APPLICATION OF LINE SURGE ARRESTERS IN POWER DISTRIBUTION AND TRANSMISSION SYSTEMS

Colloquium CAVTAT, CROATIA 25-29 MAY. 2008

General Report – Ivo Uglesic

INTRODUCTION

The International CIGRÉ Colloquium 2008 in Cavtat was organised by the Study Committees C4 (System Technical Performance) in cooperation with the Croatian National Committee and SCs A3 (High Voltage Equipment) and B2 (Overhead Lines). The goal of the Colloquium was to examine the various aspects of line arrester application (LSA) from system aspects to apparatus aspects.
Ten main topics were covered in the four Colloquium sessions. The Colloquium extended over four days, organised in half-day sessions. Participants from manufacturers and utilities, along with those from universities and research centres, gave their presentations and took part in discussions. Three invited lectures were held, 38 papers were submitted and the Colloquium was attended by 90 participants from 24 countries.

OPENING CEREMONY

In the opening ceremony, which was held on Monday, Ivo Uglesic the Colloquium Chairman, welcomed everyone and expresses his honour to have so many international experts at the Colloquium. This was followed by some further welcoming comments from Alain Xemard, Colloquium Co-Chairman. The participants were then welcomed by Dubravko Sabolic, the Director of the Croatian Operator of the Transmission System, which hosted the Colloquium.
Then followed three invited lectures which set the scene for the technical discussions that were conducted in later sessions. The first lecture was presented by Masaru Ishii from the University of Tokyo. The presentation entitled *"Circuit Model for Evaluation of Performance of Line Surge Arresters"* was very informative and gave many details on transmission tower modelling (TEM/non-TEM electromagnetic field, numerical electromagnetic analysis), lightning channel modelling (investigation with electromagnetic model, data from a real lightning channel), comparison with actual lightning data and examples of LSA installation strategy. A transmission line is a 3-D structure, and its rigorous analysis is only possible by numerical electromagnetic analysis due to its non-TEM field. However in the time range in which the arrester rating is discussed, an equivalent multiphase circuit modelled by EMTP is practical enough to investigate the performance of LSA. The parameters of a lightning channel have only a limited influence on the performance of LSA. Comparison with observed data associated with actual lightning confirms the validity of the described circuit model.
The second lecture entitled *"Issues in Long-term Reliability of Transmission Line Surge"* was given by W. A. Chisholm from Kinectrics/University of Québec. The presentation covered electrical, mechanical and environmental issues of line surge arresters. The examples of typical applications of line surge arresters in Canada were demonstrated. It was concluded that mechanical effects dominate electrical effects in terms of LSA life cycle costs. The gapped LSA may offer benefits in areas of ice and snow. The value of LSA investment is significantly reduced by the rates of component degradation: broken lead wires (fatigue, vibration, corrosion, restraint of conductor motion), broken hardware (excessive force during galloping), insulation defects and moisture entry and insufficient energy capability – change in V-I curve.
The third presentation was presented by Salih Sadović from the University of Sarajevo. A presentation entitled *"Different Line Surge Arrester Applications"* covered following issues: line lightning performance improvement; multi-circuit outage reduction; compact lines; security of the population; line uprating, switching surge control; different voltage level lines; replacement of ground wires; overvoltage control in the vicinity of HV and EHV substations; live line working.

SUMMARIES OF PRESENTED AND DISCUSSED PAPERS

Session I
Topic 1: Interaction between LSAs and electrical system

Paper 5: Decreasing Backflashover Numbers on Medium Voltage Overhead Lines Located in Regions with High Soil Resistivity (D. Mišković, I. Uglešić)
The possibility of decreasing backflashover on medium voltage overhead lines located in regions with high soil resistivity is presented. The practicability of using chemical rods for improving grounding resistance and an existing experience in using chemical rods as part of the grounding system is reported. The techno–economic analysis of using chemical rods and metal oxide surge arresters has been conducted, with determining justifiability criteria of using them. In the conclusion, comparison with existing experience is made and recommendations for the future use are suggested.

Paper 13: Current Standard Practice in EHV/HV Italian Substation Design: Oriented Modelling and Simulation of Lightning Protection System for Improving Design Criteria (F. Delfino, G. B. Denegri, P. Girdinio, M. Invernizzi, R. Procopio, M. Rossi, D. Falorni, A. Freddo, V. Iuliani, G. Toschi)
The protection of power substations towards the effects of lightning overvoltages is discussed. A simulation model of an EHV/HV Italian standard substation is setup in order to re-discuss the current design practice, in terms of type and location, for the relevant protection devices. The developed model and simulations have been devoted to investigate the effectiveness of the protection provided by the combined use of surge arresters and spark gaps towards lightning disturbances. Current utilisation of metal oxide surge arresters in the Italian transmission grid is basically limited to autotransformer protection, as close as possible to the machine windings. The adoption of additional LSAs at line end terminals is suggested, proposing comparison of different design solutions. Effects of present installation of spark gaps at line terminals are criticized with regard to LSAs, also promising for their significant cost reduction in the last decade.

