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LIGHTNING TRANSIENTS IN TELECOMMUNICATION CABLES WHICH CROSSES WITH HIGH VOLTAGE OVERHEAD TRANSMISSION LINES

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Abstract: This paper presents the mathematical model for the prediction of transients induced in underground telecommunication cables during direct lightning stroke on the grounding wire of high voltage HV overhead transmission line. Different places of crossing and different distance between towers and telecommunication cables were analysed.

Keywords: Lightning protection, Overvoltages, Telecommunication cables, HV transmission line

1. INTRODUCTION

Modern telecommunication requires a large variety of equipment. Typical telephone exchange and subscriber equipment contain many electronic elements and devices, such as all types of microcomputers, microcontrollers, hard discs and others. Extensive miniaturization has reduced the ability of equipment to withstand the overvoltages induced in telecommunication cables.

Overvoltages can cause damages or misoperations. Most of transients are caused by lightning strokes. Additionally, in the case when telecommunication cables were in neighbourhood of HV transmission line, created threat caused by voltages and currents this line.

For these sources of disturbances, several theoretical studies have been performed and different models have been proposed to estimate the severity of voltages and currents induced in telecommunication lines by:

- indirect lightning strokes,
- transient in HV transmission lines after switching action during normal operation or faults.

In this paper both these sources of disturbances were considered and mathematical model was employed for the prediction of transients induced in underground transmission cables during direct lightning stroke to the tower of the HV line.

Different places of crossing and different distance between towers and telecommunication cables were analysed.

2. METHOD OF ANALYSIS

In this study, the lightning stroke into tower of HV transmission line between two substations. HV line towers are interconnected by ground wires, installed to shield phase conductors from direct strokes and to reduce the induced voltages on the phase conductors by lightning strokes to nearby ground.

2.1 Parameters of lightning current waveshapes

In mathematical simulation, the lightning stroke was represent as a surge current source at the top of tower. The shape of this current i_s was described as difference of two exponential functions:

$$i_s(t) = \frac{I}{\eta}\left(e^{-\alpha t} - e^{-\beta t}\right)$$

where:

t - time, I - peak current, η - correcting factor

α and β - reciprocals of time constants.

According the standards [5, 6], such a waveform is characterized by the peak value 200 kA, front time 10 μs and time to half value 350 μs and simulated the surge current of the first lightning stroke in the channel.

For obtaining this current, parameters used in above equation are following: *I=200kA, η=0,976, α= 2049,38 s^{-1}, β=563 768,3 s^{-1}*.

In calculation, Fast Fourier Transform spread lightning current out into 32 frequencies. It has been done by FFTSES software [5].

2.2 Model of HV overhead power line

In analysis the energetic system consists with 2 HV substation and 220 kV line with 19 towers between them. The towers were with horizontal configuration conductors (Fig. 1.). The distances between towers were assumed as 200 m.

In theoretical calculation the configuration of tower, presented in Fig. 1., was maximal simplify and composed with the following elements:

- fundamental steel structure of tower consists four slanted conductors and some horizontal, vertical and crossing conductors (Fig. 2),
- eathting system of tower.

This earthing system was modelled in detail, and it consists of:

- ring earth electrode around the tower,
- vertical earth electrodes (depth 4 m) at the corners of ring.

Ring earth electrode consists with steel conductors with cross section 200 mm^2.

