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ELECTRIC AND MAGNETIC FIELD DISTRIBUTION NEARBY FUEL TANK DURING LIGHTNING STRIKE

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Summary: In this paper a numerical method is proposed to simulate the lightning stroke to the center point of a large fuel tank. Computation concerned the potential, electric and magnetic fields distribution nearby tank caused by lightning current. CDEGS software from the Safe Engineering Service & Technologies was used for the simulation [6].

Keywords: direct lightning stroke, fuel tank, electric and magnetic fields, potential differences,

1. Introduction

The main damage to structure, life hazard and electric hazard of systems in oil and gas factories are caused by surge currents and voltages during lightning stroke. Additionally, lightning protection of oil and gas installations is very important in view of possibility occurrence of the explosive vapour-air mixtures at normal work conditions [3, 4].

There are two basic mechanisms by which lightning may caused damages, fire or explosion at a site. The first is a direct lightning stroke to the structure or surrounding installations. The second is caused by magnetic and electric fields during lightning stroke to nearby structure or installation. These fields induced voltage/current surges into power and signal lines or loops constructed by conductive elements.

This paper presents a method for the simulation of direct lightning stroke to the fuel tank. In this case can appear:

- strong electric and magnetic fields in the air space inside and outside the tank,
- high potential differences between the tank and conductive elements of other installation (control and electric systems).

The values of fields and potentials inside and around the tank are presented.

2. Numerical simulations

The specific numerical model of the tank in concern (built with straight cylindrical conductors of appropriate electrical parameters) is shown in Fig. 1.

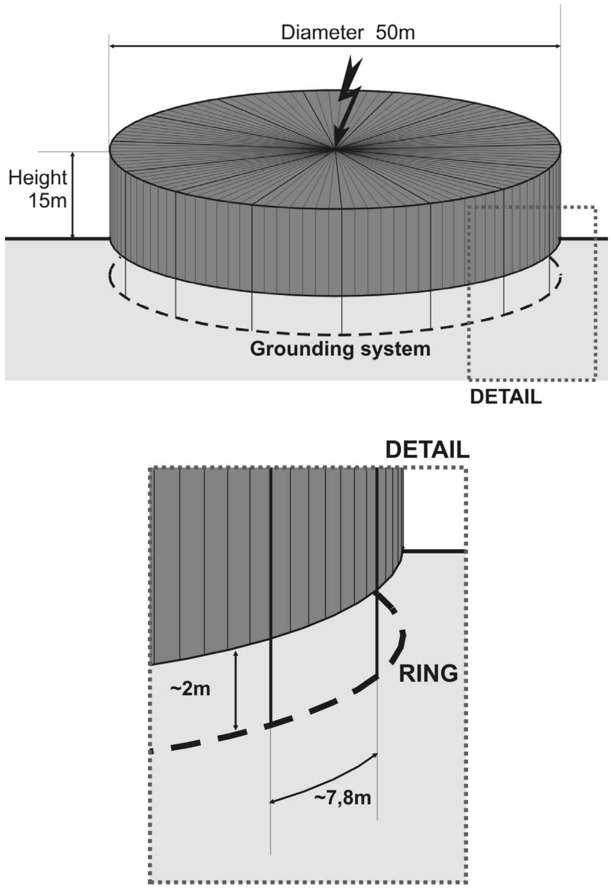

Fig. 1. Wire-grid approximation for the tank walls

Metal tank, with the following dimensions:

- diameter $2R = 50$ m,
- height $h_t = 15$ m

was presented as an inter-connecting conductor grid, forming a cage. The bottom of the tank is earthed. The earthing system consists of ring earth electrode around the tank buried at 2 m depth in homogeneous soil (uniform ground model) with resistivity ρ=100Ω·m and relative permittivity ε_r=1.

In the case of theoretical model, a direct lightning stroke was simulated by an ideal current source with the following double-exponential function:

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

where: *t - time, α= 2049,38 s*$^{-}$*, β=563 768,3 s*$^{-1}$*, I=100kA, η=0,976.*

According to the standard IEC 61312-1 [5], such a waveform is characterized by the peak value 100 kA, front time 10 μs and time to half value 350 μs (for the III protection level). This current source was connected to the middle of the roof.

3. Computation results

Electric and magnetic field strength were computed for define observations points inside and outside the tank on the vertical plane, which crossed the centre of the tank.

