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An Influence of the Petrol Pump for the Atmospheric Electric Field Distribution in the Surroundings of the Vehicles

Alenka Milovanović [1]

Abstract: In this paper the potential and electric field distribution in the surroundings of the cargo vehicles is approximately numerically determined, when they are exposed to the Atmospheric Electric Field (AEF), having uniform intensity and vertical polarisation. The cases of the cargo vehicles either isolated or near by petrol pumps are observed. Several results of total induced charge and electrical moment of the vehicle, including maps of equipotential and equienergetic curves are presented. The Equivalent Eelectrode Method (EEM) is used to solve this problem.

Keywords: Electrostatic Field, Equivalent Eelectrode Method, Vehicle.

1 Introduction

One of the biggest problems in petrol industry is static electricity. Every year static electric sparks cause ignition, explosion or fire whether in process of refining petroleum or during pouring and transportation petroleum and its derivates. Over the last few years a number of fires occurred on petrol stations in Europe and USA [1]. Because of that there is needed to investigate electric field distribution surroundings vehicles which transport petroleum derivates.

For the eliminations of static electricity the vehicles which transport petroleum derivates, are grounded with special procedure. But it can be shown that it's not always enough. Because of existing external electric field (field generated by static electricity or field made by electric power plant), the induced charge distributed on their surface affects the electric field distribution, amplifies the electric field, especially on the peaks and on the edges of the vehicles, so discharges are possible.

In this paper the potential and AEF distribution in the surroundings of the grounded cargo vehicles will be determined, when the vehicles are isolated and stand still and when the vehicles are situated on petrol station near by petrol pumps.

The intensities of the AEF are approximately $100\ \mathrm{V/m}$ - $130\ \mathrm{V/m}$ for an ordinary summer day and increase considerably in the thunderstorm can reach several thousand $\mathrm{V/m}$. Such AEF is practically steady with normal orientation to the earth. Existing

[1] Faculty of Technical Engineering, University of Kragujevac, Svetog Save 65, 32 000 ^ačak, Serbia&Montenegro, Phone: +38 32 342 101, E-mail: alenka@tfc.kg.ac.yu

object on the earth surface perturb the atmospheric electric field, so the AEF distribution in urban region is very complex [2]. It can be assumed that in the open space, where the vehicles are located, the AEF is steady and homogeneous with normal orientations to the earth, so in this paper the influence of the vehicles to the electric field distribution is observed on the adequate conductive model exposed to AEF with normal orientations to the earth having zero potential.

The AEF distribution is determined using electric scalar potential integral equations and EEM for its numerically solution [3]. The Equivalent Electrode Method has been developed at the Faculty of Electronic Engineering in Niš (Serbia and Montenegro), 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.

2 Theoretical Approach

In order to determine electric field and potential distribution in the surrouncle 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 EE located on the vehicles surface, have the same radius, potential and charges as the electrode part which are presented.

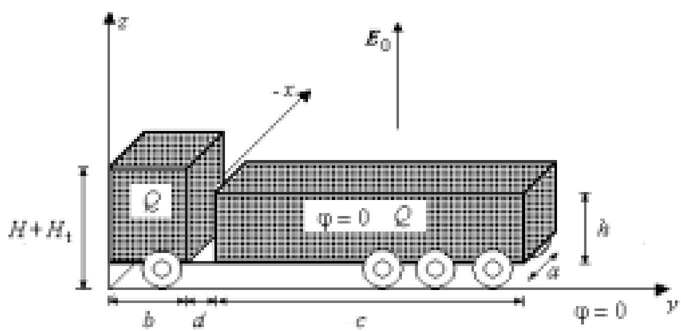

Fig. 1 - *Mathematical model of vehicle.*

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.

When the vehicles is grounded and stand still, vehicle potential is equal to the earth potential having zero value. The total induced charge on the vehicles surface is Q. After taking into consideration the earth influence on the vehicle by method of images the approximate potential expression is presented as

$$\varphi = -E_0 z + \frac{1}{4\pi\varepsilon_0}\sum_{n=1}^{N} q_n \left(\frac{1}{|\mathbf{r}-\mathbf{r}_n|} - \frac{1}{|\mathbf{r}-\mathbf{r}'_n|} \right), \qquad (1)$$

where:

E_0 is the strength of the vertical oriented atmospheric electric field;
q_n is the charge of the $n-$ th EE;
N is total number of the EE;
$\boldsymbol{r}$ is radius vector of the field point;
$\boldsymbol{r}_n$ is radius vectors of the EE middle point; and
$\boldsymbol{r}_n'$ is radius vector of the EE image.