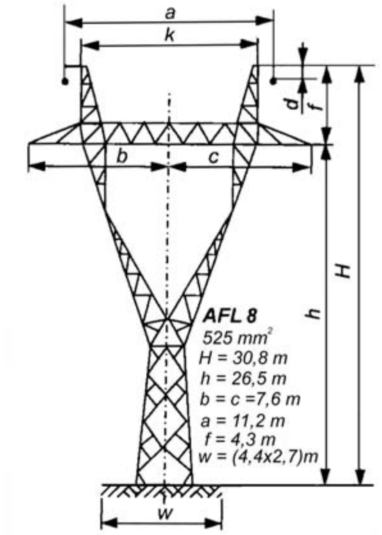


Fig. 1. Single circuit steel tower with horizontal configuration conductors

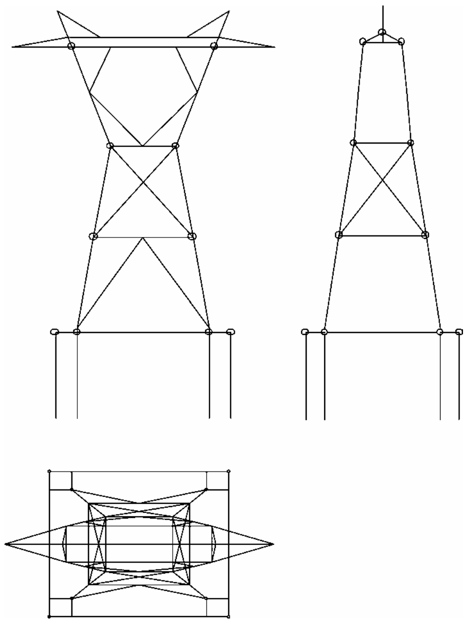


Fig.2. Model of HV tower with eathing system

Conductors were buried at 1 m depth in homogeneous soil (uniform ground model) with resistivity ρ = 100 Ωm and relative permittivity $\varepsilon_r = 1$.

2.3 Telecommunication lines

The lightning transients have been computed for the shielded cables with following parameters:

- cables run under the ground on 200 mm depth,
- distance between layers – 10 mm and between cables in each layer – 10 mm,
- cables were under the HV power line.

The arrangement of control cables is presented in Fig.3.

In calculations different places of crossing and different distances between towers of HV lines and telecommunication cables were considered.

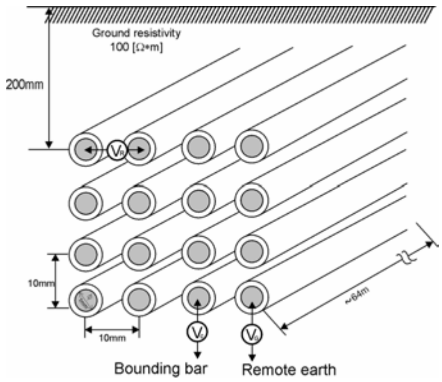


Fig. 3. Arrangement of cables under HV line

In further part, the results of calculations were presented for the following arrangement of lines:

- telecommunication cables were under the ground, perpendicularly to the power HV lines (Fig. 4 and 5),
- crossing of lines stepped out in the middle of span.

In everyone different arrangement larger lightning threat appeared.

2.4 Determination of lightning transients

During a direct lightning stoke on the tower of HV line, the surge current i_s will be divide into three parts (Fig.4.).

One part of current (current i_s) will flows through the tower to the ground.

The remaining part of lightning current will divides equally (currents i_1 i_2) and flows in opposite directions in the ground wires.

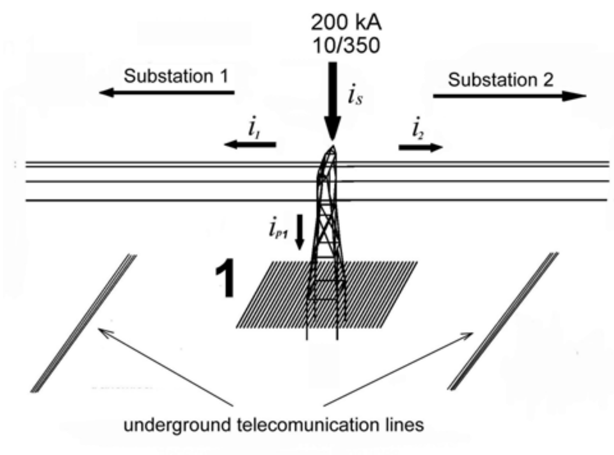


Fig. 4. Arrangement for the simulation of a direct lightning stroke to the top of the tower

