Conference on the Computation of Magnetic Fields

Saratoga Springs, New York
July 13-17, 2003

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

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***Abstract* — This paper presents an accurate analyis of electric field for Charge Transfer System which was recently developed to reduce the likelihood of lightning stroke to premise. Since a CTS has many sharp metal points, its geometric modeling is very difficult. To calculate accurate electric field of the CTS, squuential sub-window technique which analyzes local electric field in a small region compared with total system is used. The electric fields of brush tip and top of the CTS which play an import role in lightning mechanism are calculated. The Flanklin rod was also analyzed and compared with the CTS to evaluate the effect of brush of the CTS.**

INTRODUCTION

Lightning rod has been used to protect some premises from direct lightning stroke which can cause fire, explosion, physical damage. In recent years, due to the explosive progress in computer and telecommunication technology, the secondary effect of the lightning stroke became major concern in many cases. Electromagnetic field generated by lightning current near by a conductor connecting the lightning rod to the grounding system may cause malfunction or disruption of sensitive electronic equipment. Therefore, lightning protection of the premises becomes more and more important to provide a specified level of safety. The prevention of the direct lightning strokes into the premise is the only way to eliminate the damages from consequences of the secondary effect.

Charge transfer system (CTS) was recently developed to reduce the likelihood of lightning directly to the premise. Its idea of preventing the lightning stroke is based on the point discharge phenomenon [1]. When sharp-edged object such as pointed electrode is exposed to the strong electric field, it starts to emit electric current into the surrounding air. This current is a result of ionization process in the air surrounding the sharpened points and it weakens the electric field. However, the effectiveness of the CTS has not yet been confirmed [2]. Therefore, some works to evaluate the CTS are needed. First of all, an accurate calculation of local electric field that causes the ionization process is required. But, its accurate numerical analysis is very difficult since the CTS has many sharp metal points whose geometry is too complex to model. In this paper, to resolve this problem a sub-window technique is employed. This technique is good for analyzing a model whose concerned area is too small compared with the total system.

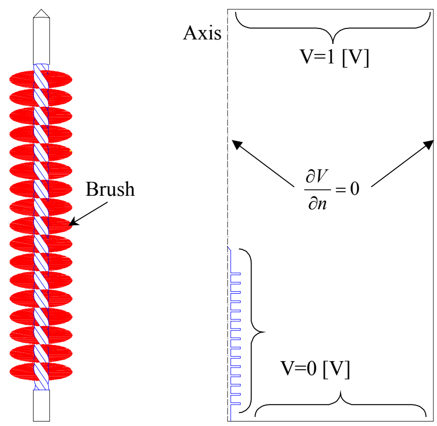
CHARGE TRANSFER SYSTEM

There are several kinds of CTS according to ionizer types: umbrella type, Ball type, Barbed wire type, doughnut type, and cylindrical type [2]. All of these CTS have many spiral brushes along the axis. Since this geometry is real 3 dimensional, its exact modeling is almost impossible and practically not useful. In this paper, the brushes are simplified into many narrow disks and modeled by an axisymmetric problem. For the analysis of the CTS, an accurate calculation of electric field is required since it determines where the initial ionization process will start.

The finite element method (FEM) is most popularly being used for electric field calculation. However, the FE analysis of the CTS has a critical problem in geometrical modeling for the brush of the CTS. The thickness of brush is about 70 [μm] whereas its radius is 25[mm]. It means that the concerned area is too small to analyze the system accurately. In this paper, a sequential sub-window technique using FEM is employed for calculation of local electric field of the CTS.

ANALYSIS OF ELECTRIC FIELD OF CTS AND DISCUSSION

We apply the sub-windows technique method to a cylindrical CTS as shown in Fig. 1(a). To calculate the electric fields due to the lightning, the thunderstorm cloud is represented by a simple electrode on the top line where 1[V] is applied as shown in Fig. 1(b). Since the top brush has a high strength of electric field, this region is concerned. In the first geometrical modeling, the brushes are divided into several groups and simplified as shown in Fig. 1(b).