Paper 16: The Possibility of Insulation Level Reduction on 110 kV Overhead Line with Built-in Post Insulators Using Line Surge Arresters (S. Vižintin, I. Kobal, M. Bečan)
A possible suppression of overvoltages could enable a decrease of the demanded insulating strength and corresponding distances. This is of the utmost importance for lines with post insulators, since shorter insulators could be used. The possibility of reducing lightning overvoltages by using LSAs installed in parallel to the insulators was investigated. A computational model was implemented first and then the physical model of wooden pole with composite line post insulators was built for testing in high-voltage laboratory. Power frequency and impulse tests were performed on insulators and between phase conductors in dry and wet conditions. Besides standard tests also non-standard impulse shape tests were carried out to obtain withstand voltages for different arching distances. The conclusion was reached that - speaking in terms of lightning overvoltages - it is possible to use insulators for the insulation level U_m = 72,5 kV (140/325 kV), if LSAs in all three phases are installed. Further analyses are needed to verify the conclusion reached.

Paper 20: Case Study for Application of Transmission Line Arresters at Croatian 400 kV Line Along the Adriatic Coast Mountains (L. Klingbeil, Z. Baus, S. Nikolovski, I. Ivanković)
Line arresters can improve system reliability by reducing the multi-phase and multi-circuit line outage rates. The majority of line arresters presently used are designed for improving the lightning performance of transmission lines and reducing the line-to ground outage rate. The small case study on how to approach a typical LSA-project has been presented. The object of the research was the 400 kV transmission line from substation Melina to Konjsko in Croatia, the so-called southern power interconnection. It is situated in the mountains, not far from the Adriatic coastline, so there are indications for partly insufficient grounding conditions as well as locally increased values of ground flash density. This transmission line is very important for the power supply of a whole region and therefore obviously in the focus for possible enhancement of its reliability.

Paper 33: Line arresters on distribution lines in hilly regions (A. Sekso, I. Sekso, J. Trbus)
A brief historical review of applications of line arresters in the world was given. One of the first international conference (CIGRE-IEEE Workshop) on Line Arresters (LA) was held in Rio de Janeiro, Brazil in 1996, but the first world's summary on application of LA's on HV lines was presented on CIGRE SC 33 Conference in Zagreb, Croatia in 1998. A variety of texts on this subject have appeared in many books, studies and application guides,

including documents of CIGRE SC C4 Working Group C4.301. The lightning protection of distribution overhead lines in hilly regions in northern Croatia was analysed. A specific number of direct hits to the line sections is calculated using the CIGRE methodology which gives the basis for the choice of locations and parameters for the line arresters which will be installed in the network.

Topic 3: Different applications of LSA

Paper 12: Line Surge Arresters Applications on the Compact Transmission Lines (S. Sadović, D. Lepley, E. Brocard, J. M. George)
The application of line surge arresters on compact transmission lines is presented. Single and double circuit compact transmission lines are considered. Line lightning performance is computed using Sigma slp simulation software. Different line surge arrester installation configurations are considered. Line lightning performance is computed for different tower footing resistance. Influence of the tower footing resistance on the double circuit outage rate is presented. Line performance before and after line surge arrester installation are compared. Line lightning performance of the unshielded line with line surge arresters is compared with the performance of the shielded line without line surge arresters. For double circuit shielded compact lines, double circuit outage rate is computed.

Paper 19: Reduction of the visual impact of overhead transmission line systems through utilization of line surge arresters as lightning protection (T. K. Soerensen, J. Holboell)
The main reason for the increasing public resistance to overhead transmission line systems in Denmark is the impact on the environment with emphasis on the visual aspect. The omission of shield wires combined with installation of a suitable number of line surge arresters is investigated as a possible alternative to transmission lines equipped with shielding wires, thereby reducing tower height, allowing more compact designs of towers, thus minimizing the visual environment impact of the lines. The use of line surge arresters as lightning protection on the line has been investigated by transient simulations on a 400 kV line with either shield wires or line surge arresters. It has been shown that line surge arresters can be used instead of shield wires; however this has consequences with respect to the performance of the line and the required protection level in substations. The use of line surge arresters gives the possibility to decrease the height of towers, thereby improving the visual impression of the overhead line. The results are important in particular with respect to the possible future tower top geometries.

