2003년도 대한전기학회 하계학술대회 논문집 2003.7.21-23

# 유한요소법을 이용한 쌍극자 공간전하 방전분산형 피뢰침 정전유도구체의 국부전계 해석

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# Local Electric Field Analysis for Evaluation of Charge Transfer System Using Sequential Sub-window Techniq

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**Abstract** - In this study, in order to increase electric field intensity near a lightning rod a floating conductor is adopted. If a floating conductor is located near the lightning rod, the positive and negative charges are equally induced on the lightning rod and the floating conductor, and the local electric field intensity near them increases. This increase of electric field intensity can ignite easily the ionization process of the surrounding air and the corona phenomenon begins there. It occurs before the usual lightning process begins on the top of the conventional rod. The charges of the ground or some buildings are emitted during the corona process through the floating conductor. Therefore, the probability of the main lightning on the conventional rod can be reduced.

## 1. Introduction

The use of floating conductor in charge transfer system can generate easily corona on conductor surface. The aim of this study is to investigate this phenomenon theoretically and qualitatively and to evaluate its effect numerically and quantitatively. The precise analysis of electric field intensity on conductor surface is fundamentally required to evaluate where the initial ionization begins and how much it occurs.

Since a floating conductor has a net charge of zero, it is electrically neutral. But as it comes close to a charged body, some charges, positive or negative, are induced on a side of the conductor surface and its corresponding opposite charges are also induced on the other side of the conductor. Of course, the sum of the charges on the conductor surface is zero. The potential of the neutral floating conductor is not zero and it depends on the geometry of the system.

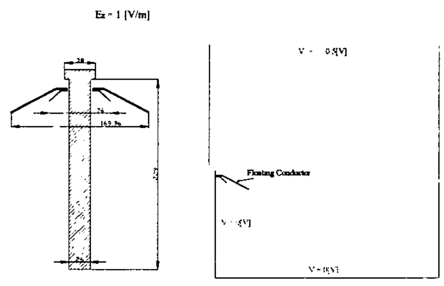
In this study, in order to increase electric field intensity near a lightning rod a floating conductor is adopted. If a floating conductor is located near the lightning rod, the positive and negative charges are equally induced on the lightning rod and the floating conductor, and the local electric field intensity near them increases. This increase of electric field intensity can ignite easily the ionization process of the surrounding air and the corona phenomenon begins there. It occurs before the usual lightning process begins on the top of the conventional rod. The charges of the ground or some buildings are emitted during the corona process through the floating conductor. Therefore, the probability of the main lightning on the conventional rod can be reduced.

The partial differential equation governing the electrostatic system is derived from Maxwell's equations and it is represented as a Laplace equation of boundary value problem. This kind of problem can be calculated effectively using the finite element method that can be generally applied to complex structured problems.

## 2. Analysis Of Electric Field of Bipolar Air Terminals and Discussion

A bipolar conventional air terminal consists of conventional lightning rod and umbrella typed conductor which make it easy to ignite ionization process in the air between the rod and the floating conductor. Since the geometry of bipolar conventional air terminal is axisymmetric, it is modeled by an axisymmetric electrostatic problem. For the analysis of the bipolar conventional air terminal, an accurate calculation of electric field is required since it determines where the initial ionization process will start. The finite element method (FEM) is used for electric field calculation.

Figure 1 shows the bipolar conventional air terminal and its finite element model. To calculate the electric fields due to the lightning, the thunderstorm cloud is represented by a simple electrode on the top line where 0.5[V] is applied to make normalized external field by 1 [V/m]. The floating boundary condition is applied to the conductor, because it is not linked to electrically any other bod



(a) Cylindrical bipolar air terminal    (b) Finite element model

Fig. 1. Model description

The analysis region is discretized into 33,958 triangular elements with the first order shape function and the corresponding 17,104 nodes as shown in Fig. 2. The finite element method is applied to the model and its numerical results are obtained. Figure 3 shows the equi-potential lines.

