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Distribution of Earth Atmospheric Electric Field in the Vicinity of the Vehicles For Transport Petroleum Derivates

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Abstract: In this paper using Equivalent Electrode Method (EEM) Atmospheric Electric Field (AEF) distribution in the vicinity of the cargo vehicle is approximately numerically determined, when the vehicles are situated on petrol station near by petrol pump and people. The petrol pump is always grounded, but human body and vehicle are treated as grounded or "floating" electrodes. Several results of electric field enhancement factor for the vehicle including maps of equienergetic curves are presented.

Keywords: Atmospheric electric field, induced charge, equivalent electrode method, vehicle.

1 Introduction

The earth atmosphere carries electric charges in the form of free ions, charged water droplets and charged ice or snow particles. These charges produce electric field at the earth's surface. In fear weather conditions the surface field - Atmospheric Electric Field is about $100\,\mathrm{V/m} - 200\,\mathrm{V/m}$ [1, 2]. Below a storm cloud, however, it is many times stronger and may reach several thousand $\mathrm{V/m}$. The aim of this paper is to determine potential and electric field distribution in the surroundings of the petroleum transport vehicles when they are exposed to the Atmospheric Electric Field. It can be assumed that in the open space, where the vehicles are located, the Atmospheric Electric Field is steady and homogeneous with normal orientations to the earth. The vehicles affect the Atmospheric Electric Field distribution and it can be shown that induced charges distributed on the their surface amplifies the

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electric field, especially on the peaks and on the edges of the vehicle, so discharge is possible.

For the determination Atmospheric Electric Field distribution Equivalent Electrode Method is used [3,4]. This method has been developed at the Faculty of Electronic Engineering in Niš, suggested by Professor Dragutin M. Veličković, and it is oriented to the approximate numerical solving of the problems of the non-rotational fields of the theoretical physics.

Because of existing practical problem of petroleum transport the several different cases are observed [5–7].

2 Theoretical Approach

In order to determine electric field and potential distribution in the surroundings of the vehicle the mathematical model of vehicle is first created. Than the vehicle is presented with flat rectangular planes which are substituted with small spherical conducting bodies, so called Equivalent Electrodes (EE), Fig.1. The Equivalent Electrodes located on the vehicles surface, have the same radius, potential and charges as the electrode part which are presented, e.g. rectangular thin plate sides $\Delta x/N_a$ and $\Delta y/N_b$, where N_a and N_b are number along sides a and b respectively (Fig. 1).

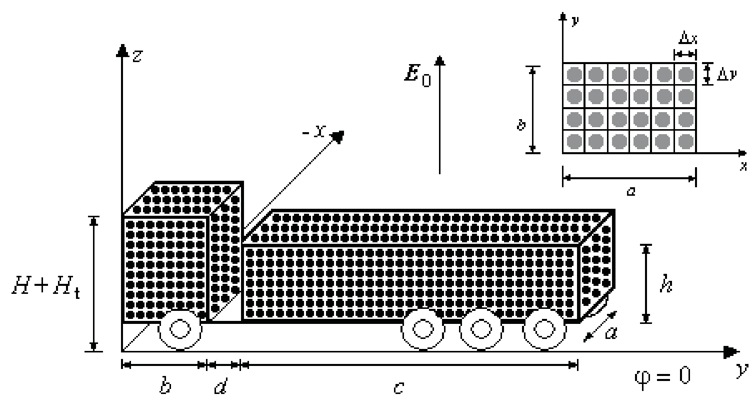

Fig. 1. Representation of the vehicle with small spherical Equivalent Electrodes
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It is necessary to point out that the model with flat rectangular planes is used in this paper because of the edge effect, although the method can be applied for different shaped models.