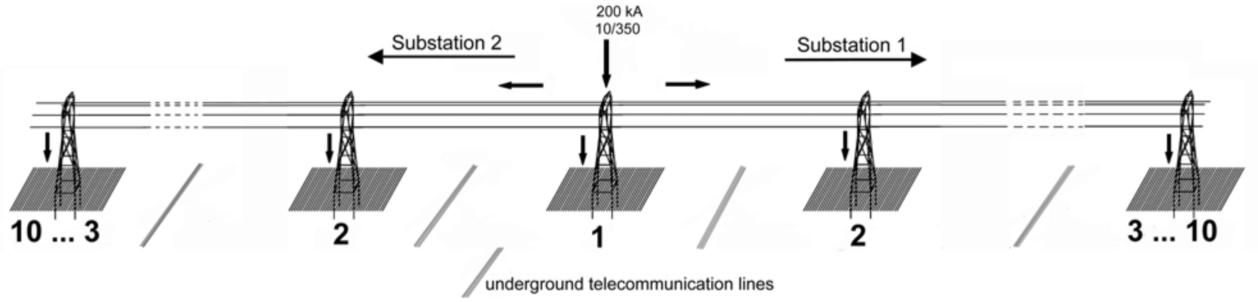


Fig. 5. Analysed electric power system

The analyses have been performed by the MultiFields [4, 5] software package, which is a part of CDEGS package.

The computation methodology assumes the frequency domain analysis, in which each conductor in the network is partitioned in small segments.

The segments should be short enough so, that the current is assumed to vary linearly along with the segment for all analysed frequencies, but they should be also large enough to meet the thin wire approximation.

Each such segment is represented by an electric dipole located at its centre and the electromagnetic quantities at an observation point are obtained by the sum of the contributions from all of the dipoles.

The field of a single dipole is expressed as the sum of the source term, the image term and the Sommerfeld integral. The Sommerfeld integrals have been computed by the Double-Integration method i.e. numerically, without any approximation.

3. COMPUTATION RESULTS

Below computation results are presented for the direct lightning stroke into the tower no. 1 (in Fig. 5), which was in the middle of HV line. The lightning current flows through the all towers and in ground wires (Fig.6.).

These surge currents caused transient in telecommunication cables. For determining these transients, the arrangements of isolated cables or cables shorted at the ends have been assumed.

Some examples of currents induced in two cables (length 100 m) shorted at the ands are presented in Fig. 7.

The program CDEGS was additionally used to compute the transient voltages, which appeared between cables (V_R) and between cables and local bounding bar (V_C) or true earth (V_G).

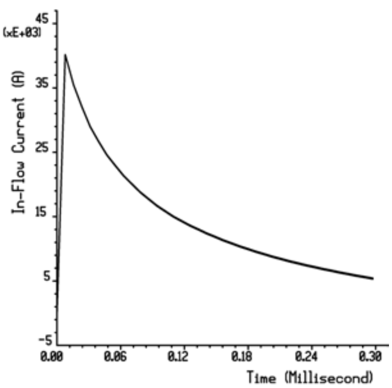
In analysed arrangements the impulse voltages V_G were much greater than V_C.

Some examples of these voltages V_G in telecommunication cables, which were between different towers near the strike point, are presented in Fig. 8.

In worst cases, the telecommunication cables between the towers no. 1 and 2, the voltages between the wires of cables and true earth V_G reached the values 52- 55 kV.

