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A FULL-SCALE SYSTEM FOR LIGHTNING DATA ACQUISITION, WITH SPECIAL REFERENCE TO INDUCED VOLTAGES ON DISTRIBUTION LINES

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Abstract - Lightning is responsible for a great number of damages and outages on distribution lines. Although the overvoltages caused by direct lightning discharges may reach higher amplitudes, the voltages induced by discharges in the vicinity of the line usually represent a more serious problem due to their higher frequency of occurrence.
The importance of obtaining more field data motivated the development and implementation of a full-scale system for lightning data acquisition, with special reference to the lightning induced voltages. This paper describes the most important features of the system, which has been implemented at the University of São Paulo and put into operation at the end of the last summer season. The research aims at characterising the lightning induced voltages on lines with and without arresters. When lightning strikes in the vicinity of a non-conventional experimental line, designed and built specially for the purpose of this study, induced voltages waveforms are recorded simultaneously at different points along the line. In case lightning hits a 62.5 m tall tower built for the development of the study, 67 m far from the line, the stroke current is measured as well. The paper describes the pioneer methodology developed for the investigation and discusses some aspects related to the computer program that manages the lightning voltages and currents measuring systems. Some preliminary results obtained so far are also presented.

1. INTRODUCTION

In spite of the theoretical and experimental studies performed by various researchers since a long time concerning lightning induced voltages, strong divergences can still be observed between the existing theories, even in the simplest situation, as in the case when neutral and ground wires, transformers and surge arresters are not considered.

In [1] a novel method was developed, based on Rusck's theory [2], but involving such modifications as to allow not only the consideration of the effects of lightning strokes in metallic structures but also the effects of the channel length, of the extension and configuration of the line and of the presence of the upward leader. The comparison between the voltages calculated by the developed model and the experimental results obtained in Japan [3-5] confirmed the significative improvement in Rusck's model as a result of the introduction of the referred modifications.

Although the mathematical model developed in [1] has been validated by comparison with experimental results, an evaluation of its performance in other situations is important. It is worth to note that, due to the complexity of the phenomenon, such an evaluation is possible only if the parameters that affect significantly the induced voltages are known. The difficulty in obtaining the parameters values in those conditions is certainly one of the reasons for the existence, still now, of different theories. So, the limited number of available cases and the lack of knowledge of the parameters values, like the return stroke propagation velocity, the channel length and the occurrence of the upward leader in the Japanese studies have motivated the development of a reduced scale model that allowed for a much more extensive analysis of the phenomenon [6-9]. A time after, starting with the model proposed in [1], a new methodology was developed, which makes possible the calculation of induced voltages when lines are protected by ground wires and/or surge arresters, taking into account, also, the presence of transformers and a neutral grounded in various points. In [10] results are presented concerning the use of this new model for the case of induced voltages on overhead lines due to lightning strokes in nearby metallic structures.

The study here described will evaluate the effectiveness of surge arresters as protective devices against lightning. It is a innovatory work, because with the exception of the research conducted in [7] with a reduced scale model, there is no knowledge of any other experimental study, with the direct determination of the effect of surge arresters. So, besides the possibility of direct evaluation of the protection system effectiveness, the results obtained will allow the achievement of a comparative analysis of the measured induced voltages and the voltages calculated by the mathematical model developed in [10]. Those results will represent an important contribution to the state of the art of the knowledge of the phenomenon, considering the few existing field data with simultaneous records of induced voltages and lightning stroke currents.

2. METHODOLOGY

The proposed work intends to obtain simultaneous recordings of lightning stroke currents in a tower and the

corresponding voltages induced on two single phase distribution lines situated in the vicinity of the tower.
The tower, the lines and the measuring and data acquisition systems are located in the University of São Paulo campus. Figure 1 shows the relative position of each component of the whole system.

The tower is metallic and 62.5 m high (Figure 2). For the measurement of the stroke currents a shunt resistor Rs was installed at its base, so that the current will flow through the resistor and, then, will reach the grounding system, as indicated in Figure 3.