After taking into consideration the earth influence on the vehicle, the approximate potential expression is presented as

$$\varphi = -E_0 z + \sum_{n=1}^{N} q_n G_n, \tag{1}$$

where:

E_0 is the strength of the vertical oriented atmospheric electric field;

q_n is the charge of the n-th Equivalent Electrodes ;

$$G_n = \frac{1}{4\pi\varepsilon_0}\left(\frac{1}{|\boldsymbol{r}-\boldsymbol{r}_n|} - \frac{1}{|\boldsymbol{r}-\boldsymbol{r}'_n|}\right) \tag{2}$$

is Green's function of potential of the Equivalent Electrodes , including image component;

$\boldsymbol{r}$ is radius vector of the field point;

$\boldsymbol{r}_n$ is radius vectors of the Equivalent Electrodes middle point;

$\boldsymbol{r}'_n$ is radius vector of the Equivalent Electrodes image;

N is total number of the Equivalent Electrodes ; and

ε_0 is air permittivity.

Using boundary condition that the potential of the vehicle and of the Equivalent Electrodes is equal, system of N linear equations can be put. After solving this linear equations the unknown charges of the Equivalent Electrodes , q_n, $n = 1, 2, \dots, N$ will be determined, and other values of interest can be evaluated in standard way.

The strength of the local electric field on the surface of the vehicle can be determined by the formula

$$E_{\mathrm{n}n} = \frac{q_n}{S_n \varepsilon_0}, \tag{3}$$

where q_n is the charge and S_n is the surface of the n-th Equivalent Electrodes .

If we presume that parallelepiped models of humans and pump are also conductors [8–11], the induced charges are distributed on their surface and applications of the Equivalent Electrode Method are the same as on the vehicles.

3 Numerical Results

On the basis of the presented theoretical analysis one general computer program is make and numerous calculations are realized. The part of obtained results will be presented in this paper.

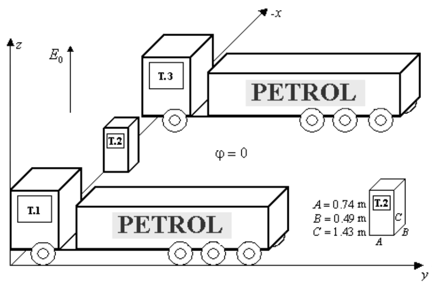

Fig. 2. Petrol pump (T2) and vehicles (T1 and T3). Petrol pump is placed between vehicles at a distances $x = 0.9\,\mathrm{m}$ and $x = 0.6\,\mathrm{m}$.

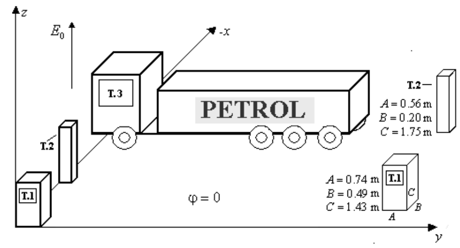

Fig. 3. Petrol pump (T1), human body (T2) and vehicle (T3). The human body is placed between petrol pump and vehicle at a distance $x = 0.9\,\mathrm{m}$.

Two different cases are observed. First, when the vehicle is placed in vicinity of the other vehicle, Fig. 2 and second, when the human body is placed between vehicle and petrol pump, Fig. 3. Dimension of the vehicle is $a = 2.5\,\mathrm{m}$, $b = 2.2\,\mathrm{m}$, $c = 9\,\mathrm{m}$, $d = 0.5\,\mathrm{m}$, $h = 2\,\mathrm{m}$, $H + H_t = 3.6\,\mathrm{m}$ and other dimension is shown in Figs. 2 and 3. The petrol pump is always grounded, but human body and vehicle are treated as grounded or “floating” electrodes.

The Atmospheric Electric Field distribution is in the vicinity of the petroleum transport vehicles is presented with map of equienergetic curves, Figs. 4, 5, 6, 7 and 8.

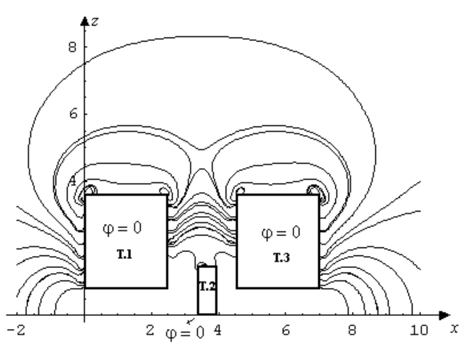

Fig. 4. Equienergetic curves in plane $y = 0.2\,\mathrm{m}$. Petrol pump (T2) and vehicles (T1 and T3) are grounded.

