

Lightning Current Distributions in LPS of a Building with a Radio Base Station on the Roof

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Abstract— The paper presents results of numerical calculations of lightning current distributions in LPS (Lightning Protection System) of a building and in PE (Protective Earth) conductor of the supplying a.c. power line during direct strike to a Radio Base Station (RBS) located on the building roof. The calculations have been performed using a software package based on electromagnetic field theory and method of moments. They concern large RBS with three sectorial antenna masts and six equipment cabinets installed on two adjoining metallic platforms. The analyses concentrate mainly on the effects of location of the antenna masts on the lightning current distributions. The normative surge current waveform was used as to represent the characteristic of the first return stroke.

Key words: lightning, lightning current distribution, Lightning Protection System (LPS), Radio Base Station, numerical analysis.

I. INTRODUCTION

An accurate estimation of threat related to direct lightning strike to a structure requires evaluation of current distribution in LPS, cable systems and/or other conductive construction elements. This allows for calculation of:

- separation distances between LPS, conductive construction elements and cable systems,
- step and touch voltages,
- electromagnetic fields intensities,
- voltages and currents in cable systems inside the structure.

The knowledge on lightning current distribution is also required for application and achieving a proper coordination of SPDs (Surge Protective Devices) in cable systems.

Lightning current distributions in LPS of buildings have been studied so far quite extensively (e.g. [1], [2]). Those studies relate to various buildings of different dimensions and heights. However, they actually do not take into account the presence of equipment and installations on the roofs.

In the paper the results of numerical calculations of lightning current distributions during direct strike to the antenna mast of a radio base station located on a building roof are presented. The calculation results include current flows in LPS of the building and in PE conductor of the supplying a.c. power line.

The results of current distributions in LPS and PE conductors for different soil resistivity and different striking point are presented in [3]. This paper concentrates mainly on the effect of location of the struck antenna mast.

These results provide basic knowledge on the threat related to dangerous sparking as well as currents in supplying a.c.

power line. This information is crucial for calculation of separation distances and selection of SPDs in installations.

II. BASIC ASSUMPTIONS

The calculations were performed with HIFREQ program, which is based on electromagnetic field theory approach and method of moments and takes into account buried conductive elements and soil parameters [4].

The numerical method requires the object in concern to be represented with a network of cylindrical conductors partitioned in segments. Under thin-wire approximation and using linear current distribution in a segment, each such segment can be regarded as electric dipole. The electromagnetic field related to a single dipole is expressed using Maxwell's equations. Superposition rule is used to take into account the effects caused by all the dipoles (segments). For calculation of unknown currents in segments, linear equations are formulated based on boundary conditions on conductors surface and with conservation of Kirchhoff's and Faraday's laws [4], [5].

The geometrical representation of the basic structure for calculations is shown in Fig. 1. It consists of a building (50 m x 20 m x 20 m) and a radio base station located on its roof.

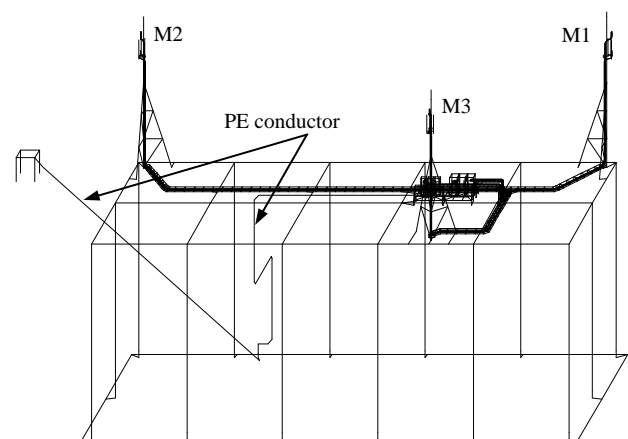


Fig. 1. Basic structure under consideration

The building is equipped with an external LPS with down conductors located every 10 m. Its grounding system has a form of a ring electrode buried at 0.8 m depth around the building in 1 m horizontal distance from the walls.

The grounding system of the supplying transformer is located about 60 m away from the building. It consists of a ring electrode with additional 4 vertical electrodes at the corners. A single insulated wire, used as the PE conductor, is buried in the ground and links the building with the transformer grounding system. A uniform soil with 500 Ωm resistivity was applied in calculations.

The radio base station consists of three sectorial antenna masts and six equipment cabinets located on two adjoining metallic platforms. The cabling systems between the antennas and the cabinets are installed inside metallic ducts and on metallic support ladders. Since the numerical method does not allow for modeling of coaxial, shielded and twisted pair cables, the parallel-wire cable structures are applied instead. The cables are terminated with matched resistances and as in real conditions.