Using boundary condition that the potential of the vehicle and of the EE is equal to zero, the system of N linear equations can be put, $\varphi = 0$, $n = 1,2,..., N$.

After solving this linear equations the unknown charges of the EE, q_n , $n = 1,2,..., N$ will be determined. So the total induced charge on the vehicle and the electrical moment of the vehicle, which defines the electrical properties of the vehicle at the largest distance is

$$Q = \sum_{n=1}^{N} q_n \,, \quad \boldsymbol{p} = p\hat{\boldsymbol{z}}, \quad p = 2\sum_{n=1}^{N} q_n z_n \,. \tag{2}$$

Also, it is possible to determine the total induced charge of the single parts of the vehicle, for example trailer, or cabin, if the charges of the equivalent electrodes, which present observed part of the vehicle, are added.

The strength of the electric field on the vehicles surface can be determined by the formula (3),

$$E_n = \frac{q_n}{S_n \varepsilon_0}, \tag{3}$$

where q_n is the charge and S_n is the surface of the $n-$th EE .

When the vehicle is situated in petrol station near by petrol pumps which are always grounded, Fig. 2, pumps affect the AEF distribution in the vicinity of the vehicle. If we know that pumps are also conductors, the induced charges are distributed on their surface and applications of the EEM are the same as on the vehicles. Parallelepipeds models of petrol pumps are also replaced by EE and the approximate potential expression is presented as

$$\varphi = -E_0 z + \frac{1}{4\pi\varepsilon_0} \sum_{n=1}^{N_\mathrm{u}} q_n \left(\frac{1}{|\boldsymbol{r} - \boldsymbol{r}_n|} - \frac{1}{|\boldsymbol{r} - \boldsymbol{r}_n'|} \right), \tag{4}$$

where $N_\mathrm{u} = N_\mathrm{V} + N_\mathrm{P}$ is total number of the EE. N_V and N_P are total number of the EE on the surface of the vehicle and pumps. So the total induced charge on the vehicle and pump is

$$Q_{\mathrm{V}i} = \sum_{n=1}^{N_\mathrm{V}} q_n \quad \text{and} \quad Q_{\mathrm{P}i} = \sum_{n=N_\mathrm{V}+1}^{N_\mathrm{P}} q_n \,.$$

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. The position of the vehicle (T2) related to pumps (T1 and T3) is presented in Fig. 2 .

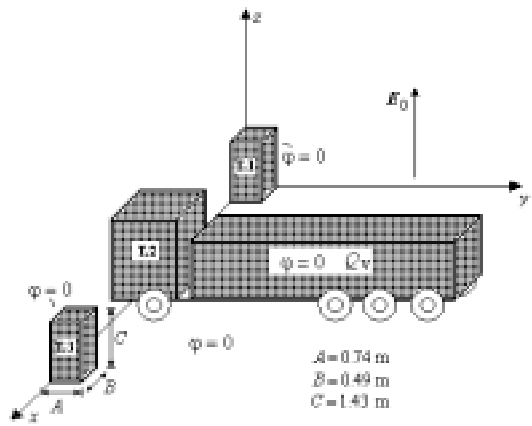

Fig. 2 - *The vehicle near by petrol pumps.*

Table 1

Convergence and accuracy of the results of total induced charge of the vehicle and electrical moment of the vehicle with number of the used EE, Fig. 1, when $a = 2.5\,\text{m}$, $b = 2.2\,\text{m}$, $c = 9\,\text{m}$, $d = 0.5\,\text{m}$, $h = 2\,\text{m}$, $H = 2.8\,\text{m}$ *and* $h_1 = H + H_t = 3.6\,\text{m}$.

Number of *EE* N	$\dfrac{Q}{4\pi\varepsilon_0 h_1^2 E_0}$	$\dfrac{p}{4\pi\varepsilon_0 h_1^3 E_0}$
96	0. 961 441 0	1. 462 885 3
384	0. 960 823 5	1. 448 327 4
600	0. 959 055 6	1. 444 338 0
864	0. 957 531 1	1. 439 531 5
1176	0. 956 256 7	1. 436 452 9
1536	0. 955 187 7	1. 433 939 0
1944	0. 954 282 9	1. 431 847 8
2400	0. 953 508 9	1. 430 080 0

The convergence and the accuracy of the obtained results for total induced charge of the isolated grounded vehicle Fig. 1 and electrical moment of the vehicle, with the number of used EE are presented in the **Table 1**.