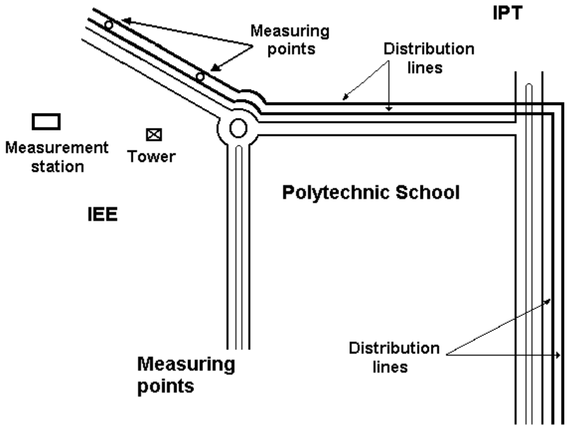

Figure 1 – General view of the system.
IPT : Technological Research Institute
IEE : Institute of Electrotechnics and Energy.

Figure 2 – 62.5 m high tower.

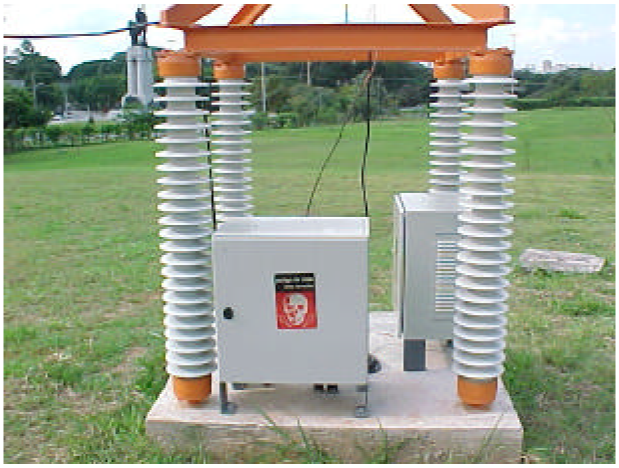

Figure 3 – Tower base.

The use of crossarms with a length greater than that of the conventional ones allowed the installation of two single phase lines supported by the same poles, as shown in Figure 4. Surge arresters were installed at strategic points of the line that is situated more distant of the tower, while the other one was kept without any protection.

In order to verify the effect of the separation distance between the two lines (i.e. the length of the crossarms) on the induced voltages, various simulations were performed, using the methodology described in [10]. The simulations have shown that the differences between the voltages induced in the line without protection and those induced in the same line not considering the presence of the line with arresters are not relevant. This indicates that the adopted distance of 6 m between conductors (related to the length of the crossarms) is enough in order to have a not significant interference of the surge arresters of the protected line on the voltages induced on the line without protection.

Figure 4 – Experimental distribution system with two single phase lines (with and without surge arresters).

In Figure 5 are indicated the real dimensions of the experimental distribution system, detailing the position of the surge arresters and the measuring points M1 and M2. At the two ends of the line without protection resistors were installed with a resistance value equal to the surge impedance of the lines (Zc), in order to attain matching and avoid reflections of the surge waves. On the other hand, the protected line has arresters at one end, while the other one is matched. One of the measuring points (M1) is near to one arrester (about 30 m), while the other (point M2) is located at a distance of 193 m from the closest one. So, the influence of the distance between surge arresters can be evaluated. It must be noticed that each point corresponds, in reality, to two measurements, one on the protected line and another on the unprotected one.

The system for the measurement of the induced voltages at each point is composed by two voltage dividers, two oscilloscopes, two mini modems, a battery and a battery charger. Figure 6 shows the measuring system at point M1. Before the measuring system was installed, tests were made in order to verify the eventual leakage in case of rain and the temperature rise inside the boxes that house the oscilloscopes and other equipment.

