EFFECTS OF ELECTRICAL SOIL PROPERTIES ON ELECTRIC FIELDS AROUND EHV TRANSMISSION LINES

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ABSTRACT - This paper discuss the effect of the electrical properties of soil, permittivity and conductivity, on the electric field values around EHV transmission lines. Also, this paper studies the effect of soil thickness on the field values. The assessment of such electric fields is based on the charge simulation technique with complex fictitious charges. A simultaneous combinations of finite realistic earth conductivity and permittivity are considered. The field values obtained by this technique are compared with those obtained by using a boundary element method. Also, a comparative study is done between the field values obtained by this technique and those obtained by measurements.

KeyWords: Electric fields, Electrical properties of soil

I. INTRODUCTION

The prospects of hazard related to electric fields emanating from power lines still draw worldwide attention [1-4]. Environmental studies of power lines are necessary to provide a scientific basis for interpreting the kinds of impacts that are most apparent to persons who live, work, or recreate near such lines. It is essential to predict accurately the magnitudes of these fields.

It is believed that the ground underneath the transmission lines, specially at the middle east region, is not a pure conductor. Large lengths of power lines are erected above a dry sandy soil ground, where its thickness depends on the underground moisture level. Computations of the electric field based on the assumption that the earth is either a pure conductor or lossless dielectric have been adequately presented [5-7]. The effect of both, soil permittivity and soil conductivity, on the field values is limited in scope and literature.

This paper evaluates the electric fields underneath EHV transmission lines in view of soil electrical properties. The charge simulation technique with complex fictitious charges is the principle tool used in the computation. This paper discusses also the effect of soil permittivity, conductivity and thickness on the computed electric field.

II. ELECTRIC FIELD CALCULATION

The line conductors are simulated by a discrete set of inner charge distribution, whose position and type are predetermined, but whose magnitude is unknown. The air-soil interface is to be simulated by a discrete fictitious line charges. The choice of numbers and locations of simulating charges and the constraint boundary charges are reached by following a long process of iterative optimization.

Fictitious charges $Q(j), Q_A(j)$ and $Q_B(j)$ are numbered as j=1 ~ k, k+1 ~ m and m+1 ~ N for conductors, air dielectric and soil dielectric, respectively.

In order to determine the simulating charges, a system of equations is formulating by imposing the following boundary conditions [8]:

(a) On the electrode surfaces :

$$\sum_j p(i,j)\,Q(j) + \sum_j P(i,j)\,Q_B(j) = V_i \qquad (1)$$

(b) Potential continuity on the air-soil interface:

$$\sum_j P(i,j)\,Q_A(j) - \sum_j P(i,j)\,Q_B(j) = 0 \qquad (2)$$

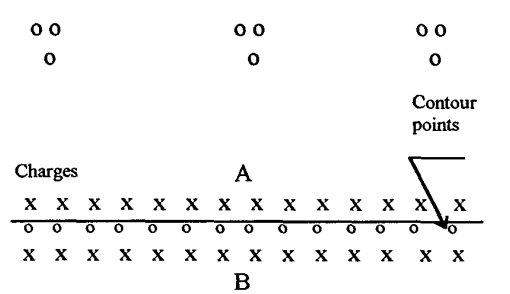

Fig.1 EHV line simulation

(c) Continuity of normal flux density (D_n) on the air-soil interface:

$$\left(\varepsilon_A + \frac{1}{j\omega\,\rho_A}\right)\left(\sum_j F_n(i,j)\dot{Q}(j) + \sum_j F_n(i,j)Q_A(j)\right)$$

$$-\left(\varepsilon_B + \frac{1}{j\omega\,\rho_B}\right)\left(\sum_j F_n(i,j)\dot{Q}(j) + \sum_j F_n(i,j)Q_B(j)\right)$$

$$= 0$$

where F_n is the normal field coefficient, ε_A and ε_B are the permittivities of the air and soil, respectively and σ_A and σ_B are the conductivities of the air and soil, respectively.

III. RESULTS AND DISCUSSIONS

The analysis of this paper is applied to the case of a typical 500 kV transmission line such as that between High-Dam and Cairo in Egypt, typically with flat phase configuration, three subconductors per phase (3x30.6 mm), phase spacing of 12 m, minimum clearance to ground of 9 m, and a span of 400 m. The conductors height at tower is 19.1 m. The right-of-way (r.o.w) is taken as 25 meters away from the center line of tower as specified by the Egyptian Electricity Authority. The electric field distribution near EHV transmission lines are computed at mid-span of the transmission line and at 1 m above terrain level, which is the standard reference height. The depth of underground water (D) is usually taken as 5 meters.