(a) Cylindrical CTS (b) Finite element model

Fig. 1. Model description

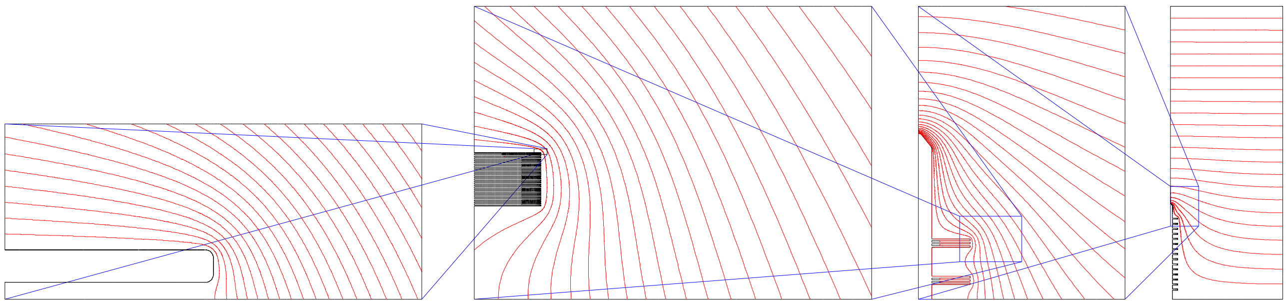
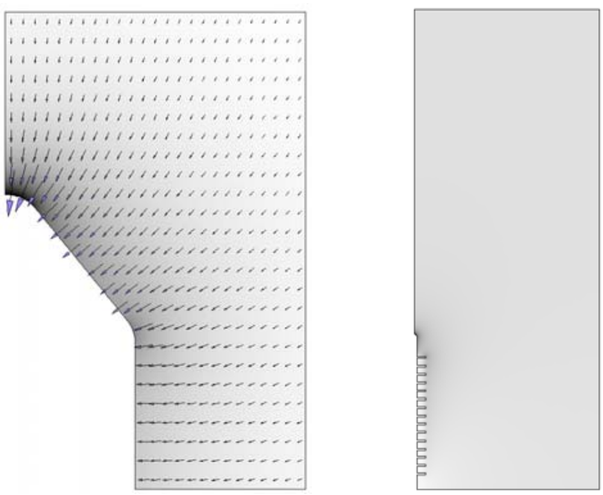


Fig. 2. Closing up by sub-windows

In the first step, the original model is analyzed with a relatively rough mesh. Its numerical result is used for a boundary condition of the second step where the top of CTS and higher brushes region are closed up by sub-window. Next, the higher brush group is closed up again and exactly modeled with 26 brushes. Finally, the top brush is closed up once more and analyzed. So we obtained electric field distribution nearby the top of brush. This procedure is shown in Fig. 2. The electric field at the right top brush is 88 [V/m], which is the maximum value over the entire system. To calculate the electric field at the top of CTS, the sub-window technique is also applied and its results are shown in Fig. 3. The maximum electric field at the top of CTS is 67 [V/m], which is less than that at the brush. It means that the field near the brush can cause the very first ionization.

On the other hand, to evaluate the effect of brushes, the CTS without brushes (Flanklin rod) is also analyzed. The calculated maximum electric field at the top of the rod is 75 [V/m], which is greater than that of the CTS. From this result, we can infer that the air nearby the brushes is ionized before the lightning current is conducted at the top of CTS.



(a) Sub-window for the Top of CTS (b) Original model

Fig. 3. Field intensity of CTS

Figure 4 shows the induced charge density along the brush surfaces at the second sub-window in the Fig 2. From this result we can see that the electric field is concentrated at the top part in the brushes and there is almost no field in the region between the brushes.

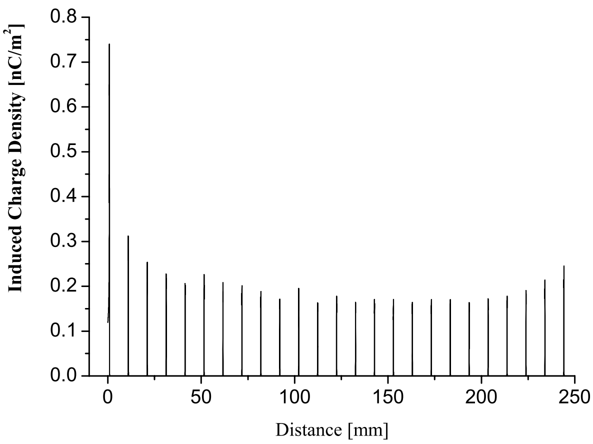


Fig. 4. Induced Charge at brushes of the CTS

CONCLUSIONS

The electric field of brush tip and top of the CTS that play an import role in lightning mechanism was obtained by sequential sub-windows technique. The Flanklin rod was also analyzed and compared with the CTS to evaluate the effect of brushes. This method can be used for evaluating local electric field of all CTS.

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