DISTRIBUTION OF STEP AND TOUCH VOLTAGES ALONG HV OVERHEAD TRANSMISSION LINE DURING LIGHTNING STROKE

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Abstract: This paper presents the results of numerical simulations of lightning transient scalar potential as well as touch and step voltage distributions in and around a HV overhead transmission line in case of direct lightning stroke to the pylon.

1. INTRODUCTION

This paper describes a method for computing touch and step voltages near a grounding system, for example in and around a HV pylon. Knowledge of the lightning strike point allows the quick approximation of the touch and step voltages [1]. In the urban areas this knowledge is very important. In cities there are many places where HV lines crosses sidewalks or roads. The computations revealed that the lightning transient step and touch voltages along HV line might be very high and very risky for human being [2,3].

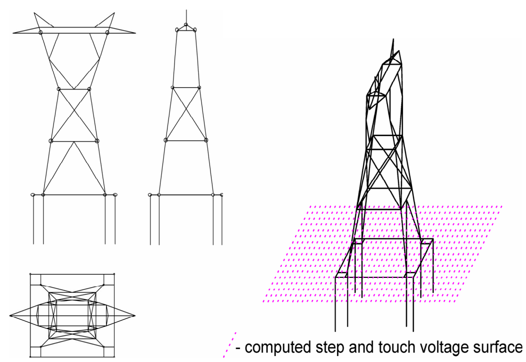


Fig. 2. Graphic representation of the HV overhead transmission line pylon numerical model and 3D view one of the computed step and touch voltages nearby the pylon

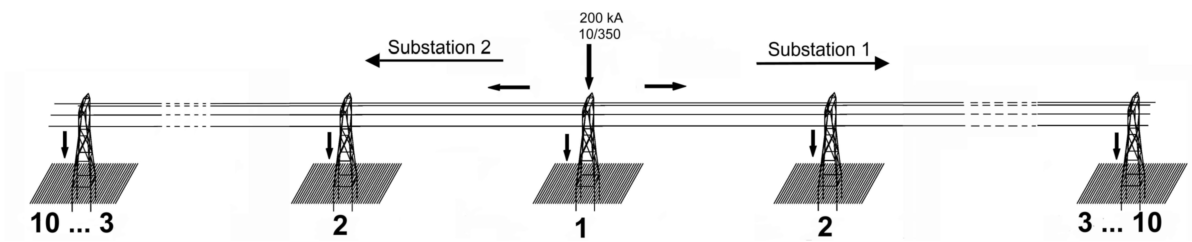


Fig. 1. HV overhead transmission line with surge current injection point

2. ANALYZED OBJECT

HV overhead transmission line has got a 3,8km length. Distances between pylons are equal and amounted 200m. Analyzed HV line is symmetrical in all directions.

The numerical model includes an earthing network as well as simplified models of aboveground elements such as pylon structure and bonding network. Numerical simulations were performed by MultiFields software package, which is a part of CDEGS package [4].

The computation methodology assumes frequency decomposition of the time domain current surge [5], frequency domain computations for a single harmonic unit current energization and superposition of the frequency domain computations modulated by the amplitude of the lightning current.

This seems to be the a good approach as it allows the computations in wide frequency range, allows for modeling relatively complex structures with both underground as well as aboveground elements.

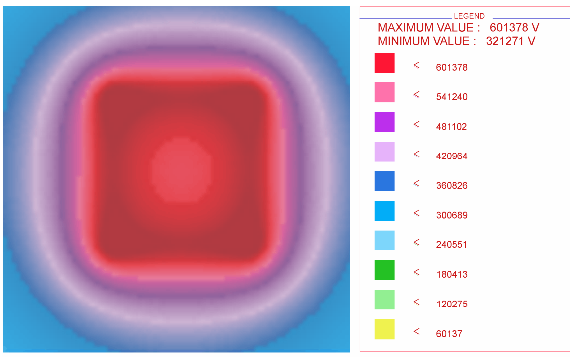
A direct lightning stroke is simulated by an ideal current source injected the surge current in different points of lightning protection system. In analysis, the lightning current has the following mathematical expression:

$$i(t) = \frac{I}{\eta}\left(e^{-\alpha t} - e^{-\beta t}\right) \qquad (1)$$

where:

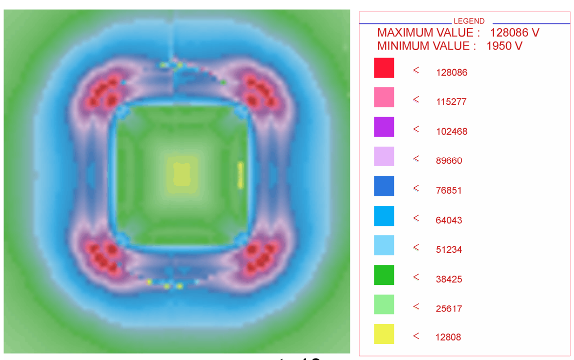
t - time, a - reciprocal of time constant, b - reciprocal of time constant, I - peak current, η - correcting factor

In calculation the parameters of the lightning current were the following: I=200kA, η=0,976, α= 2049,38s^{-1}, β=563 768,3 s^{-1}. This simulated, according the standards, the surge current in the lightning channel with peak value 200 kA and shape 10/350 µs.



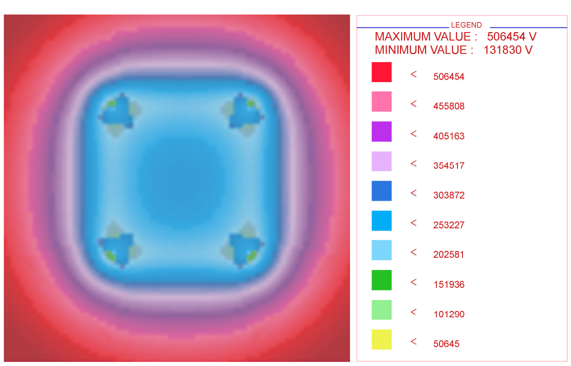
Scalar Potential t=10µs

Fig. 3. Scalar potential distribution (10/350µs, peak current 200kA, pylon 1-1)



Step Voltage t=10µs

Fig. 4. Step voltages distribution (10/350µs, peak current 200kA, pylon 1-1)



Touch Voltage t=10µs

Fig. 5. Touch voltage distribution (10/350µs, 200kA peak current, pylon 1-1)

3. COMPUTATION RESULTS

The maximal obtained values of lightning transient scalar potential can reach 600kV around the vertical ground conductors, also that connecting the earthing terminals to the earthing system – fig.3. About 4 times lower values – 120kV are observed in about 20m distances from the pylon.

The maximum values of step voltages - up to 128kV can be expected around the vertical ground conductors of the pylon, especially close to the corners – fig. 4. Such values of step voltages extend to about 2m diameters around the ground conductors.

The values of touch voltages increase rapidly outside the pylon with increasing distance to the outside. For example, up to 202 kV of touch voltage can be expected within about 2 m distances to the station fence. Close to the fence corners, this distance can be even significantly smaller as for the case of direct touching the structure. The touch voltages computed for long distances are estimated with the assumption of indirect touching the structure.

It should be pointed out that the distribution of scalar potential as well as step and touch voltages is strongly dependant on soil resistivity and the effective area for a given lightning current shape. Further detailed analysis for these cases will be taken.

4. CONCLUSIONS

In relatively small objects, such as pylon of the HV overhead transmission line, which was considered in this paper, the metallic parts near the pylon can create a great danger for living being. Since the effective area for dissipating the lightning current into the earth can be comparable or greater than the area of the pylon earthing system, potential gradients at the edge of the earthing network can be very high resulting in large step voltages.

4. ACKNOWLEDGMENT

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5. REFERENCES

1. Ma J., Dawalibi F. P.: "Analysis of Grounding Systems in Soils with Cylindrical Soil Volumes" IEEE Transactions on Power Delivery, vol. 15, no. 3, July 2000; pp. 913–918.
2. Ala G., Di Silvestre M. L.: "A Simulation Model for Electromagnetic Transients in Lightning Protection Systems", IEEE Transactions on Electromagnetic Compatibility, vol. 44, no. 4, November 2002.
3. AC substation earthing tutorial - ERA Technology Ltd.
4. "HIFREQ User's Manual: Frequency Domain Analysis of Buried Conductor Networks" Safe Engineering Services & Technologies Ltd., Montreal Canada.
5. "FFTSES User's Manual: Fast Fourier Transform", Safe Engineering Services & Technologies Ltd., Montreal Canada.