Ground potential rise, step and touch voltages during lightning strokes to GSM base station

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Abstract: One of the major tasks of a grounding system is to ensure safety for persons during various fault conditions. The purpose of this paper is to provide knowledge about the step and touch voltage distributions in and around a freestanding GSM communication tower during direct lightning stroke in it. Scalar potential at the earth surface as well as step and touch voltage distributions were computed based on field theory approach. The results of calculation give the possibility to find the most dangerous places for persons, which can be present on the area of station or in close vicinity.

Keywords: Lightning protection, lightning dangerous, step and touch voltages, GSM base stations.

1. Introduction

The objectives of a good grounding system of GSM station are follow :

- to connect all components together with the least impedance between them. This will minimize the potential differences between components should surge current occur, which in turn will minimize the lightning dangerous.
- to provide the path of least impedance from the ground system components to earth ground. Any surge that does occur will be dissipated quikly. In general ground system resistance of less 10 Ω or 5 Ω must be achieved.

Additionally, the objective of a grounding system is to ensure safety for persons during direct lightning stroke to the tower. In the worst case, the safety of persons working at on the station's area may be seriously compromised. Still not much information concerning the actual values of step and touch voltages, that persons can be exposed during lightning strokes, is provided [7].

Moreover, the analyses are often relate to a single frequency (usually low frequency). This doesn't give a complete information for surge currents because the behaviour of groundung system strongly depend from the frequency.

Furthermore, the conductive elements over the ground structures are also often neglected. These structures however, are very important because on the one hand, a current distribution in these structures is determined by the location and specific behaviour of earth electrodes and on the other, a current distribution in buried electrodes depends on the geometry of the aerial part of the structure.

This paper presents the results of numerical simulations of:

- lightning transient scalar potential,
- touch and step voltages distributions

in and around a GSM base station in the case of direct lightning stroke to the communication tower.

The numerical model includes an earthing network as well as simplified model of human body [2, 7] and elements above ground such as tower structure, bonding network or metallic fence around the station.

2. Model of the GSM Base Station

For the computations of scalar potential, step and touch voltages a real base station was modelled. The model is presented in Fig 1. It is composed of straight cylindrical conductors of appropriate dimensions and electrical parameters.

The station consists of a 60 m high communication tower put on an equilateral triangular basis of a side length of 2.5 m and a small container in close proximity of the tower.

The dimensions of the container are 3.8m x 2.5m x 3m and the area marked by the station fence corners extends to about 29 m per 22 m as indicated in Fig.1.

The earthing system and other underground structures of the station were modelled in detail (Fig. 1a). This earthing system consists of:

- ring earth electrodes around the tower and the container located at the distance 1.5m from the bases of tower and container,
- ring earth electrode of the station located 0.5 m away from the fence on its internal side,

- horizontal earth electrodes that connect the corners of the tower and the container ring electrodes to the ring earth electrode of the station (5 connections).

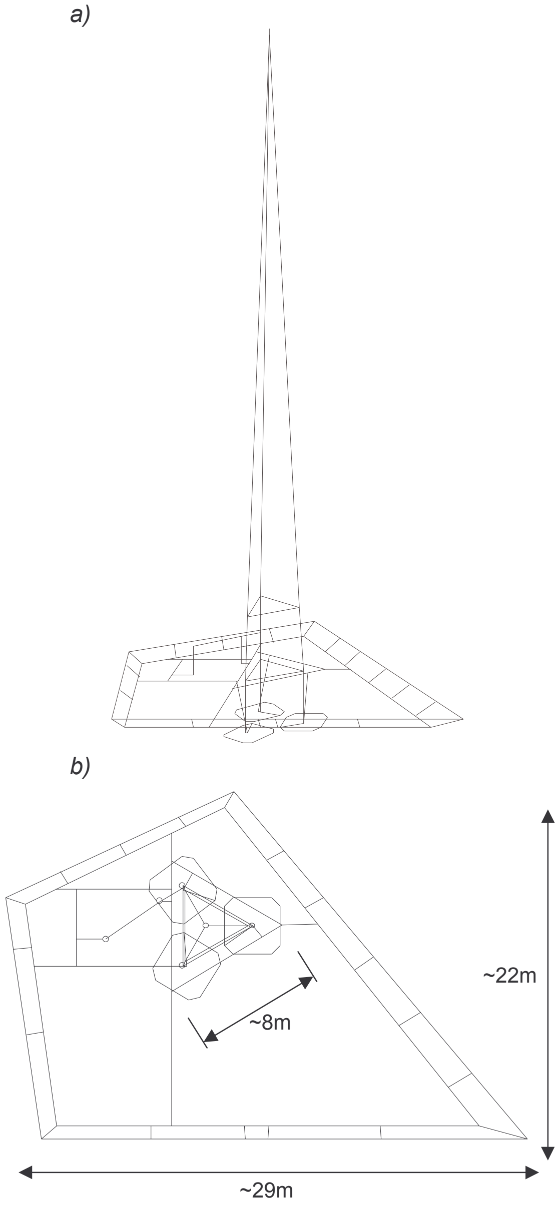

Figure1: Graphic representation of GSM base station numerical model– a) 3D view, b) top view

The earthing network is buried at a depth of 60 cm. Apart from the earthing system described above, the tower foundation bases were also modelled. They include three square ring electrodes around each tower leg buried at a depth of 3.2 m and vertical reinforcing rods of the tower footing, which link these ring electrodes to the tower legs.

