the far distant field formula is based on the electromagnetic field being proportional to the channel-base lightning current.

VII-16 "*Experimental study of lightning protection design using a surge protective device in panel-board*", N. Watanabe, H. Shimizu, Y. Makibayashi

The authors analyse the lightning protection for the special case of a high-function panel-board with a built-in SPD. The study is restricted to the special conditions of the installation networks used in Japan. The low-voltage power distribution network is realized as T - T configuration. The experiments are based on tests with the 8/20 μs current impulse and the 0.5 μs ring waveform.

For the special case of the high-function panel-board the authors suggest one-point earthing as most effective lightning protection system.

VII-17 "*Lightning protection improvements on security camera systems installed in electric power substations* ", A. Nobrega, N. Silva

The paper focus on the special problem of the lightning protection of security camera systems installed in the vicinity of high power transmission lines. Several such systems are installed at the Serra da Mesa power plant and the Samambaia power station. Both facilities are located north from Sao Paulo, Brazil. This region is characterized by high numbers of lightning strikes and a very poor soil resistivity.

To avoid direct lightning strike, the systems are protected by lightning rods connected to the earth grid. The internal lightning protection requires the grounding of the neutral conductor and the installation of surge arrestors close to the devices to be protected.

It may be worth to discuss Figure 9 more in detail especially as far as the long earth wire to the earth termination is concerned.

VII-18 "*Practical issues of metal-oxide varistor modelling for numerical simulations*", N. Suljanovic, A. Mujcic, V. Murko

Different metal-oxide varistor (MOV) models use combinations of inductances and resistors, where the non-linear voltage-current characteristic is taken into account by the non-linear resistors. This non-linear voltage-current characteristic is also taken into account by the use of voltage-controlled current or voltage sources. For instance such models are popular for simulations with the computer code PSPICE.

The paper compares the different varistor models and shows the advantages and limitations. It seems that none of these models is able to reproduce the voltage-current behavior of the MOV for all applications correctly.

VII-19 "*Experimental study for the application of zinc oxide type class I SPD*", M. Shiozaki, S. Shiga, K. Otsuki, Y. Shimojima

The intention of the paper is to present the abilities of the newly installed high-current generator. The elements and the circuit of the generator can be changed to produce impulse currents of 8/20 µs and 4/10 µs waveform. Using a crowbar switch it is also possible to produce the standardized 10/350 µs impulse current up to 100 kA. With these current waveforms the energy coordination on class I and class II SPD and the current withstand capability of zinc oxide disc are investigated.

VII-20 "*Discharge capability and residual voltage of class I and class II SPDs*", J. Schimanski, H. Heckler, M. Wetter, K. Scheibe

The paper discusses the residual voltage characteristics of spark gaps and varistors exposed to surge voltages and surges currents. The comparison of spark-gab-based class I SPD and varistor-based class I SPD shows that the residual voltage of class I spark gap is less stressing for devices to be protected.

The authors conclude that varistor-based class I SPD only pretend to be an adequate protection against 10/350 µs surge currents. Varistor-based class I arrestors are not able to replace modern high-performance class I spark gaps which allow low residual voltages even with long-duration surge currents.

VII-21 "*Design of SPDs class I for low voltage electric systems, using combination of metal oxide varistors*", C. Avendano, H. Ibanez, H. Ortiz

The paper introduces a method to design class I varistor-based SPD. This type of SPD consists of several varistors installed in parallel. For the combination of the varistors, a formula is developed taking into account the tolerances of the individual varistors. The analysis is supplemented by calculations with the computer code PSPICE.

The tolerances and the non-linear voltage-current characteristic of the varistors prevent the homogeneous current share to the individual varistors. Therefore, the varistor-based class I SPD require varistors with very low tolerances. The authors conclude that the tolerance should be less than 2 %.

VII-22 "*Malfunction area map of telecommunication systems due to lightning surge*", N. Aoki, T. Tominaga, K. Tajima, H. Yamane

The malfunctions of telecommunication systems caused by lightning are investigated at certain locations in Japan. Most of the malfunctions occurred during summertime where the lightning activity is highest. Based on measurements a mathematical model is developed to predict the probability of such malfunctions.

VII-23 "*Coordinating surge protection devices with metal-oxide varistors at direct lightning stroke. Application note*", V. Murko, A. Stagoj, N. Suljanovic, A. Mujcic

Objective of the paper is the coordination of cascaded SPD. The computer models are based on the PSPICE computer code simulating different scenarios of cascaded SPD with surge currents of 8/20 µs and 10/350 µs waveform. The calculations are proved with experimental tests in laboratory.

The authors suggest that the coordination of SPD should be tested with both impulse currents, the 8/20 µs and 10/350 µs surge currents.

VII-24 "*Proposal on graphical analytical method how to estimate energy coordination of multistage surge protective device*", H. Kijima, K. Taktani, R. Tobisawa

The paper may be suitable to open the eyes for the aspects which need to be taken into account when multistage SPDs for surge protection have to be applied. Computer simulation of the behavior of the current distribution and energy dissipation of non – linear devices under current impulse conditions demands excellent knowledge on what is going on.

The presented graphical method is more transparent but it might be very time consuming too.

The report does not address the required power for the decoupling series resistor, which is suggested in the paper. For some application such energy losses and voltage drop may not be accepted.