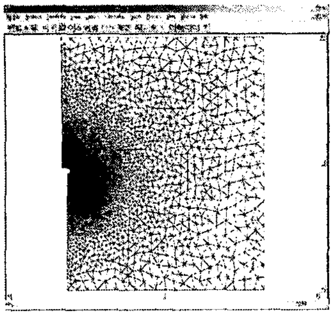


Fig. 2. Finite element mesh

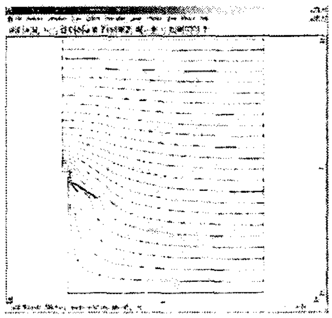


Fig. 3. Equi-potential lines

To closely examine the electric field near the floating conductor, this part is zoomed using sequential sub-window technique as shown in Fig. 4. It shows the equi-potential lines near the floating conductor where we can see that the electric field intensity between the rod andthe floating conductor is the strongest. And the highest value of electric field is about 87 [V/m] which is 87 times stronger than the applied external field as show in Fig 5. The electric field distribution near the floating conductor is shown in Fig. 6.The induced voltage of the floating conductor is 0.095 [V] which relate to the capacitance between the rod and the floating conductor.

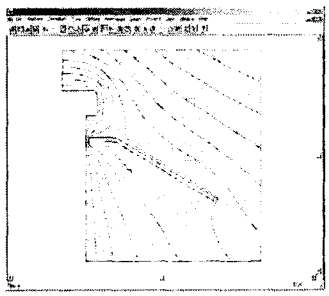


Fig. 4. Equi-potential lines near the floating conductor

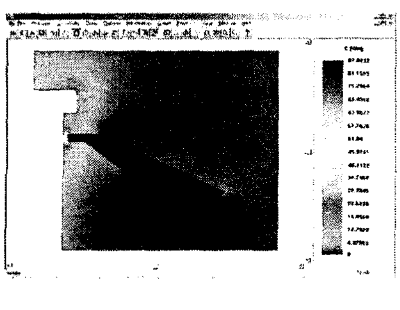


Fig. 5. Electric field intensity near the floating conductor

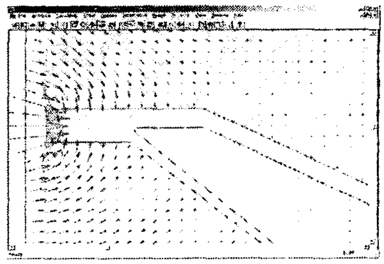


Fig. 6. Electric field distribution near the floating conductor

The induced charge density on conductor surface surrounded by air is calculated by

$$\rho_s = D_n = \varepsilon_o \frac{\partial V}{\partial n} \qquad (1)$$

where $D_n$ is the normal component of electric flux density, $\varepsilon_o$ is the permittivity in free space, $V$ is electric scalar potential and $n$ is the outward normal unit vector on the floating conductor surface. To examine discharge characteristics, the induced charge densities is calculated along the surface as shown in Fig.7 and its result is shown in Fig 8 where we can see that the electric field is concentrated at the between the rod and the floating conductor. From this result, we can infer that the air between the rod and the floating conductor is ionized before the lightning current is conducted at the top of the ro