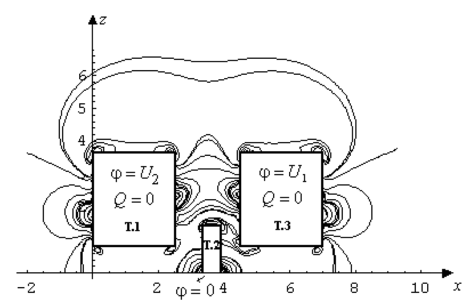

Fig. 5. Equienergetic curves in plane $y = 0.2\,\mathrm{m}$. Vehicles (T1 and T3) are not grounded and petrol pump (T2) is grounded.

Maps of equienergetic curves defining the geometric positions of the points of constant intensity of the electric strength, or constant energy volume densities,

$$
\begin{aligned}
E &= |\boldsymbol{E}| = \mathrm{C}^{\mathrm{te}}, \\
w_e &= \frac{1}{2}\varepsilon E^2 = \mathrm{C}^{\mathrm{te}}.
\end{aligned}
\tag{4}
$$

Knowing shapes and position of equienergetic curves is necessary in order to determine areas in which breakdown and ignition are possible.

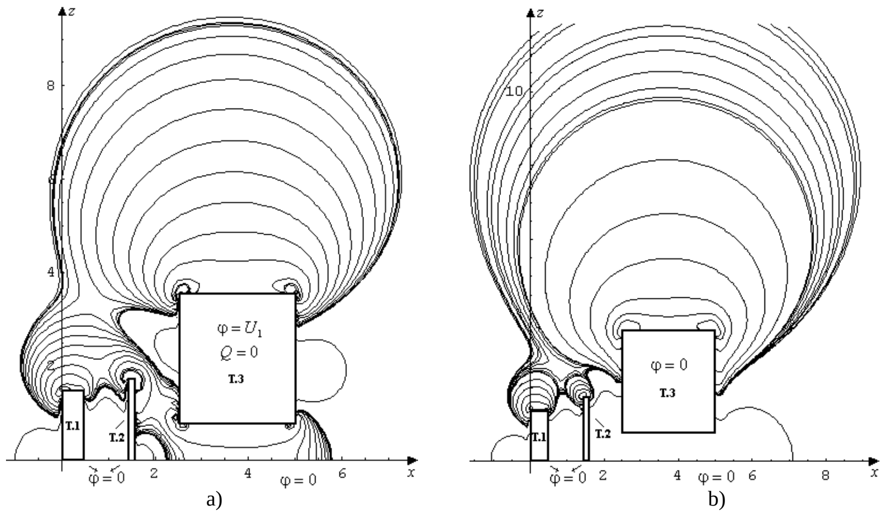

Fig. 6. Equienergetic curves in the plane $y = 0.2\,\mathrm{m}$: a) Human body (T2), petrol pump (T1) and vehicle (T3) are grounded; b) Human body (T2) and petrol pump (T1) are grounded and vehicle (T3) is ungrounded.

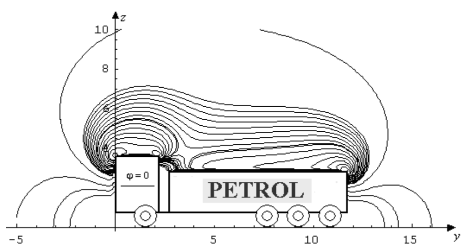

Fig. 7. Equienergetic curves in the plane $x = -3.75\,\mathrm{m}$. (Human body (T2), petrol pump (T1) and vehicle (T3) are grounded).