Additionally, from the earthing system described above, structure consists of the following elements:

- simplified tower structure i.e. the three tower legs (the oblique linking elements were omitted),
- simplified representation of the container bonding configuration with its connection to the earthing network,
- simplified metallic fence around the station together with its connections to the station earth ring electrode.

3. Numerical simulations

Numerical simulations were performed by MultiFields [10, 11] software package, which is a part of CDEGS package. The computation methodology assumes frequency decomposition of the time domain current surge, 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.

The field theory approach is used for frequency domain computations. The theory is based on numerical solutions of electric field integral equations.

The investigated structure is represented as an appropriate network of conductors partitioned in short segments. Under certain assumptions, the network of segments can be considered as a thin-wire structure.

The lengths of the segments are chosen so that the current can be assumed to vary linearly along with them for all the analysed frequencies. Thus, the segments can be represented as electric dipoles and all the electromagnetic quantities at any observation point can be expressed as a sum of contributions from all the dipoles.

The field of a single dipole consists of the source term, the image term and the Sommerfeld integral. For the current determination and to impose the boundary conditions at the conductor surfaces, the two-potential (scalar - vector) Method of Moments (MoM) is used [10].

This method of simulation can naturally take into account all the electromagnetic phenomena, is relatively flexible and makes possible to model complex structures where both aboveground as well as buried elements can be treated globally.

Direct lightning stroke to the tower was modelled by an external current source placed at the top of the structure. The lightning current was described by double-exponential waveform, according to the equation:

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

where:

t – time
α – reciprocal of time constant
β – reciprocal of time constant
I – peak current
η – correction factor

The parameters of the lightning current were taken according to the Standard IEC 61312-[12] for the III and

IV protection levels. The peak value of current was 100kA and shape 10/350μs

4. Computation results

Fig. 2 presents a contour plot of the scalar potential distribution on the earth surface in and around the station.

The maximal obtained values of lightning transient scalar potential can reach 400kV around the vertical ground conductors, also that connecting the earthing terminals to the earthing system.

About 4 times lower values – 120kV are observed in about 20m distances from the station fence.

Since the earthing terminals are also connected to other far distant objects (for example power supply nets), the resulting transferred potential at these objects can be very high . Theoretically, in extreme cases it achieves values a few hundret kV.

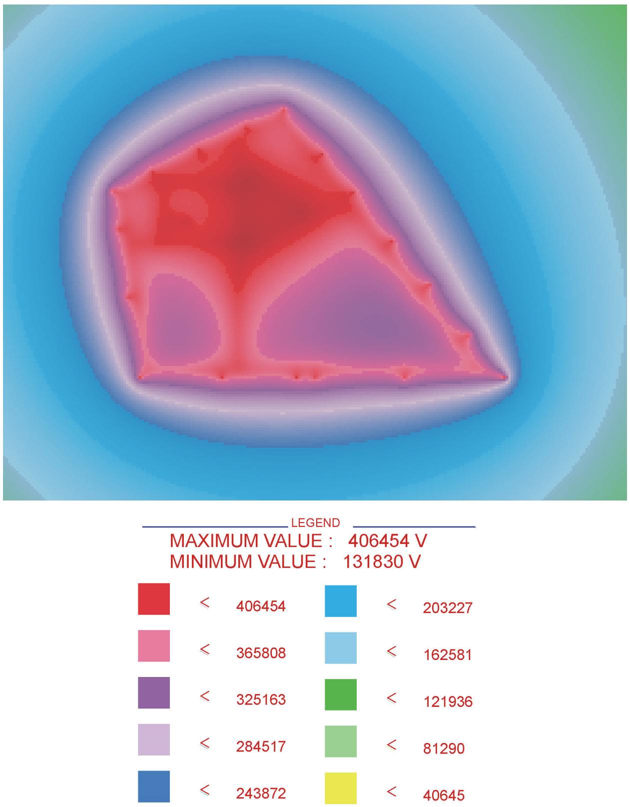

Figure 2. Ground potential rise in and around the base station

Fig. 3 and 4 presents the computed step and touch voltages in and around the station.

As in Fig. 2, the results correspond with the peak values of the computed quantities.The distribution of touch voltages around the considered area is quite similar to the distribution of scalar potential, with the exception of course that it is inversed. The minimal values of touch voltages, up to 27kV can be expected around the tower.