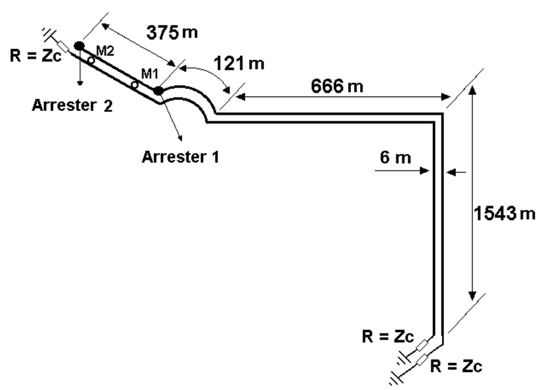

Figure 5 – Experimental system.
M1 and M2: Voltage measuring points.

Figure 6 – Measuring system for induced voltages.

At approximately 40 m from the tower a shielded cabin was constructed, where are located the equipment responsible for the switching of the voltage measuring system and the control of the data acquisition and storage. In the cabin there is also a time switch that controls the power supply of the four oscilloscopes situated on the experimental distribution system, two in each of the poles chosen for the measurement of the induced voltages (points M1 and M2 in Figures 5 and 7). The switching of the measuring system for lightning currents is made externally to the cabin.

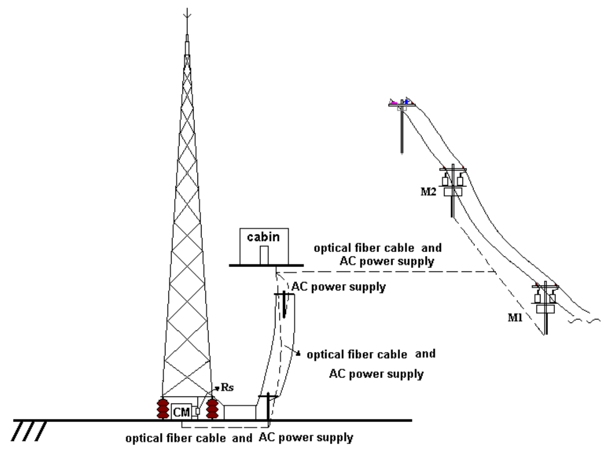

Figure 7 – Connection of the measuring points to the cabin.
MI: lightning current measuring point.
M1 and M2: voltage measuring points.

In order to avoid overvoltages that could damage the system, the oscilloscopes are powered by stationary batteries, so that they are electrically insulated from the AC network. Surge protective devices were installed at the supply input of the battery chargers and at the DC supply input of the oscilloscope that measures the lightning currents.

When a thunderstorm is imminent, the AC supply of the oscilloscopes is turned off from the battery chargers, closing the NC contacts of a relay and, in this way, connecting the DC supply of the oscilloscopes. A computer with a multiplex circuit is connected to the five oscilloscopes through mini modems. The electric signals stored in the oscilloscopes are transmitted by optical fiber cables to the computer in the cabin, being the mini modems responsible for the electrical/optical and optical/electrical signals conversion. The computer stores the records relative to the induced voltages on the two lines and the currents of the discharges that strike the tower. After a measuring period (at the end of the thunderstorm), the connection of the charger circuit with the AC supply is restored and, at the same time, the oscilloscopes are disconnected from the batteries.

3. THE TEKLINK V2.1 SOFTWARE

A specific software was developed (Teklink V2.1) [11], which controls the acquisition of the induced voltages and lightning currents waveforms stored in the oscilloscopes. After acquisition, the data are stored in a permanent database. The software was totally designed and developed with object-oriented characteristics, using Delphi 6.0 of Borland.

To complete the acquisition system, it was also designed a multiplex hardware that connects the oscilloscopes to a microcomputer and allows to control remotely eight oscilloscopes.

As the software was developed to be modular, it is possible to acquire electrical signals, to control their storage and to generate instantaneous graphs from the data of the database. Figure 8 presents the Block Diagram of the Teklink software.