Paper 22: Line Surge Arresters Applications on the Multi Circuit Overhead Lines (S. Sadović, T. Sadović)
The application of line surge arresters (LSA) on the different voltage level multi circuit overhead lines is presented. Double circuit shielded compact line with and without distribution circuit on the same tower is analysed. Distribution circuit has lower insulation level, meaning that almost all flashovers will happen on that circuit. Flashovers on the distribution circuit diverts a fraction of the lightning current along its phase conductors, improving at the same time coupling between distribution and transmission circuits. All software simulations are performed using Sigma slp software package. A short description of the modelling for multi circuit flashover rate determination is given. In order to prevent flashovers on the distribution circuit LSA are installed on this circuit only. The improvement in the transmission circuit lightning performance is similar to that obtained without LSA. LSA installed on the distribution circuit are much cheaper than transmission LSA.

Topic 10: LSA monitoring

Paper 11: Real-Time Remote Monitoring of Line Surge Arresters (M. Muhr, T. Sadović)
The development of a new arrester monitoring system is presented and its main features are shown. In order to determine arrester energy duty in service it is important to know the frequency of the arrester operation and the shapes of the impulse currents discharged through the arrester, since energy is related to the discharge current shape. Monitoring of the current shape gives valuable information on the energy discharged through the arrester, as well as the frequency of its operation. It can help to determine lightning stroke parameters such as the discharge was due to a shielding failure or a backflashover. This data is transmitted to a distant server in order to discuss the real stresses imposed on the arrester. This new monitoring system is presented from the hardware and software point of view. Important points to consider regarding the data acquisition and triggering are also discussed.

Paper 38: First Experience in Monitoring of Line Surge Arresters Installed on 110 kV Transmission Line Ston – Komolac in Croatia (S. Bojić, I. Dolić, A. Sekso, J. Radovanović, D. Škarica)
First results and experience in real time monitoring of LSAs installed on 110 kV transmission line Ston – Komolac in southern part of Croatia are presented. The line is situated in a region with high soil resistance and exposed to a high level of lightning activity. Due to the great number of annual outages, it was decided to install 110 kV gapless, IEC Class II line arresters. Also, to improve analysis of expected results the 61 line arresters were equipped with Excount-II type of monitoring sensors. First results in application of LSA are showing significant reduction of line outages with relatively strong registered activity of monitored line arresters. Although the analysed time period of eight months with LSA application is too short to allow strong final conclusions, the obtained first experience will be very helpful in assessment of further LSAs application in Croatian transmission network.

Session II

Topics 4 and 8 : LSA designs (gapless, gap-type); Installation practice of LSAs /mechanical aspects

Paper 6: Pilot Study on the Use of Gapless Transmission Line Arresters (TLA) as an Alternative to Gapped TLA in TNB Transmission System (Iryani M. Rawi, M. Pauzi Yahaya)
The Transmission Division of Tenaga National Berhad (TNB), Malaysia, manages and operates the 132kV, 275kV and 500 kV transmission systems that form an integrated network known as the National Grid. TNB's National Grid system spans the whole of Peninsular Malaysia. It represents the backbone of the electricity industry and the Transmission Division is responsible for the safe, adequate, reliable and economical operation of the grid system in conformance to the Malaysian Grid Code. TNB Transmission Division together with TNB Research Sdn. Bhd. has conducted a pilot study on the use of gapless LSAs as an alternative to gapped LSAs. Gapped LSA has been used in TNB Transmission System since 1995 and it is proven that the LSA has improved the overhead lines performance by decreasing the number of lightning outages on the lines. However, due to high cost of the Gapped Type LSA, TNB has explored on the alternative and proposed Gapless Type LSA. Three manufacturers have participated in the pilot project and 148 units of Gapless LSA were installed on a 12 km 132kV lines from Balakong to Serdang Substation. The arresters were monitored for almost a year and the successful pilot study has given valuable experiences and knowledge to TNB Engineers on the selection of lightning protection equipment for overhead line system and enhancing the technical specification for the 132kV arresters.

Paper 27: Design Features and Performance of Gapped Transmission Line Arresters (Makoto Yamaguchi, Hiroki Kajino, Hiroki Saito, Shinji Ishibe)
It is well known that LSAs have a great impact on the improvement of the power quality against lightning and are categorised into gapped and gapless type, the advantages and disadvantages of which are often compared. Gapped LSAs are the mainstream in Japan because they are compact and make it pšossible to continue the power supply without disconnectors in case of LSA failures owing to external air gaps. On the other hand, they are required to have the suitable flashover performance against the withstand voltage of the insulators and the follow-current interrupting performance, which are not required for gapless LSAs. The advantages of gapped LSAs and their performance on protecting insulators and interrupting follow-current have been reported.