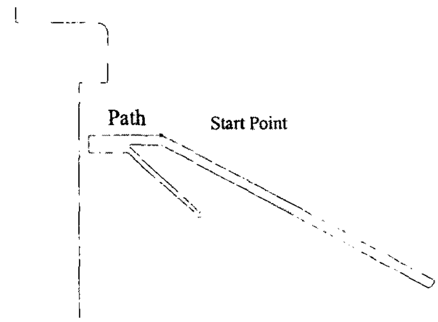



Fig. 7. Electric field distribution near the floating conductor

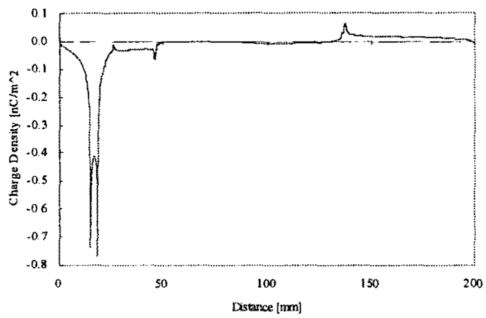
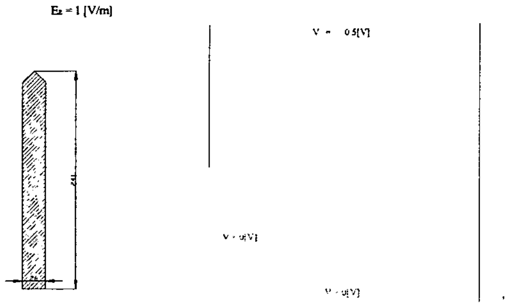



Fig. 8. Induced charge at the floating conductor surface

On the other hand, to evaluate the effect of umbrella typed conductor, the conventional rod is also analyzed. Figure 9 shows the conventional rod and its finite element model. Its numerical results are shown in Fig 10 and Fig. 11. The induced charge densities of the conventional rod surface are also calculated as shown in Fig. 12.



(a) Cylindrical (b) Finite element model
conventional rod

Fig. 9. Conventional rod description

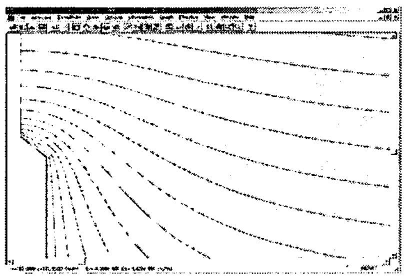


Fig. 10. Equi-potential lines of conventional rod

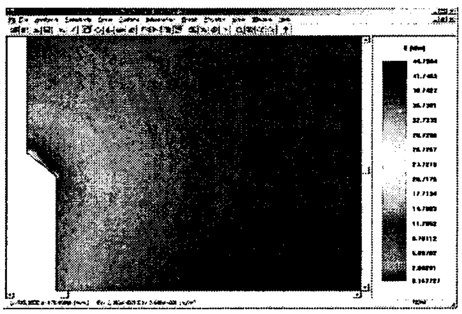


Fig. 11. Electric field intensity of conventional rod

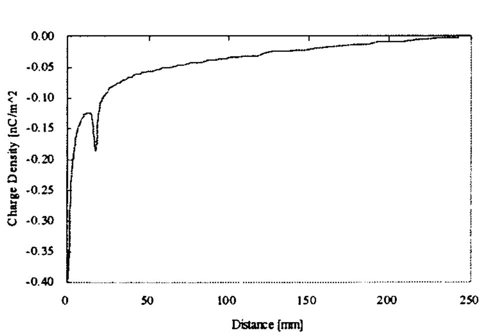



Fig. 12. Induced charge at the conventional rod surface

The maximum field value and the maximum charge density is summarized in table I. From this table we can infer that the bipolar air terminal ignites easily the ionization process before the usual lightning process begins on the top of the conventional rod.

TABLE I Comparison of Maximum Field and Maximum Charge Density

| Rod | Max. Field [V/m] | Max. Charge Density [nC/m$^2$] |
|---|---|---|
| Bipolar | 87 | 0.77 |
| Conventional | 45 | 0.39 |

### 3. Conclusions

The local electric field of a bipolar air terminalwas investigated by finite element method. The conventional air terminal was also analyzed and compared with the bipolar one to evaluate the effect of the floating conductor. From its numerical results, we can see that the proposed model increases the electric field intensity between the rod and the floating conductor. It means that the use of floating conductor in an air terminal can generate easily corona on conductor surface before the usual lightning process begins on the top of the conventional rod.

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