Direct lightning strike to the antenna mast M2 with different location of the mast M2 is considered.

In calculations, a lightning strike to antenna mast was represented with a current source located on the top of the mast. The lightning current waveform of 10/350 μs was assumed to simulate the threat related to the first return stroke, according to the international standards on lightning protection [6]. The peak value of the lightning current was 100 kA, as for the III-rd protection level [6].

The lightning current waveform was described with Heidler's formula, recommended also by international standards on lightning protection [6], [7]:

$$i(t) = \frac{I}{\eta} \cdot \frac{(t/\tau_1)^{10}}{1 + (t/\tau_1)^{10}} \cdot \exp(-t/\tau_2) \quad (1)$$

where: $I = 100$ kA – current peak value, $\eta = 0.93$ – correcting factor, $\tau_1 = 19$ μs , $\tau_2 = 485$ μs – front and tail time constants of the current impulse, t – time [4].

III. RESULTS

The calculated lightning current distributions, in case of direct strike to the antenna mast M2, are presented in Fig. 2. The results relate to different location distance of the antenna mast M2 from the point where all the antenna cables meet the ladder in front of the equipment cabinets. These location distances are 41 m, 22 m, 13 m and 7 m.

As generally can be expected for the current distribution between lightning down conductors of the building LPS, the highest peak value of surge current is observed in the lightning down conductor located directly beneath or close to the struck mast (the current injection point). This is also clearly visible from the current distributions shown in Fig. 2.

What regards the location of the struck antenna mast, the highest current peak value in the down conductor beneath the struck mast is observed in case where the struck mast is located close to the building corner (Fig. 2 a)). In this case the current distribution between the lightning down conductors is the most non-uniform, ranging from 4 kA to 15.9 kA.

More uniform current distribution can be expected when the struck mast is located in the middle of the roof edge.

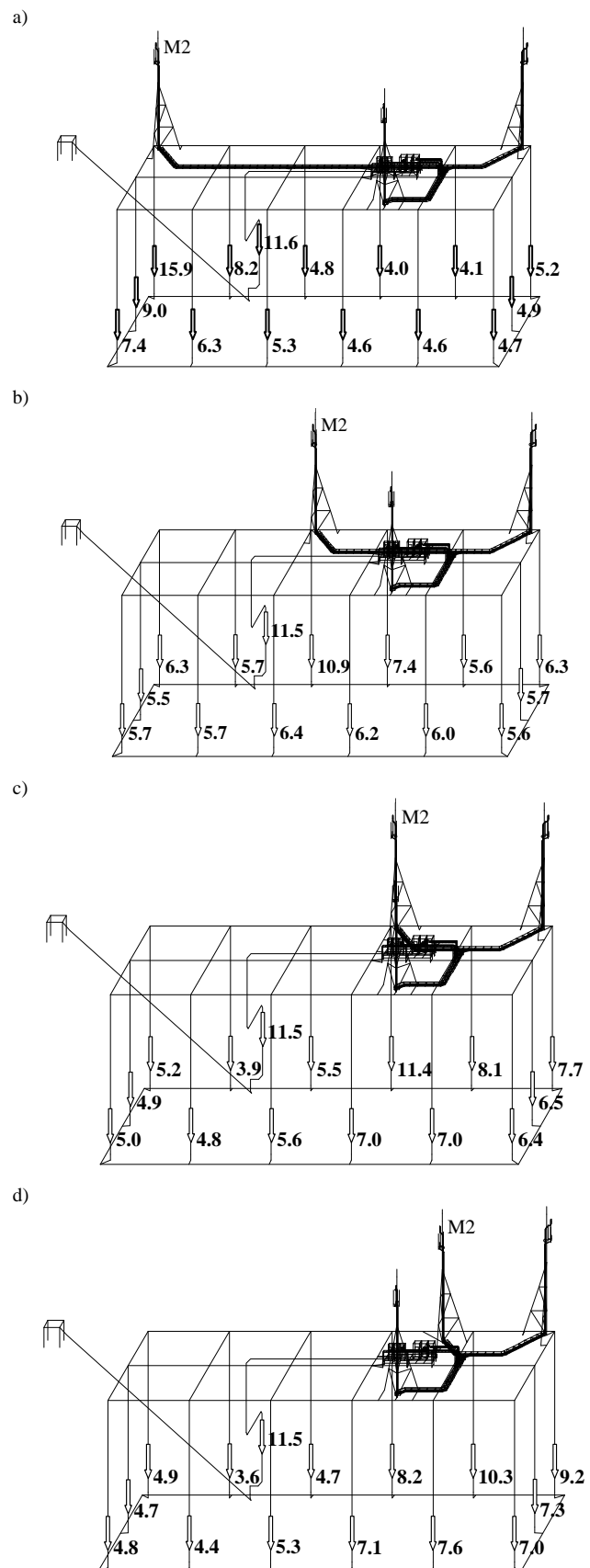


Fig. 2. Lightning current distributions during direct strike to the antenna mast M2 located in a distance: a) 41 m, b) 22 m, c) 13 m, d) 7m; from the ladder