Paper 1: Installation of LSA on a 400 kV Double-circuit Line in Russia
(L. Stenström, J. Taylor , N.T. Osiptsov, F. Persson)
Necessary information for making decisions regarding installation of LSA in a double circuit 400 kV line running between substation Vyborgskaya in Russia and substations Yullikyalya and Kyumi in Finland are discussed. Lightning discharge energy requirements for LSA have been calculated and the risk for single- and double-circuit lightning related faults with and without arresters has been estimated as a function of tower footing resistance. The decisions regarding the ultimate number and location of arresters along the line are described and the type and technical data of the arresters selected are given. Furthermore the measuring system used to monitor lightning surges through the arresters is presented as well as the experience from the installation and the 3 years of service.

Paper 9: Application of Gapless Surge Arresters for Lightning Protection of Transmission and Distribution Lines (M. G. Comber)
The use of arresters for preventing external flashover of distribution and transmission line insulators due to lightning surges is possible due to two key developments: (1) availability of arresters in lightweight polymeric housings, making installations on lines much more manageable than previously possible with heavy porcelain-

housed arresters; (2) much greater emphasis on reliability of electrical service, where in today's world service interruptions are far less tolerated than in decades past. The presentation was focused on the use of direct-connected gapless surge arresters in a wide variety of physical and electrical installations, including both retrofit and new line applications. Issues pertaining to installation and operation were discussed and examples of how these issues had been addressed by product design features were presented.

Topics 6 and 7 : Simulation / selection tools; LSA Selection

Paper 7: Evaluation of Energy Stress on Line Arresters (I. Uglešić, V. Milardić, B. Filipović-Grčić, A. Tokić)
Determination of optimal LSAs number, location and rating is important for the improvement of the reliability and availability of a transmission system. In selection of the LSA special attention should be paid to their energy stress which depends on complex interactions between the arrester locations, grounding, shielding and the local lightning environment. LSAs experience higher energy stress compared to station arresters. The calculations of energy stresses were carried out for a double-circuit 220 kV line with a single shielding wire. Parametric studies were conducted in which arrester discharge energy was a function of: time to half value of stroke current, number of towers with arresters, footing resistance, span length and angle of power frequency voltage. Arrester energy stress is analyzed in case of stroke to tower and shielding failure. From the conducted analysis it can be concluded that the energy stress on LSAs is lower for shorter span lengths. Tower footing resistance has only minor effect on the discharge energy. Arrester discharge energy strongly depends on time to half of the stroke current, number of towers with installed arresters and angle of power frequency voltage.

Paper 2: Application of ANN and Genetic Algorithm for Evaluation the Optimum Location of Arresters on Power Networks due to the Switching Overvoltages
(Reza Shariatinasab, Behrooz Vahidi, Seyed Hossein Hosseinian, Akihiro Ametani)
Switching surges are of primary importance in insulation co-ordination of EHV lines, as well as in designing insulation of apparatus. The magnitude and shape of the switching overvoltages vary with the system parameters, network configuration and the point-on-wave where the switching operation takes place. An artificial neural network (ANN) based approach is presented to estimate the peak value of overvoltages and the global risk of failure generated by switching transients during line energizing or re-energizing in different nodes of a power network. Then a genetic algorithm (GA) based method is developed to find the best position of surge arresters on power networks so as to minimize the global risk of the network.

Paper 15: Modeling of overhead transmission lines with line surge arresters for lightning overvoltages (M. Jaroszewski, J. Pospieszna, P. Ranachowski, F. Rejmund)
The lightning overvoltages could lead to failure of the devices connected to the transmission line. A fundamental constraint on the reliability of an electrical power transmission system is the effectiveness of its protective system. The role of the protective system is to safeguard system components from the effects of electrical overstress. Surge arresters are an important means of lightning protection in distribution systems. Therefore, it is necessary to analyse the influence of such overvoltages in order to apply the line surge arrester for improving the reliability of transmission line system. The method used to analyze the increase in voltage due to lightning was by using the ATP/EMTP software. The improvement of lightning performance of a transmission line after installing line surge arresters is analysed.