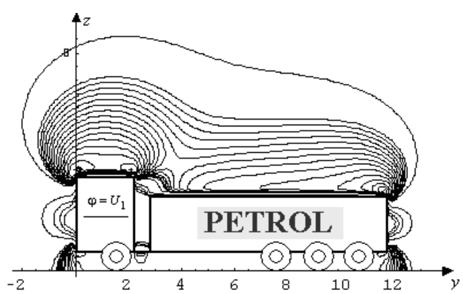

Fig. 8. Equienergetic curves in the plane $x = -3.75\,\mathrm{m}$. (Human body (T2) and petrol pump (T1) are grounded and vehicle (T3) is ungrounded).

The greater values of enhancement factor, which is defined as the ratio of the electric field strength on the surface to the impressed electric field for the vehicle,

$$k = \frac{E_n}{E_0} \tag{5}$$

exist on the cabin surface, Fig. 9.

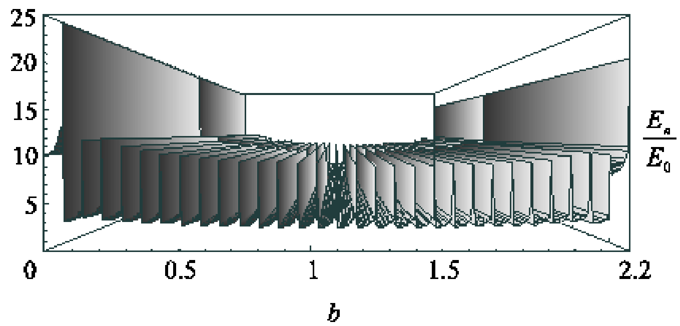

Fig. 9. Electric field enhancement on the cabin surface.

The maximum values of electric field enhancement factor k, for different ratio $a/\Delta x$ is presented in Fig. 10. The results presented in Fig. 10 refer to the isolated grounded vehicle. By decreasing Δx (thus increasing the number of EE aling the side a) the electrical field strength on the cabin surface determined with higher accuracy, especially in vicinity of the cabin wedges where it is strongest.

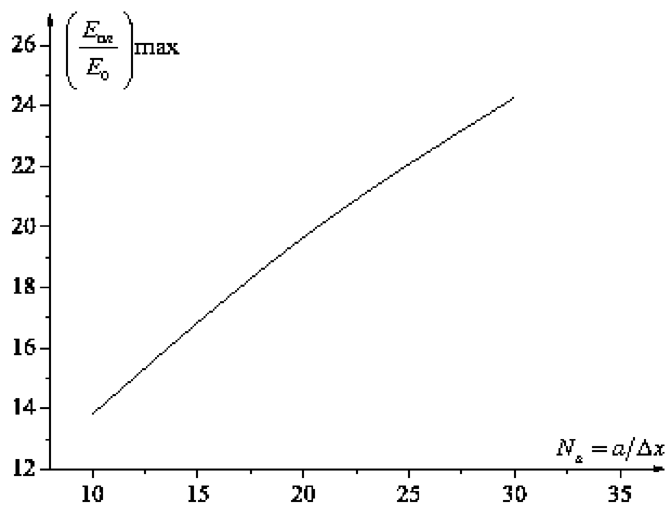

Fig. 10. Maximum values of the electric field enhancement factor for different ratio $a/\Delta x$. N_a is the number of EE along the side a.

4 Conclusion

Distribution of earth atmospheric electric field in the vicinity of the vehicles for transport petroleum derivates is determined using potential integral equation and Equivalent Electrode Method for its solution. Several cases are observed. The obtained results are presented with map of equienergetic curves. Knowing shapes and position of equienergetic curves is necessary in order to determine areas in which breakdown and ignition are possible. The difference between equienergetic curves of grounded and ungrounded vehicles are very significant. When the vehicles are grounded the induced charges distributed on their surface amplifies the electric field especially on the peak and on the edges of the vehicles, so discharge is possible. The greatest values of electric field enhancement exist on the cabin surface.

In this paper the vehicles with flat rectangular planes are observed, because of the edge effect. The latter investigations will be oriented for different shaped models.

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