Fig.2 shows the lateral distributions of electric field strength obtained by Charge Simulation Method (CSM) compared with that obtained by Boundary Element Method (BEM) [9] and those obtained by measurement. The comparison shows a good agreement between the electric field values obtained by the charge simulation method and the measured values.

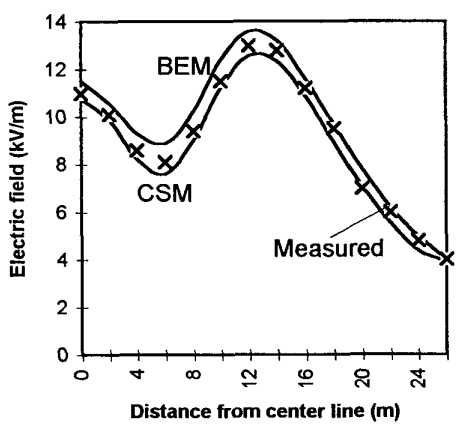

Fig.2. Electric field distribution

$\sigma = 0.01\ \mu S/m$, $\varepsilon_r = 4$

Fig.3 shows the electric field distribution under the typical 500 kV line at different longitudinal distances, Z, from mid-span. The electric field values are maximum at mid-span, where the conductors clearance to ground is minimum.

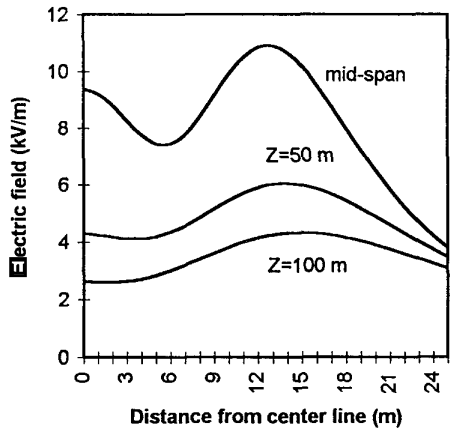

Fig.3 Field profiles at different longitudinal distances from mid-span
$\sigma = 1.E\text{-}10$ S/m, $\varepsilon_r = 3$, D = 5 m

The effect of the soil permittivity on the electric field lateral distribution at mid-span is shown in Fig.4. It is noticed that the electrical field values increased as the soil permittivity increased. It is also seen that the maximum increasing is at the outermost conductor.

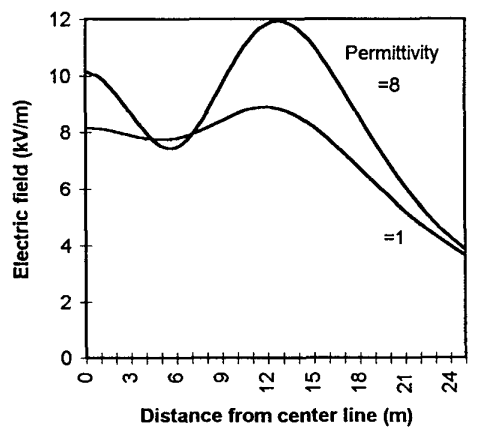

Fig.4 Electric field distribution at different soil permittivity
$\sigma = 1.E\text{-}10$ S/m, D=5 m

The effect of the soil permittivity on the maximum value of the electric field (Em) and the electric field values at right-of-way (Er.o.w) is shown in Fig.5. It is seen that the maximum value of the electric field increased with increasing the soil relative permittivity, while the electric field at right-of-way is approximately constant.