For electric field strength, the maximal obtained values reached 220 kV/m. Some example of the electric field shape shows fig.2.

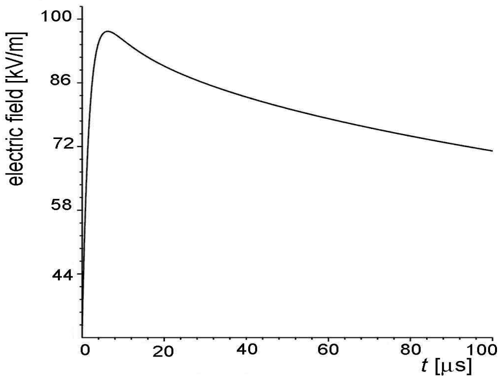

Fig. 2. The shape of electric field inside the tank

Three-dimensional perspective for the magnetic field distribution on vertical plane was presented in Fig. 3.

For the estimation of lightning dangerous it is very important to calculate the scalar potential caused by surge current.

For the analysed tank, the maximal obtained values of lightning transient scalar potential can reach 200 kV. Fig. 4 presents some example of scalar potential near the tank's wall.

4. Conclusions

A numerical procedure, based on the fields approach, has been proposed to calculate the field strength and scalar potential caused by lightning stroke into the fuel tank.

The values of electric and magnetic fields reached 200 kV/m and 26 kA/m adequately.

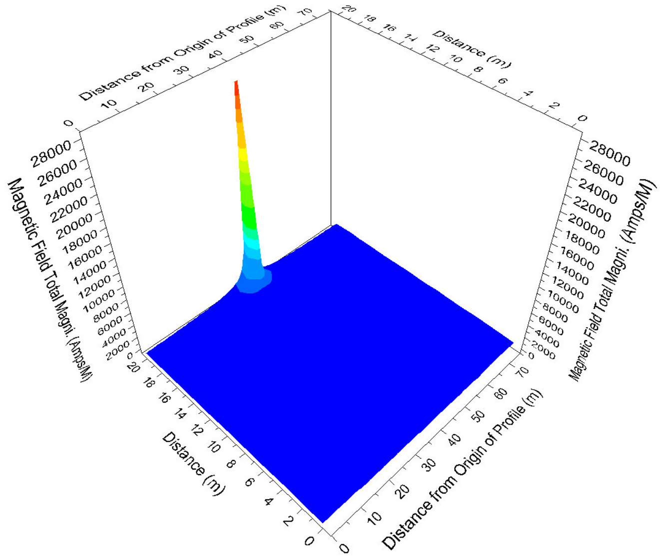

Fig. 3. Magnetic fields distribution on the plane at the time t = 8 μs

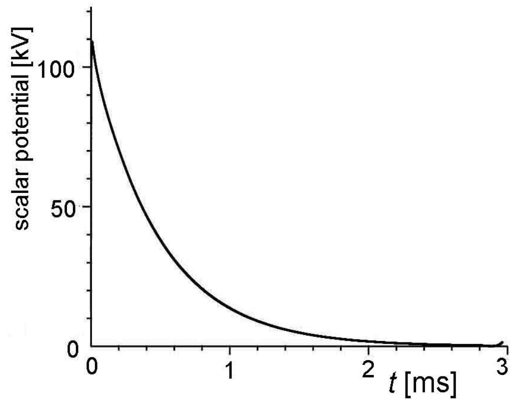

Fig. 4. Scalar potential near the wall

5. References

1. Buccella C., Orlandi A.: An Efficient Technique for the Evaluation of Lightning-Induced Voltage in a Cylindrical Vessel Containing Charged Oil. IEEE Trans. On Industry Applications, vol. 39, No.2, March/April 2003, pp.368-273
2. Durham M.O., Durham R.A.: Ground Systsem design Consideration for Vessels. IEE Industry Application Magazine, November/December 2001, pp. 41-49.
3. Mariani E., Rodriques M.: Controlling the risk of fire caused by lightning in hydrocarbon storage tanks. ICLP 2000, Rodos-Greece, 2000, pp. 786-791.
4. Mueller T., Graff D.: The Use of Surge Protection Devices in the Petrol/Petrochemical Industry. IEEE Trans. On Industry Application, vol. 34, No. 6, November/December 1998, pp.1351-1358.
5. IEC 62305-1, Protection against lightning - Part 1: General principles.
6. CDEGS - Software, Safe Engineering Services & Technologies Ltd., Montreal Canada.