With increasing the distances between lines and the tower, which was stroke by lightning, decreases the voltages between wires and true earth.

a)



b)

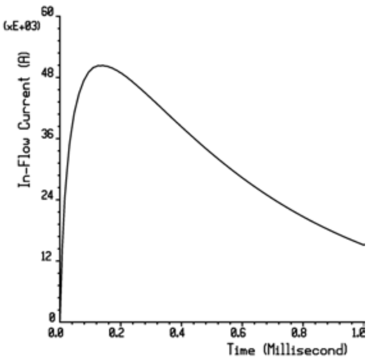


Fig. 6. The surge current distribution, a) current in one, from four, fundamental conductor in tower's model, b) current in ground wire

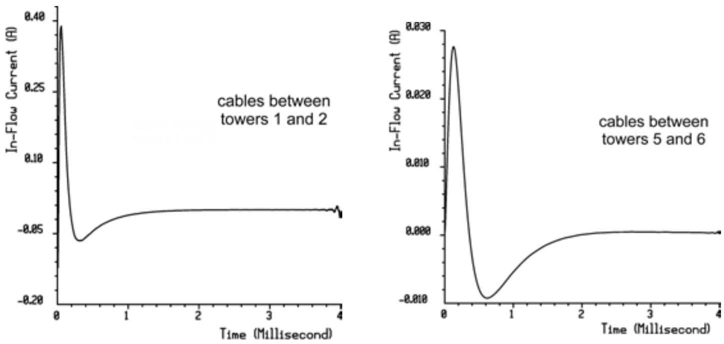


Fig. 7. Short circuit currents in telecommunication cables

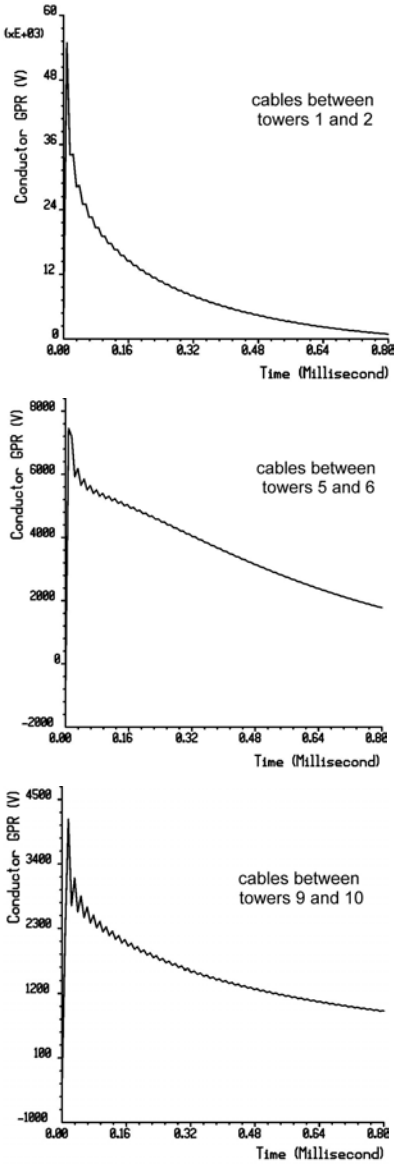


Fig. 8. Impulse voltages between the wires of cables and true earth

4. CONCLUSION

In article a method for computer analysis of lightning transients in telecommunication cables, which crosses with HV overhead line, is presented.

The advantages of the proposal calculation model are the following:

- all possible points of lightning stroke to the grounding wire or to the tower at the transmission area can be represented in theoretical model,
- the analysis of surge voltages and currents induced in telecommunication underground cables is possible,
- different places of crossing and different distance between towers and cables is possible to take into account.

The study shown that, the magnitudes of lightning surges induced in wires can reach the values, which are dangerous for electronic telecommunication devices.

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BIOGRAPHICAL NOTES

Andrzej W. Sowa was born in Warsaw, Poland in 1951. He received M.Sc. and Ph.D. degrees from Warsaw University of Technology in 1974 and 1979 respectively. Since 1978, he has been with the Department of Electrical Engineering, Technical University of Białystok. He has been working in the field of Electromagnetic Compatibility, particularly concentrating the problems of lightning and overvoltages protection. He is the author and co-author of 5 books and above 300 papers, patents and conference presentation in the above fields.

Jaroslaw Wiater graduated in power system at Electric Power System Faculty of Technical University, Bialystok in 2002. Main research area is application of computer technology in damage analysis at electric power substation during direct lightning strikes.