Modelization of earth electrode excited by atmospheric discharges based on FEM

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1. Brief introduction

The aim of this paper is to obtain the distribution of tensions in the land excited by currents type ray using different types of electrodes: the goad electrodes and the deep goad electrodes, and as an exceptional case an electrode type drags was used.
In this work, the program ANSYS® that is based on the finite elements method (FEM) was used. After the simulation of the distribution of tensions, different parameters were obtained, such as the tensions of step (Vp) and of contact (Vc) which determine the security of the installation of put in the earth (PE) protection.

Key words: Earth electrodes, grounding systems, protection systems, wind energy.

2. Model and Simulation

Continuing the investigation of Navarro *et al.* [1] that managed to obtain different correlations between the parameters from an grounding electrode. These correlations are used for different configurations from electrodes and different values from resistivity of the soil. In this case we are going to analyze three typologies of grounding electrode.
The first electrode modelled and simulated is the electrode of goad. This is the most popular electrode in the installations of PE, this electrode is denominated electrode 1 (Figures 1 and 2).

The second electrode (electrode 2) modelled is the electrode 1 but buried to certain depth.
The third electrode modelled is a formation with three electrodes 1 at certain angle α with the horizontal, this formation is named electrode type drags (Figure 3).
The simulation process inject the ray current in de superior face of electrode, and calculate the land distribution of tensions.
For the simulation is employed the different resistivity of lands and the different dimensions and typologies of electrodes.

Fig. 1: Commercial electrode of goad , electrode 1.

Fig. 2. FEM model of the electrode 1.

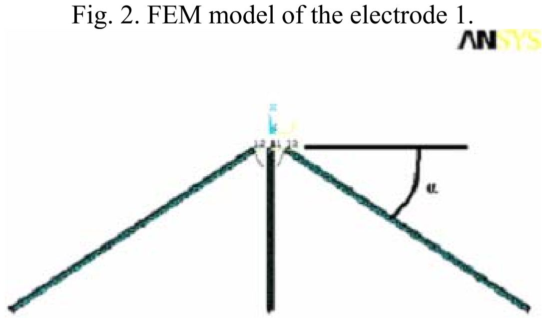

Fig. 3. FEM model of the electrode type drags.

The inductive coupling in the electrode type drags is calculated witch the methodology exposed in the work of Cortina *et al.* [2].

3. Results

Figure 4 and Table I shows the voltage distribution in the soil surface, and figure 5 shows the theoretical and the simulated results, for a copper goad of 1 meter of length and 0.02 meter of diameter and a soil resistivity equal to 100 Ωm.

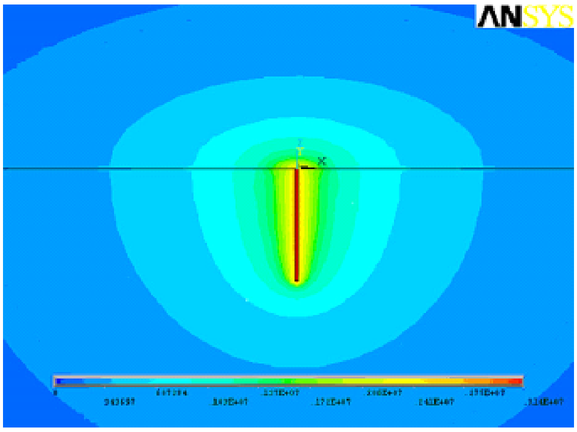

Fig. 4. Voltage distribution in the soil surface, 31 kA direct current.

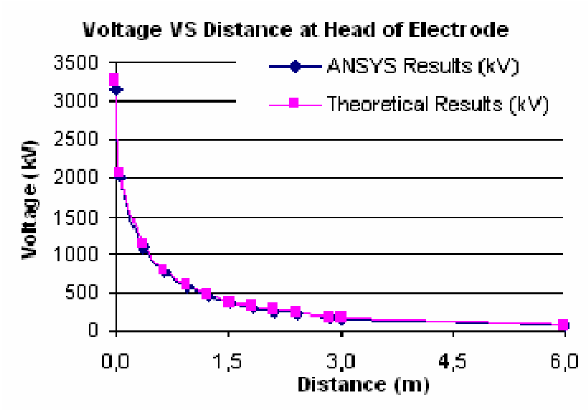

Fig. 5. Theoretical and the simulated results.

TABLE I: Voltage VS Distance at Head of Electrode

Distance (m)	ANSYS Results (kV)	Theoretical Results (kV)	Error (%)
0,0000	3142,4000	3266,2139	-3,79
0,0100	3142,4000	3232,1741	-2,78
0,0600	2016,5000	2072,0519	-2,68
0,3540	1085,7000	1130,4435	-3,96
0,6480	761,9900	787,9360	-3,29
0,9420	573,7800	603,3552	-4,90
1,2360	446,3400	469,3381	-4,90
1,5300	364,0000	379,2391	-4,02
1,8240	303,3700	321,5513	-5,65
2,1180	256,3700	275,2374	-6,85
2,4120	220,1400	237,0792	-7,14
2,8530	174,9700	172,9339	1,18
3,0000	158,3700	164,4601	-3,70
6,0000	64,8740	67,8398	-4,37

With the previous simulation the resistive part of model has been validated, that the simulation has been made injecting a DC of 31 kA.
The next step is inject a stroke current 1,2/50 of 31 kA at the same model developed.
The result of the transient simulation is represented in the next table:

TABLE II: Max. voltage VS Distance at Head of Electrode

Distance (m)	ANSYS Results (kV)
0,000	5450,96
0,010	5450,93
0,060	4325,68
0,354	3375,73
0,648	3007,70
0,942	2763,50
1,236	2568,47
1,530	2412,06
1,824	2281,28
2,118	2162,87
2,412	2063,15
2,853	1926,69
3,000	1876,73
6,000	1383,02

For the next calculations of the inductance, a serial RL circuit (Figure 6) has been considered for represented the grounding electrode.

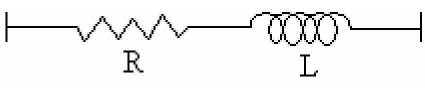

Fig. 6: Serial RL circuit considered

The inductance when the voltage is max, is:

$$L = 89,65\,\mu H \quad (1)$$

4. Conclusion

The main advantage in this models, is that any parameter can be changed, i.e., the excitation current, the resistivity, the magnetic permittivity, and the forms of the grounding electrodes.
The limitation of the proposed models is that the capacity of the grounding electrode was not considered, which is very important to obtain a more realistic model of the grounding electrode.

References

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