Session III

Topic 2: Line performance improvement in terms of continuity of service

Paper 3: Reduction of the double-circuit flashovers on a 400 kV overhead line (A. Xemard, J. Michaud, F. Maciela, T. Lassaigne, F. Sauvegrain, P. Auriol, J. G. Roumy, O. Saad, Q. Bui Van, A. Dutil)
Double circuit flashovers may cause very severe system disturbances when they occur on some critical double-circuit lines of an electrical network. Line arresters offer an efficient solution to protect these specific lines against double circuit outages due to lightning. The study was conducted on a double-circuit 400-kV line. The protection was provided by line arresters against double circuit outages due to lightning. The efficiency of several configurations of line arresters have been compared. For that purpose, the double-circuit lightning flashover rates of the line with and without line arresters has been calculated using a newly developed software which includes a three-dimensional electro-geometric model and is able to take into account the random nature of lightning. This

software automatically launches EMTP-RV (restructured version of EMTP) for analyzing fast front overvoltages impressed on line insulation. The energy stressing the line arresters will also be calculated in order to evaluate the risk of failure of the line arresters due to excess energy absorption. Furthermore, the effects of several other parameters such as the tower footing resistances, the lightning withstand voltages of insulator strings as well as the protective levels of line arresters have also been investigated.

Paper 4: Line Surge Arresters Potential Applications on Hydro-Québec TransÉnergie Transmission System (P. Prud'homme, A. Dutil)

Hydro-Québec transmission lines are often located in regions having a high soil resistivity. Many of them are double circuit lines and operating statistics show that almost 50 % of flashovers initiated by lightning impact both circuits. Such outages may have a significant impact if the line provides power to an isolated region. The province of Québec is also often affected by severe ice storms. For a line exposed to freezing rain, the amount of ice build-up on the shield wires represents a significant mechanical load on the towers and is often the source of short-circuits. The ice load makes the shield wires come in contact with phase conductors. Removing those shield wires could increase the capability of lines to cope with ice storms and reduce the number of short-circuits caused by excessive accumulation of ice. However, this can only be done if lightning flashovers can be mitigated by other means. Line surge arresters are an option to solve the problems related to these two aspects. Installed by thousands over the world, for more than 10 years, those arresters have proved a high degree of reliability and can now be considered as a mature technology for application on Hydro-Québec transmission lines. Hydro-Québec is considering installing some of them on its transmission system over the next few years and intends to perform special laboratory testing, particularly under icing conditions, before proceeding.

Paper 14: Surveillance of Lightning Strokes Near Transmission Lines (Andreas Wuerl, Hans D. Betz, Kersten Schmidt, Wolf P. Oettinger)

Lightning represents major problems for overhead distribution and transmission lines because it may cause outages and power quality disturbances. When advanced surge arresters and related measures can not prevent a suddenly arising line problem, precise information about occurrence of lightning in specified areas proves very helpful for the identification of possible sources of the problem. In cooperation between the University of Munich and nowcast GmbH a European network for lightning detection (LINET) has been set up starting in 2006 and by now it comprises more than 80 sensor sites in 16 countries and allows high quality monitoring of thunderstorms in large areas. The most outstanding three main features of the LINET system are high detection efficiency, excellent location accuracy, and the ability to discriminate between cloud-ground strokes and inter-cloud events by means of a newly developed 3D-technique.

Paper 35: Lightning Protection of Electric Power Overhead Distribution Lines by Long-Flashover Arresters in Russia (G. V. Podporkin, E. S. Kalakutsky, V. E. Pilshikov, A. D. Sivaev)

A method for lightning protection of power overhead distribution lines by long flashover arresters (LFAs) is presented. Even large lightning currents do not pose any threat to these arresters because the discharge develops in the air and not inside the device. LFAs, which are based on the creeping discharge effect, increase the lightning flashover length significantly and thus eliminate Power Arc Follow (PAF). To protect a line against induced overvoltages, a single arrester should be mounted on a pole. To protect a line against direct lightning strokes, LFA-M arresters should be mounted in parallel with each insulator. For covered-conductor overhead lines (CCL) using conductors with three-layer insulation a new lightning protection approach is suggested, involving use of antenna-type long flashover arresters whose essential component is the protected conductor itself. LFA's main applications and field experience have been presented.

Topics 2 and 5: Line performance improvement in terms of continuity of service; Apparatus aspects of LSA, standardization, testing

Paper 10: Basic Study on Deterioration of Transmission Line Arresters (N. Yamada, M. Nakagami)

Lightning current is thought as main factor causing deterioration of gaped line arrester. Therefore, line arresters which were applied multiple lightning current up to maximum discharging current were examined in terms of following items: reference voltage, residual voltage, leakage current, capacitance, and insulation resistance. The measurement of these characteristics was performed after tested arresters were cooled down to ambient temperature. From these results, the deterioration factors and tendencies of line arresters are revealed. The study indicates that the inspection method applied to a gapless arrester can be used. However, there are several issues to be solved such as

securing electric power supply on the tower top and method to evaluate deterioration variations. Therefore, further study is necessary to apply this method for effective maintenance work.