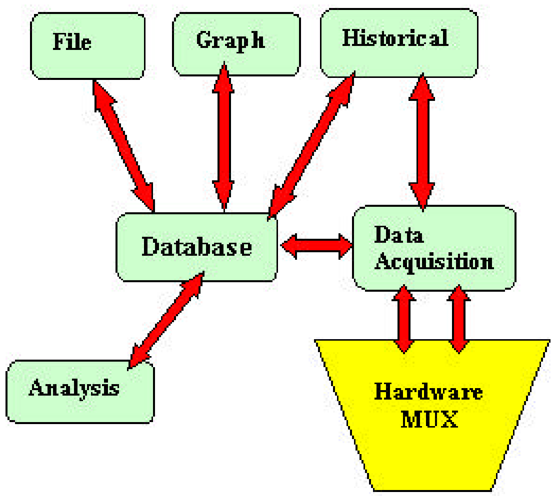

Figure 8 – The block diagram of the Teklink V2.1 software.

The Data Acquisition block is the most important part of the software, in which are defined the communication parameters, the interval between acquisitions, the acquisition mode (manual or automatic) and the sequence of oscilloscopes reading. Besides it is possible to check the communication link of all oscilloscopes. In its automatic set up, the software verifies at defined time intervals if new waveforms are stored in the oscilloscopes. When a new waveform occurs, the software begins a previously selected sequence of reading of all oscilloscopes, updating the database. After acquisition, the software enables the oscilloscopes for new measurements, repeating the cycle again. The measuring and acquisition systems were developed to work during all days of the whole thunderstorms season, including weekends, without any human intervention. It is also interesting to notice that the acquired waveforms are automatically stored in a definitive database, where they are identified by date, measuring point and time of their occurrence.

Finally, as an additional tool, the software also has a window that shows the historical of all operations done after a run. Making use of these historical, it is possible to know the status of all reading operations of the oscilloscopes. This tool allows for solving any problem that eventually happens in the system.

4 - PRELIMINARY RESULTS

Although the measurements have been started only at the end of the thunderstorms season (when the system was ready for operation), some induced voltages waveforms were stored.

Figure 9 and 10 show voltages waveforms on the two single phase distribution lines induced by the same lightning discharge at measuring points M1 and M2. In this case, the induced voltages amplitudes were not enough to reach the operating voltage of the ZnO surge arresters (class 10 kA, rated voltage 12 kV). Therefore, the measured voltages on the line protected with surge arresters were higher than the ones on the unprotected line. This is due to the reflection of the surges at the end of the line near to the measuring points.

