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COMBINED CURRENT-POTENTIAL MEASURING METHOD FOR ANALYSIS OF LIGHTNING THREAT IN STRUCTURES EXPOSED TO DIRECT STRIKES

Renata MARKOWSKA*, Jarosław Michał WIATER**
remark@pb.edu.pl * ; jaroslawwiater@we.pb.edu.pl **
Bialystok Technical University

Summary: The paper presents an experimental approach on analysis of lightning threat and effects in objects or structures exposed to direct strikes. The presented method is based on a well known idea of simulation of lightning strike using a surge generator and a combination of two measuring approaches: measurements of surge currents and potentials. The final purpose is to develop better techniques for verification of numerical electromagnetic models and an effective approach for lightning protection of structures.

Keywords: direct lightning strikes, simulation of lightning strikes to structures, measurement methods.

1. Introduction

Effective protection of objects or structures against direct lightning strikes as well as electric and electronic systems and people inside these objects requires an analysis and estimation of lightning threat.

Evaluation of lightning electromagnetic pulse effects on various objects, systems as well as on living beings is a very complicated task. Different experimental and numerical methods have been used to do so [1]. However, none of them is actually capable to fully take into account all the phenomena that occur during natural lightning. Practically, a combination of two or more different methods has to be applied.

One of widely known experimental methods used to study lightning effects on structures and systems is a method of simulation of direct lightning strikes by injecting a current from a surge generator attached to the structure in concern [2-4]. During the simulated current flow through the structure, some measurements specific to a purpose of an experiment are carried out.

The method has serious technical limitations related to low current peak values and different current waveforms attainable in practice with regard to the natural lightning currents, as well as influence of the surge generator simulation circuit on the results [1]. It has been used mainly for verification of numerical electromagnetic models of structures exposed to lightning [1]. Using these models it is possible to numerically analyze the phenomena that occur during natural lightning to larger extent [5, 6].

Two different measuring approaches have been used so far by authors to provide such verifications. One of them was based on measurements of surge current flows [5, 7] and the other on potentials with respect to remote ground [6]. Generally, they were used in different types of objects.

In this work, these two techniques have been combined together. The final purpose was to make comparisons between these techniques and to develop some better approach for verification of numerical electromagnetic models. In consequence, this will help in developing of more effective measures for lightning protection of structures.

2. Basic approach

The experiment has been carried out in a medium size telecommunication object. The object is composed of a 50 m high radio-communication tower and a two-storey building located about 9 m from the tower.

In the experiment a relatively low energy surge generator UCS 500 was used. It is capable to produce:

- A surge voltage of a peak value from 250 V to 6600 V and 1.2/50 μs waveform in an open circuit;
- A surge current of a peak value from 125 A to 3300 A and 8/20 μs waveform at a short circuit.

During the experiment, the surge generator was located on isolated table on the ground near the tower. The HV (high voltage) terminal of the generator was attached via an insulated wire to the antenna cable earthing terminal at about 2 m altitude on the tower (Fig. 1). This earthing terminal was connected also to the tower construction and to the grounding system buried in the earth.

The other terminal (COM) of the surge generator was connected via 4 long insulated return wires directly to the building LPS and/or to some additional vertical ground electrodes buried in the earth in different locations in and around the station. Different scenarios of connecting the 4 return wires and the ground electrodes were tried and analyzed. One of the scenarios is presented in Fig. 1, which shows the overall plan of the surge generator circuit arrangement.