Paper 25: Performance of Parallel Surge Arresters (A. Haddad, H. Griffiths, M. Osborne)

The operation of parallel surge arresters can improve energy absorption capability if the arresters are similar and are installed close to each other. However, it has been reported that any small difference in the individual V-I characteristics can lead to unbalance in current sharing. When the arresters are installed some distance away from each other, travelling wave effects can modify the effectiveness of parallel arresters for surge overvoltage protection. Such a situation occurs in practice with large substations or short underground cable connections. Various studies have shown that a requirement for two-arrester protection is closely dependent upon the type and length of cable used. In the case of overhead lines, the distances are much bigger and the main objective of line arresters is to reduce the flashover rates due to surge overvoltages. This is especially relevant to lines located in regions of high lightning activity, lines with compact/uprated design where the phase-to-phase and phase-to-earth air clearances are reduced. The study of parallel arresters considering the separation distance and their application to overhead lines has been presented. Various scenarios of overhead line configurations were considered and the overvoltage levels were calculated for each case. Assessment of flashover performance is also conducted for a number of conditions. A number of calculation techniques were used and compared.

Paper 26: Testing Requirements and Actual IEC Work on Distribution and Transmission Line Arresters (V.Hinrichsen)

Using line arresters is predominantly an application and dimensioning issue and less a problem of special arrester requirements and testing. As the existing arrester standards are quite mature and introduction of any additional test requirements should be well considered, only few changes or add-ons to existing standards are really necessary. For gapless line arresters most of the necessary standardization work has been done: long time aging tests on polymeric housings, mechanical test procedures (still emerging), a lightning impulse discharge test, and a mandatory short-circuit test are now available. Further improvement could be achieved by increased knowledge about some important aspects of energy handling capability, as energy injection into line arresters is quite different from a line discharge, and by some improved mechanical test procedures. Both of these subjects are under consideration within Cigré, IEC and IEEE, and in a couple of years the standards on gapless (line) arresters should be basically complete. For externally gapped line arresters (EGLA) international standardization is under way. Additional requirements, apart from those on standard arresters, are the coordination of sparkover and flashover voltages, the insulation withstand of an EGLA with failed arrester body, the demonstration of follow current interruption capability, and some additional features of shortcircuit and mechanical performance. However, also for this type of arrester a reasonable standard should be available in a few years. Application guides, both from IEC and IEEE, will cover LA applications in their next revisions, and Cigré will also publish an extensive brochure.

Session IV

Topics 5 and 9:Apparatus aspects of LSA, standardization, testing; Field experience with LSAs / reliability

Paper 29:* Specific *Consideration on Follow Current Interruption and Anti-pollution Performance of External Series Gapped Type Line Surge Arrester (EGLA)
(Yoshihiro Ishizaki, Kenji Tsuge, Misao Kobayashi, Kunikazu Izumi)

External series gapped line arresters (EGLAs), propagated in Japan for effective lightning protection of overhead transmission lines, have unique requirements originating from the external series gap. They are the coordination of sparkover voltage with the insulator assembly to be protected, withstand voltage for switching surge/ TOV, and follow current interruption. The last requirement needs to take specific considerations in evaluating the performance, since antipollution performance of EGLAs, of which arrester bodies are usually isolated from power line, has to be covered. Moreover the arrester housings for EGLAs are made of polymeric material such as silicone rubber, hence the test procedure to simulate wetted and polluted situations on the test sample needs to pay particular attention to proper evaluation. The above requirement has been discussed and a test procedure has been introduced to evaluate follow current interruption performance properly, based on the technology over more than twenty years of experience with huge numbers of EGLAs in 22 kV to 500 kV systems in Japan.