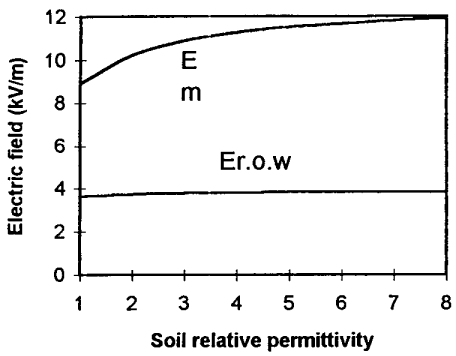

Fig.5 Effect soil relative permittivity
σ =1.E-10 S/m, D =5 m

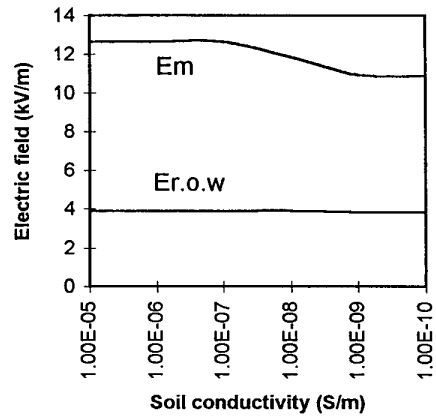

Fig.7 Effect of soil conductivity
ε_r = 3, D =5 m

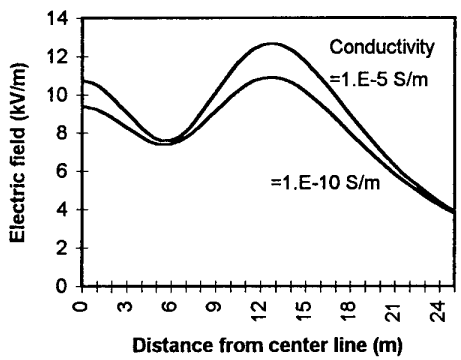

Fig.6 Electric field distribution at different soil conductivity
ε_r = 3 D=5 m

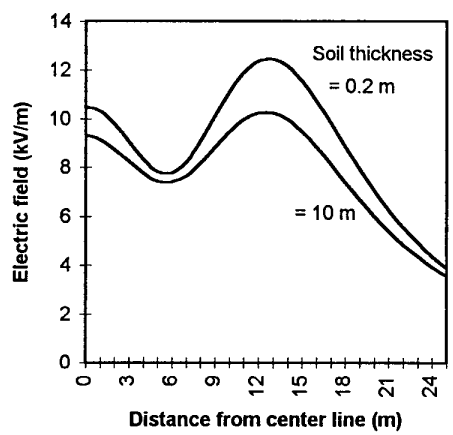

Fig.8 Electric field distribution at different soil thickness
ε_r = 3, σ = 1.E10 S/m

The effect of the soil conductivity on the electric field lateral distribution at mid-span is shown in Fig.6. It is noticed that the electrical field values increased as the soil conductivity increased.

Fig.7 shows the effect of the soil conductivity on the maximum value of the electric field and the electric field values at right-of-way. It is noticed that the maximum value of the electric field is constant with decreasing soil conductivity till it reaches 10^{-7} S/m, then it decreases with decreasing soil conductivity. The electric field at right-of-way is approximately constant with decreasing soil conductivity.

The effect of the soil thickness on the electric field lateral distribution at mid-span is shown in Fig.8. It is noticed that the electrical field values increased as the soil thickness decreased.

The effect of the soil thickness on the maximum value of the electric field and the electric field values at right-of-way is shown in Fig.9. It is seen that the maximum value of the electric field decreased with increasing the soil thickness, while the electric field at right-of-way is slightly decreased.

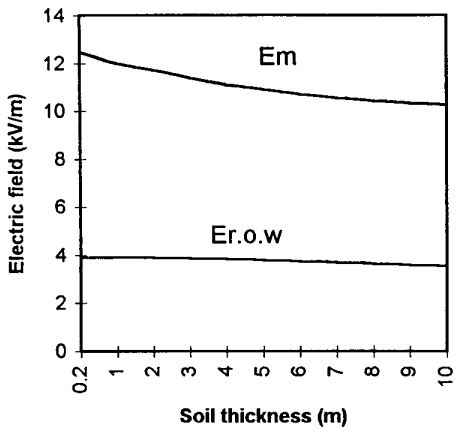

Fig.9. Effect of soil thickness
σ =1.E-10 S/m, ε_r = 3

IV. CONCLUSIONS

1. The CSM with complex fictitious charges is successfully used to compute electric field of transmission lines in view of soil electrical properties.
2. The peak value of electric field increased with increasing both soil permittivity and soil conductivity, while it decreased with increasing soil thickness.
3. A slight variation in the right-of-way electric field value is shown with increasing soil permittivity, conductivity and thickness.

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VI. BIOGRAPHIES

Mousa Abd-Allah was born in Cairo, Egypt, on August 16, 1961. He received his B.Sc. and Msc. degrees from Zagazig University, Egypt, and his Ph.D. degree from Cairo University, Egypt. Since 1997, he is an Associate Prof. in Zagazig University. His main research interests include electromagnetic fields assessment, mitigation, mitigation and environmental impacts.