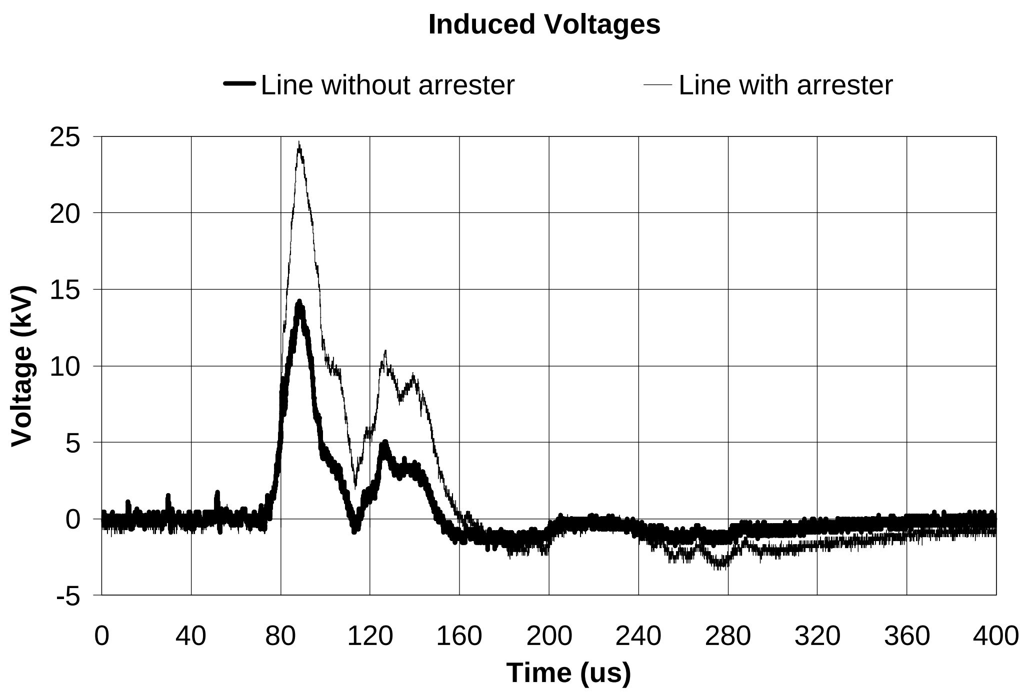

Figure 9 – Induced voltages at measuring point M1 - 17/03/2002 (4h 50’ 27” PM). Simultaneous to the waveforms presented in Figure 10.

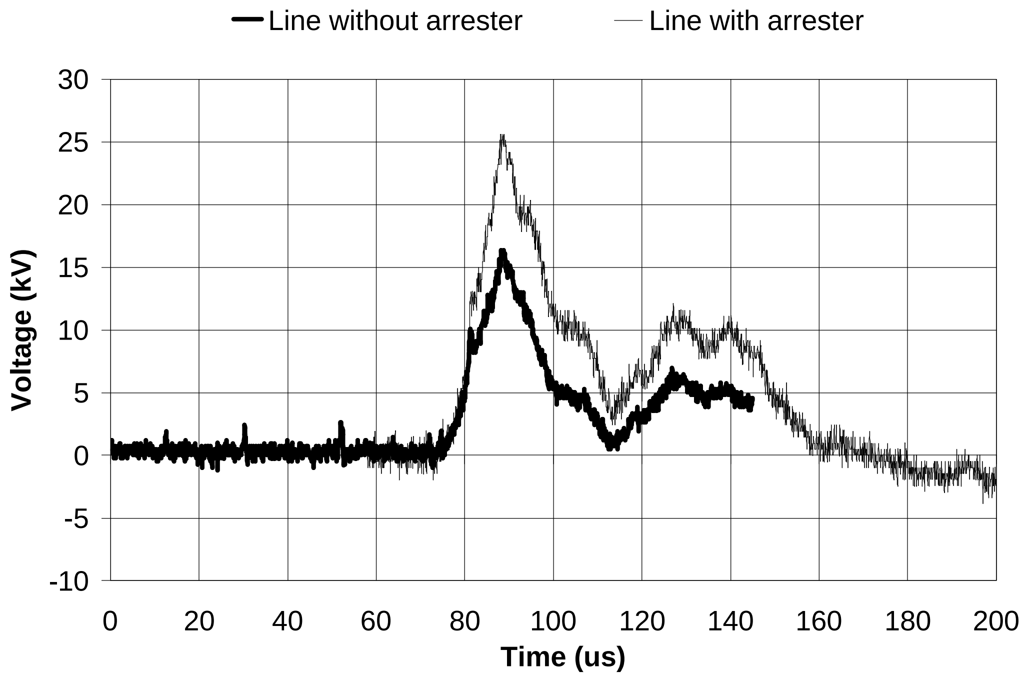

Figure 10 – Induced voltages at measuring point M1 - 17/03/2002 (4h 50' 27" PM). Simultaneous to the waveforms presented in Figure 9.

5 – CONCLUSIONS

Some general information about the measuring and acquisition data systems were presented in this paper. The whole system was developed to analyse the behaviour of induced voltages due to indirect lightning discharges and to evaluate the arresters effectiveness in the reduction of these voltages.

It is worth to emphasise the originality of the methodology used in this research, which will provide the direct evaluation of the arrester effectiveness on the mitigation of problems associated with overvoltages caused by lightning discharges in the vicinity of distribution lines.

Although the system was installed only at the end of the 2001/2002 thunderstorms season, several induced voltages waveforms were obtained and stored. In the next thunderstorms seasons, probably, a statistically relevant quantity of data will be registered. Making use of these data, it can be made a qualitative evaluation of the benefits provided by the presence of arresters on distribution lines considering the improvement of the line performance concerning indirect lightning discharges.

6 - ACKNOWLEDGMENT

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