In close proximity of the station fence, the touch voltages have nevertheless quite high values - up to about 81 kV.

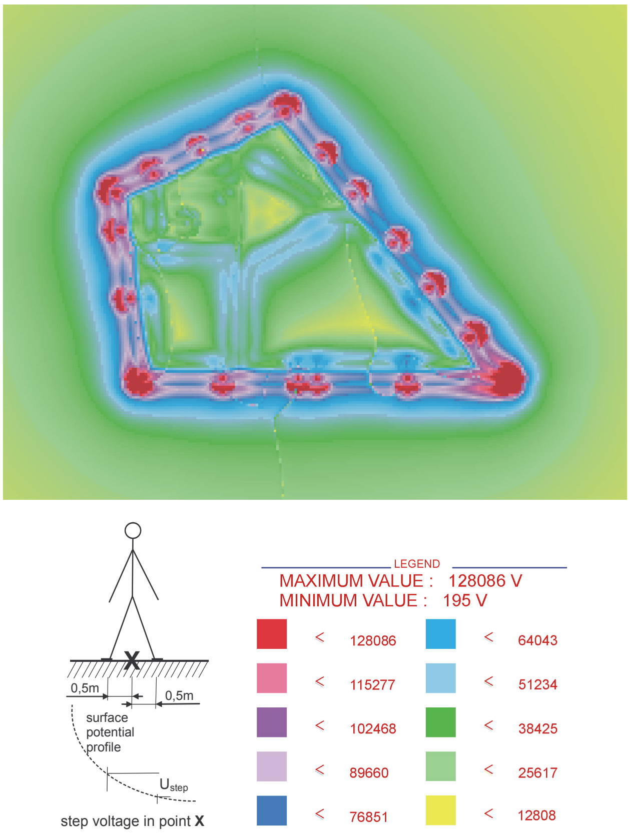

Figure 3. Step voltage distribution in and around the base station

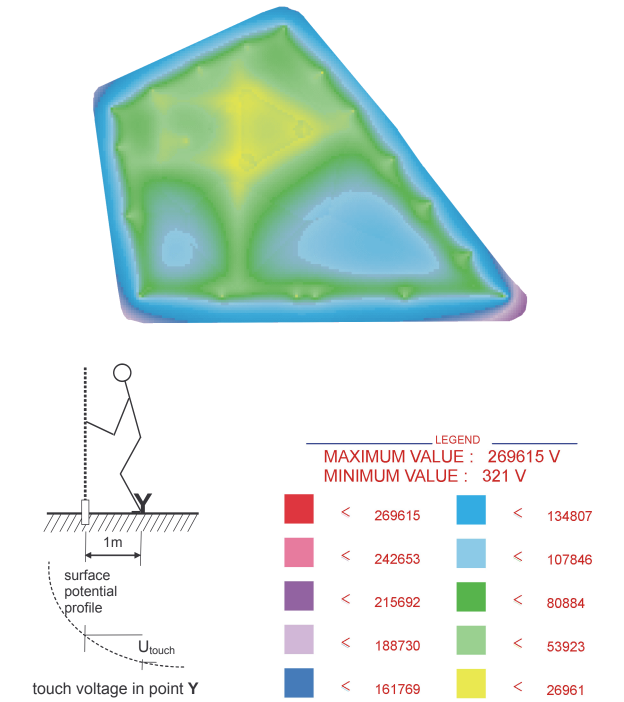

Figure 4. Touch voltage distribution in and around the base station. Assumption: indirect touch possibility (touch through additional object) – worst case than 1m distance

The values of touch voltages increase rapidly outside the station with increasing distance to the station fence.

For example, up to 135 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 maximum values of step voltages - up to 128kV can be expected around the vertical ground conductors of the station fence, especially close to the corners. Such values of step voltages extend to about 2m diameters around the ground conductors.

A very fast decrease of step voltages is observed outside the area enclosed by the fence.

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.

5. Conclusion

In relatively small objects, such as base station, which was considered in this report, the metallic fence around the station can be of a great danger for persons outside. Since the effective area for dissipating the lightning current into the earth can be comparable or greater than the area of the station earthing system, potential gradients at the edge of the earthing network can be very high resulting in large step voltages.

This depends also on the soil properties [8]. On the other hand, ways of earthing the fence might determine the values of touch voltages around the station.

In object, which was analysed, the fence is normally earthed by connecting it to the station earthing network i.e. the station ring earth electrode enclosed by the fence.

The computations revealed that the lightning transient step and touch voltages in a GSM base station might be very high.

In practice dangerous can be the voltages occurring outside a station close to the fence - 100 kV of touch voltage and 80–100 kV of step voltage.

Persons and equipment require protection from the hazardous and damaging effects of ground potential rise and step-touch voltages

Unfortunately, in many cases telecommunications site providers are simply unaware these hazards.

In some cases understanding this problem and developing a proper plan for the safe grounding and bounding systems of base stations are very important.

6. Acknowledgment

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7. References

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