The comparison of the results of total induced charge of the vehicles surface for isolated vehicle and vehicle near by petrol pumps (one or two) are presented in **Table 2**, when the number of EE is $N_V = 2400$. Dimension of the pumps are shown in Fig. 2.

Table 2

Comparison of the results of the total induced charge of the vehicles surface.

The position of the vehicle related to the pumps	$\frac{Q}{4\pi\varepsilon_0 h_1^2 E_0}$
Isolated vehicle	0. 953 508 9
The vehicle near by petrol pump at a distance $x = 1\,\mathrm{m}$	1. 019 594 0
The vehicle near by petrol pump at a distance $x = 2\,\mathrm{m}$	1. 050 512 8
The vehicle between petrol pumps at a distances $x = 1\,\mathrm{m}$ and $x = 2\,\mathrm{m}$.	1. 013 973 3

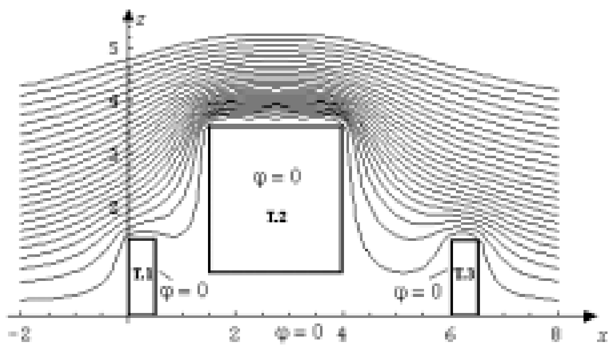

Fig. 3 - *Equipotental curves in the plane $y = 0.2$ m .*
(The grounded vehicle (T.2) is placed between petrol pumps (T1) and (T3) at a distances $x = 1\,\mathrm{m}$ and $x = 2\,\mathrm{m}$).

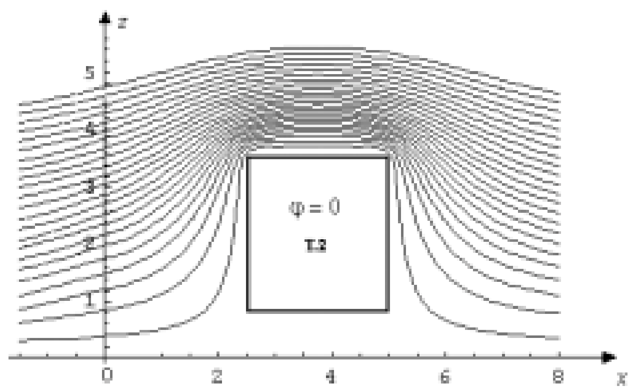

Fig. 4 - *Equipotental curves in the plane $y = 2.2\,\mathrm{m}$, which contain only grounded vehicle. (The vehicle (T.2) is placed near by petrol pump at a distance $x = 2\,\mathrm{m}$).*

The equipotential curves in several characteristic planes when the vehicle is situated in petrol station near by petrol pumps are presented in Figs. 3 and 4. The influence of the pump for the atmospheric electric field distribution in the surroundings of the vehicles is evident. The equienergetic curves in several characteristic planes, when the vehicle is placed near by petrol pumps, are presented in Figs. 5, 6 and 7.

The equienergetic curves in the proximity of the vehicle when petrol pump and human being situate it near are shown in Fig. 8. The human body is placed between petrol pump and vehicle at a distance $x = 0.9$ m. We presume that human being is also conductor [5-8] and in this case is grounded. Dimensions of the parallelepiped model of human body are: $A = 0.56$ m, $B = 0.2$ m and $C = 0.75$ m.