In the analyzed cases however, the presence of the radio base station on the building disturbs a little bit this general rule. If the RBS was not present on the roof, the current distributions in cases corresponding to that shown in Fig. 2 b) and 2 c) would be generally similar, due to symmetrical location of striking points with regard to the building width. Yet, when the RBS is present on the roof, the resulting current distribution is clearly more uniform in the case from Fig. 2 b) (5.5 kA to 10.9 kA) than in the case from Fig. 2 c) (3.9 kA to 11.4 kA).

This feature clearly indicates the influence of the RBS on the current distribution in building LPS. More uniform current distribution in the case from Fig. 2 b) is probably due to the location of all the three antenna masts and their cable ducts nearly symmetrically with respect to the equipment cabinets.

The peak currents in the down conductors of the building LPS for the case shown in Fig. 2 d) are also distributed quite uniformly, ranging from 3.6 kA to 10.3 kA. This is due to the fact that the struck mast M2 is shifted a little bit from the roof edge towards the middle longitudinal air termination rod on the roof.

The influence of the RBS on the current distribution between the down conductors of the building LPS manifest itself also by the peak currents in the two down conductors adjacent to the down conductor located directly beneath or close to the struck mast. The peak current is nearly always higher in that adjacent conductor which is located closer to the other two antenna masts or the equipment cabinets.

Finally, it should be noticed also that the location of the struck mast practically does not affect the current which flows via the PE conductor to the supplying a.c. power line. In all the analyzed cases this peak current is around 11.5 kA.

For comparison, the calculated lightning current distribution in the LPS and PE conductors without the presence of the RBS on the roof is presented in Fig. 3. It was calculated for the situation similar as shown in Fig. 2 a), when lightning strikes the building corner corresponding to the location of the mast M2.

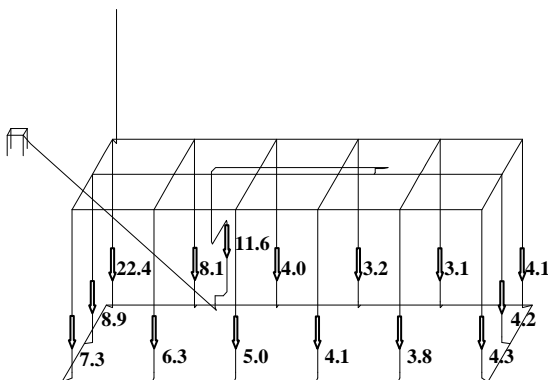


Fig. 3. Lightning current distribution during direct strike to the building corner which corresponds to the location of the antenna mast M2 as in Fig. 2 a) without the presence of the RBS

As it can be noticed from comparison of figures 2 b) and 3, the presence of the RBS on the building roof significantly

influences the current distribution in the down conductors of the building LPS. Without the RBS this current distribution is much more non-uniform, the peak currents range from 3.1 kA to 22.4 kA.

On the other hand, the presence of the RBS does not affect the current which flows out through the PE conductor of the supplying a.c. power line.

IV. CONCLUSION

In the paper the results of numerical calculations of lightning current distribution during direct strike to the antenna mast of a radio base station located on a building roof have been presented.

The analyses concentrated mainly on the influence of the location of the struck antenna mast on the currents in the building LPS conductors and in the PE conductor of the supplying a.c. power line.

As expected, the highest current in the down conductor beneath the struck mast is observed in case where the struck mast is located close to the building corner.

However, the presence of the radio base station on the building disturbs a little the general rule, according to which a more uniform current distribution is expected for the struck point located somewhere in the middle of the roof edge.

The influence of the RBS on the current distribution can be seen also when observing the peak currents in the down conductors adjacent to the down conductor located directly beneath or close to the struck mast. The current in the adjacent conductor located closer to the other two antenna masts or the equipment cabinets is nearly always higher than that in the other adjacent down conductor.

It was shown also that the presence of the RBS on the roof significantly influences the current distribution in the down conductors of the building LPS. Without the RBS this current distribution is much more non-uniform.

The presence of the RBS as well as the location of the struck mast does not affect the current which flows out through the PE conductor of the supplying a.c. power line.

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