Paper 34: Brazilian production development of class 2 polymeric surge arresters for transmission line application (TLA)
(A. A. Dellallibera, A. D. Andrade, A. C. Guará Bezerra, J. V. P. Duarte, P. M. B. Góis, R. L. Markiewicz)
Lightning performance improvement of transmission lines located in areas with high lightning discharge density and high soil resistivity has had unsatisfactory results through the use of traditional measures. CEMIG has studied and tested improvement measures in problematic transmission lines, always through the use of imported LSAs, due to the lack of Brazilian manufacturers for this kind of arrester. From technical, operational and maintenance points of view, the results have been highly successful in those studies. The actual improvement results after those experiences are presented in this work. Despite the success in this application, the high costs of the arresters and issues in the acquisition process of imported items have made the large-scale applications on CEMIG lines practically impossible, which resulted in the decision from CEMIG's engineers to create a group of Brazilian LSA development and manufacturing. In the field application, mechanical solutions were developed on the LSA prototypes in order to solve problems experienced in the past due to vibration and wind effects. During the development phase, CEMIG has installed Balestro LSA prototypes on a problematic 34.5 kV line. After the final approval was given, another 81 units of 34.5 kV LSAs were installed, as well as 34 units on 69 kV lines and 265 units on 138 kV lines. The application on 138 kV systems has been more successful than in lower voltages, due to a more effective technical/economical balance.

Paper 17: Experience of Tyco & Antamina in the Lightning Performance and Reliability Improvement of 220 kV Transmission Lines in Peru (Jorge Luiz De Franco, Craig Sutton, Carlos Riva, Jorge Tuesta Rivera, Jose Francisco Montes, Wilson Alonzo, Mussolini Tarazona, Manuel Contreras)
The Antamina Mine operations began in late 2001, with an estimated mine life of more than 20 years. The deposit is one of the largest copper-zinc ore bodies in the world. Antamina Mine is electrically connected to five 220 kV transmission lines located in regions with isokeraunic levels from 15 to 90 thunderstorm days per year. In the period from 2002 to 2006, 80 non-scheduled outages due to lightning which have affected the process productive have been observed in these lines. Antamina also has a 23 kV overhead shielded distribution ring network in which outages due to lightning have also been observed. From January 2006 till June 2007, approximately 450 units of line arresters were installed along the distribution network and 265 gapless LSAs were installed along the sections of the two 220 kV transmission lines with poorer lightning performance. From October 2006 on, only one outage due to lightning was recorded in these two lines, proving the effectiveness of this protection system. Methods to select the arresters characteristics and to define the quantity and the optimized arresters location along the lines aren presented. Field experience obtained in these first two years and the line performance / reliability of the system after the LSA application in comparison with the performance before the arresters' installation are presented and discussed.

Paper 18: Improvement of the transmission and sub□transmission overhead lines lightning performance using line arresters – Experience in Brazil (Jorge Luiz De Franco, José Pissolato Filho)
Lightning has been reported as the major cause of non-scheduled outages that occur in Brazil's power system, being responsible for approximately 50 – 70% of the outages verified in overhead lines, with rated voltages up to 230 kV and creating many issues for power supply utilities and consumers. Brazil is a country with about 50 - 70 million lightning outages a year. With this considerable amount of lightning-caused disturbances, the resulting damages caused to the electric power systems are high so that the costs of losses and repairs exceed an annual value of 350 million dollars. In Brazil, the first application of LSAs was in the middle of the nineties and from this time on more than 3,000 units of gapless line arresters were installed on overhead lines from 34.5 kV up to 230 kV. The analysis and evaluation of overhead lines lightning performance before and after the line arresters installation have shown a good effectiveness, with average indexes for the improvement higher than 70%. The information about the Brazilian experience in the application of LSAs is presented.

Topics 9: Field experience with LSAs / reliability

Paper 21: Lightning Performance Improvement of 123 kV Line Ston – Komolac by Use of Line Surge Arresters (M. Puharić, M. Mesić, M. Lovrić, J. Radovanović, S. Sadović)
Line surge arrester (LSA) application on the Ston – Komolac 123 kV line is presented. The 44 km long single circuit shielded transmission line operates in the region with a high lightning activity and high value of grounding resistance. It was decided to install LSAs for line lightning performance improvement. In order to optimise arrester installation configuration Sigma slp software simulations were performed. LSA are installed according to the results

of the software simulations. LSA are installed in summer 2007 (110 gapless, IEC-class II Line arresters). Sixty-one LSA are equipped with Excount – II monitoring sensors (monitoring arrester leakage current and peak of the impulse current). Based on the 8-month experience, LSA installation has improved line lightning performance. New line performance is close to the targeted one (improvement of 50 to 60 %).