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

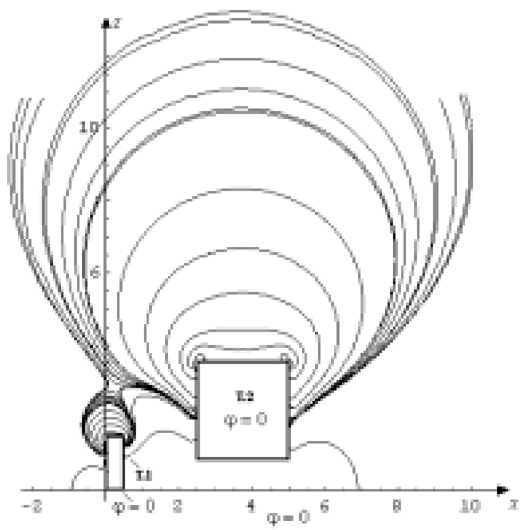

Fig. 5 - *Equienergetic curves in the plane* $y = 0.2$ m.
(The vehicle (T.2) is placed near by petrol pump (T1) at a distance $x = 2$ m*).*

4 Conclusion

The AEF distribution in the surroundings of the cargo vehicles either isolated or near by petrol pumps is determined using potential integral equation end EEM for its numerical solution. In limit process with the number of the EE the method gives exact results but very good results can be obtained using several hundred to several thousand of EE. The AEF distribution in the surrounding of the vehicle when petrol pump or human being situates it near is very complex. The influence of the pump for the AEF distribution is evident. The total induced charge of the vehicles surface depend on the shape of the vehicle, existing object in vicinity of the vehicle and intensity of the external electric field.

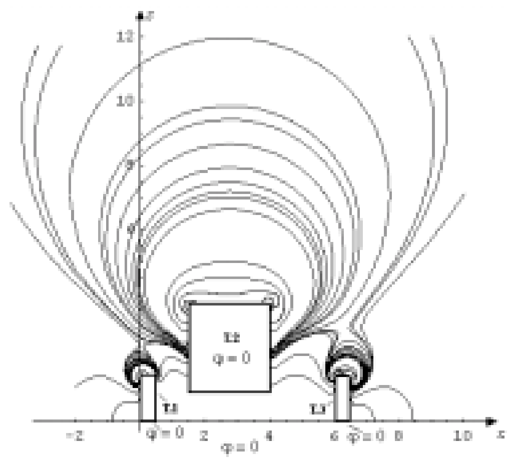

Fig. 6 - *Equienergetic curves in the plane* $y = 0.2$ m *,when the grounded vehicle (T.2) is placed between petrol pumps (T1) and (T3) at a distances* $x = 1$ m *and* $x = 2$ m .

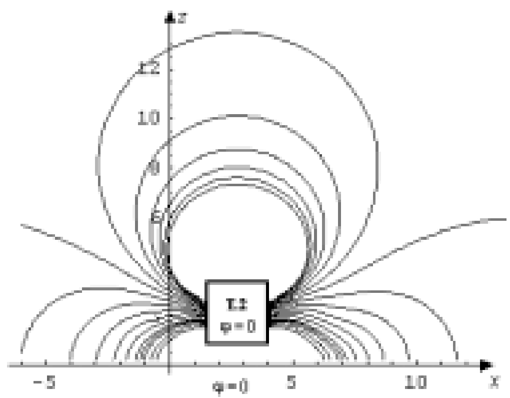

Fig. 7 - *Equienergetic curves in the plane which contains only grounded vehicle (T.2), placed between petrol pumps (T1) and (T3) at a distances* $x = 1$ m *and* $x = 2$ m .

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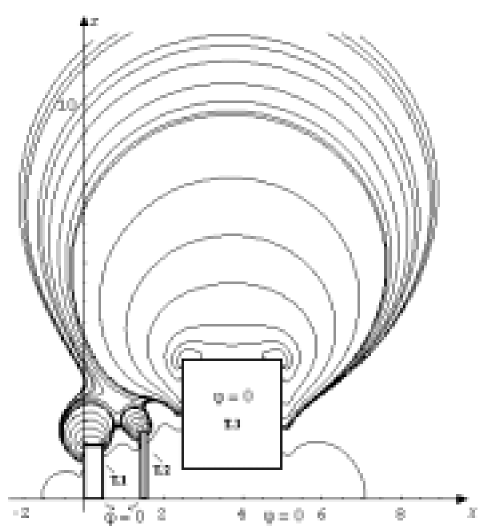

Fig. 8 - *Equienergetic curves in the plane* $y = 0.2$ m .

The human body (T2) is placed between petrol pump (T1) and vehicle (T3).