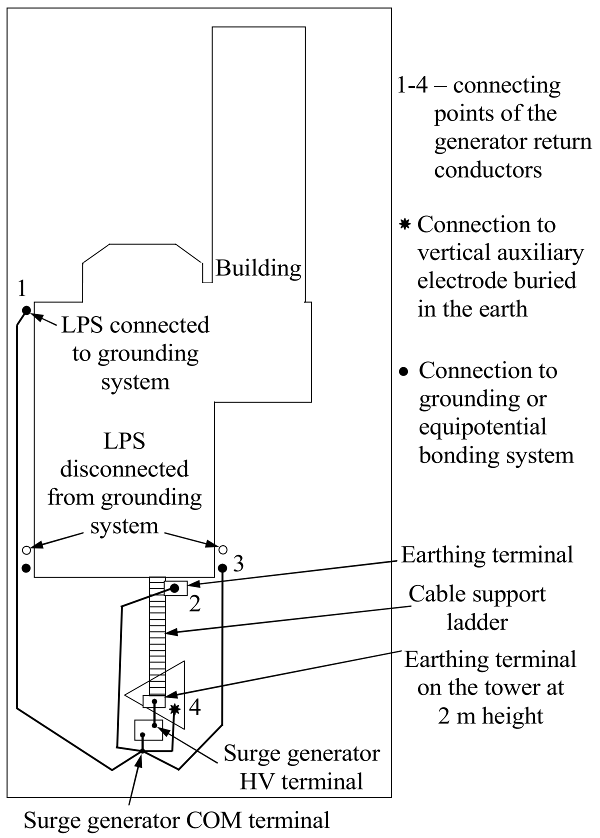

Fig. 1. Top plan of the telecommunication object together with the basic layout of the surge generator circuit

The surge current could easily flow from the generator HV terminal through the tower construction, the LPS (Lightning Protection System), the equipotential bonding system, the earthed cable installations and the grounding system of the station. Then it was directed back to the COM terminal of the surge generator via the 4 return wires.

For measurements of potentials with respect to remote ground an additional artificial grounding was provided in about 500 m distance from the station. This grounding was composed of 4 vertical wires connected together inscribed in 1m x 1m square and buried in earth 0,5 m deep.

Surge currents and potentials with respect to remote ground in different locations at the equipotential bonding system and the cable installations outside and inside the building were measured. The measurements were carried out using:

- A clamp-on current probe of 20 MHz bandwidth and a range 500 A (peak);
- A high voltage probe of 100 MHz bandwidth and a range 4000 V.

The measured currents and voltages were registered using a digital oscilloscopes and with the possibilities of saving the data on a hard drive or a floppy disc.

During the measurements, the surge generator as well as the measuring equipment were supplied from a separated power supply system based on petrol generator. The surge generator was supplied directly from the aggregate and the measuring equipment via an isolating transformer.

The equipment used in the experiment in the course of some measuring processes is presented in Fig. 2.

Fig. 2. Equipment used in the experiment in measurement processes

3. Measurement results

Example results of time domain surge currents and potentials measured during the experiment are presented in Fig. 3 and 4 respectively.

These results were obtained for the surge generator circuit arrangement exactly as the one presented in Fig. 3. The total surge current from the generator was about 290 A peak value and 20/55 µs wave-shape.

It should be sated here that the measurements were performed not at once in all the considered locations but successively for different surges produced by the generator. However, each particular surge produced by the generator was measured and proved to be the same in every successive case.