Paper 23: Line Arrester Application on a 110 kV High Alpine Overhead Line to reduce Lightning-Caused Outages (T. Judendorfer, S. Pack, M. Muhr)

A number of possibilities for the reduction of lightning-caused outages is discussed. All considerations took the special geographical situation of 2300 meter above sea level, the grounding resistance of up to 1200 Ohm and the local lightning activity of more than 6 lightning strikes per km² and year into account (4 to 5 times higher than in other Austrian regions). To improve the line performance and to decrease the line outage rate, a number of practical measures were applied to the 110 kV line. In the past, the double three phase systems of the 110 kV overhead line was constructional converted into one active single three phase system with two additional earth wires. 18 surge arresters have been installed in a line section of 9 towers, located in a high alpine part and in an area of high lightning activity. Three years of field experiences have shown that the theoretical investigations and the practical measures led to a significant decrease of lightning caused outages. In the year 2007 a new project was started to evaluate a reconstruction of the line into the original double three phase system. New numerical calculation routines were made to apply line arresters at this important 110 kV system in an Austrian extreme mountain region. Based on this results, a new application of line arresters and the constructional change of the system is planned.

Paper 28: Lightning Protection of Overhead Transmission Lines with Surge Arresters - Development of Line Arresters and the Technology in Japan (Masaru Ishii, Hiroyuki Kado, Kazuhiko Shimoda, Kenji Tsuge, Katsuaki Komatsu, Makoto Yamaguchi, Hideto Watanabe, Takeshi Iwaida, Takehiko Akedani, Hirotoshi Kohno)

The externally gapped line arresters (EGLAs) have been developed in Japan more than twenty years ago and contributed to the significant improvement of lightning protection performance of overhead transmission lines. The lightning problems and the countermeasures for overhead transmission lines first is presented. The development of EGLA for transmission lines is described. The application experiences and a new technology development established up to now in Japan is presented. EGLA has been proven as one of the best solutions for lightning protection of overhead transmission lines through more than twenty years of experience with far more than 80,000 sets in service now in 22kV to 500kV systems in Japan. This technology is also expected to improve power supply quality against lightning stroke to overhead lines in many countries.

Paper 31: Application of line surge arrester on a 230 kV transmission line CEMIG's Experience (A. C. O. Rocha, L. V. Cunha, L. C. L. Cherghiglia, S. O. Moreira, D. C. Cunha)

The analysis has been carried out by CEMIG to improve the lightning performance of the 230 kV Guilman Amorim - Ipatinga 1 transmission line. This line is part of CEMIG 230 kV grid, which supplies important industrial consumers. A great amount of load loss due to severe short-circuits, involving more than one phase on this line, pointed out the necessity to put into practice some corrective actions to avoid these occurrences. The analysis took into account different solutions that could be implemented to achieve a better performance of the line, including the application of line surge arresters. Another important conclusion of this study emphasizes the necessity to perform an economic analysis, considering all the cost involved versus the financial gains, in order to choose the best solution to improve the transmission line performance.

CONCLUSIONS

The Colloquium covered many relevant issues on LSAs and provided the opportunity for all to discuss various aspects of LSA application. The ongoing improvement of surge arrester technology on the one side, and the requirement of higher reliability of much higher utilised transmission lines on the other, lead to an increasing use of line surge arresters for nearly all system voltage levels worldwide.
The main use of line surge arresters is to improve transmission line lightning performance or to avoid double circuit outages, but also other purposes for LSA installation have been reported:

- Reduction of required insulation level and line compaction
- Reduction of the visual impact of overhead transmission line systems
- Replacement of ground wires in order to increase the capability of lines to cope with ice storms
- Overvoltage control in the vicinity of HV substations
- Improvement of lightning performance of different voltage level lines (by the installation of the LSA on the lower level insulation circuits only)
- Line upgrading
- Security of the population
- Live line working

Experience has shown that the use of LSA for the improvement of line lightning performance is more efficient than conventional methods (installation of the unbalanced insulation of the double-circuit line, reducing tower footing resistance, etc.). Many line surge arresters are in service today and substantial service experience has been accumulated, which indicates that:

- The installation of line surge arresters have shown a good effectiveness in all reported cases
- Mechanical aspects of LSA installations have turned out to be a dominant root cause of in-service failures
- Only few cases of LSA failures caused by the inappropriate electrical features have been reported.

From a standardisation point of view the market is well prepared for making increasing use of LSA application. In preparation are:

- New standard IEC 60099-8, which will cover externally gapped line arresters (EGLA)
- Application guides, both from IEC and IEEE that will cover LSA applications in their next revisions
- The extensive brochure *Line Surge Arresters Application Guid*e being compiled by the CIGRÉ WG C4 301.

The important facts about LSA that can be expected in the future are:

- The LSA design concepts will be further developed and the application of LSA will grow
- Further development of computational models, procedures and computer programs will help to determine the optimal number, location and rating of LSAs in order to improve the reliability and availability of a transmission system
- Further development of monitoring systems for line arresters will enable their on-line monitoring and better control in service.