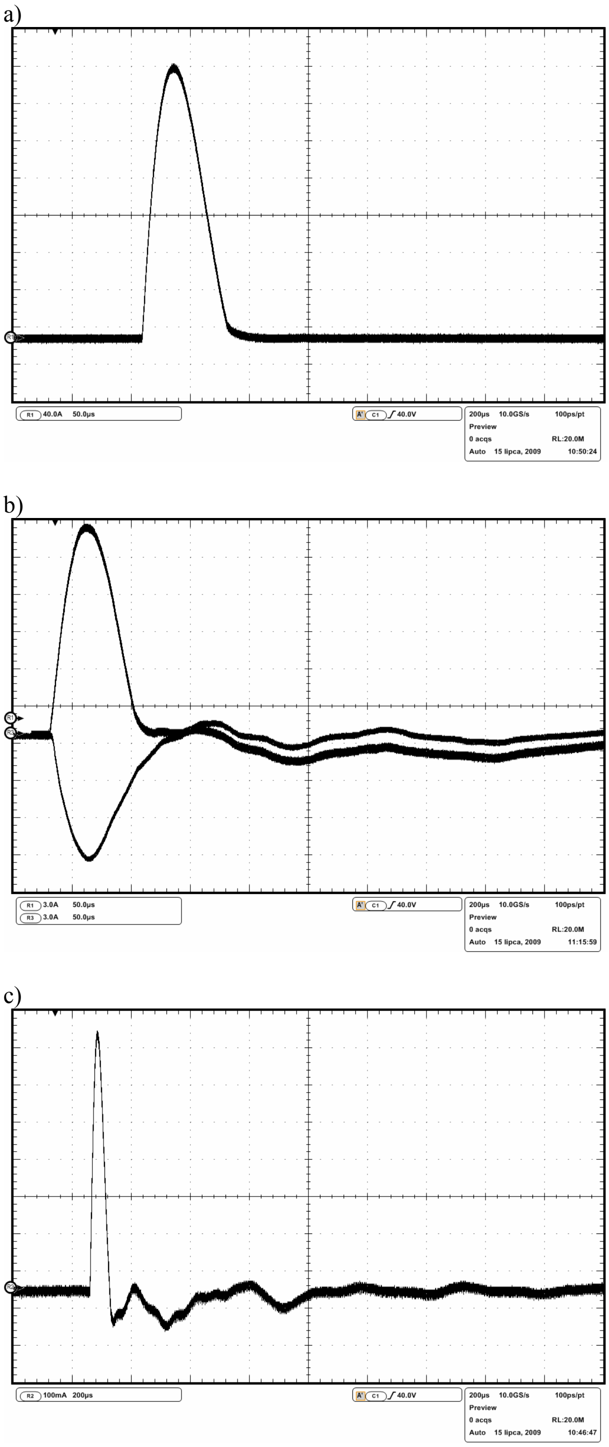

Fig. 3. Example waveforms of surge currents recorded during the experiment: a) the total surge current; b) in earthing conductors of antenna cables at the entry to the building; c) in earthing conductor of a control cabinet on the 1-st floor

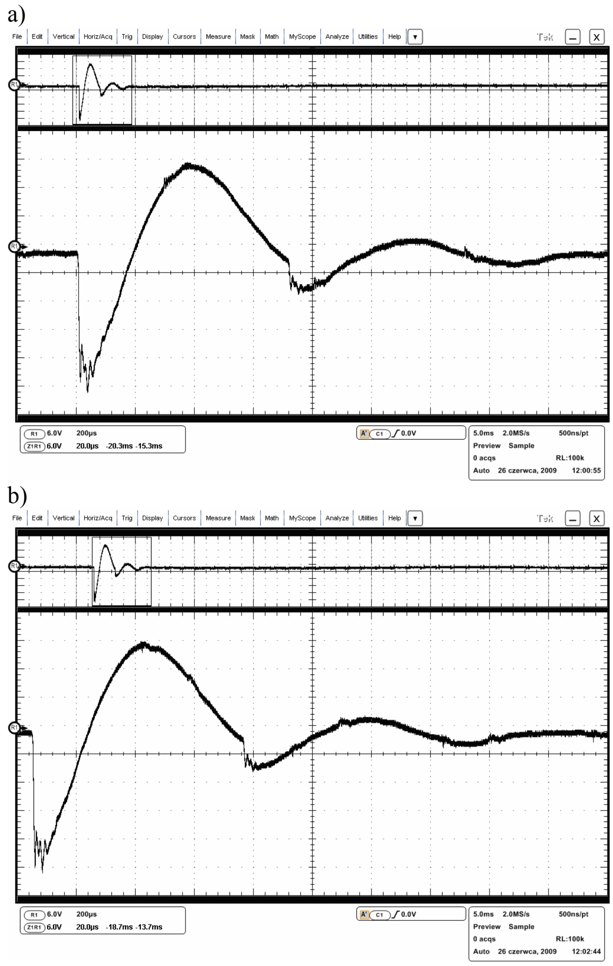

Fig. 4. Example waveforms of surge potentials with respect to remote ground recorded during the experiment at an earthing terminal inside a control cabinet on the 1-st floor

4. Conclusions

An experimental approach for analysis of lightning threat and effects in objects and structures exposed to direct strikes has been presented.

The method is based on a well known idea of simulation of lightning strike to a structure using a surge generator. Because of technical limitations, the method had been proved to be useful mainly for verification of numerical electromagnetic models of structures exposed to lightning. With such models it is possible to numerically analyze the phenomena that occur during natural lightning to larger extent. This was also the main purpose of the work presented in this paper.

Two different measuring approaches, used so far by authors separately to provide such verifications, have been combined together in this work. One is based on measurements of surge current flows and the other on potentials with respect to remote ground.

They were applied for a medium size telecommunication object composed of a 50 m tower and a two-storey building. The final purpose was to make comparisons and to develop some better approach for verification of numerical electromagnetic models.

5. References

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