Analysis of the Shielding Effect of Wire Mesh to Ion Flow Field from HVDC Transmission Lines

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***Abstract*—The electrification of objects under HVDC transmission lines due to ions generated by corona discharge may lead to pernicious consequences. This work investigates the shielding effect of the wire mesh to the drifting ions. Firstly, The mathematical model of the ion flow field with the presence of wire mesh is derived, and the flux tracing method (FTM) is adapted to simulate the interaction between the wire mesh and the drifting ions. Secondly, the indoor experiments about the shielding effect of the wire mesh to the ion flow field are presented, and measurement results are being compared with simulation results, which validate the method. Finally, the relationship between mesh parameters and shielding effect is analyzed in detail.**

***Index Terms*—Ion flow field, wire mesh, shielding effect, HVDC transmission lines.**

I. INTRODUCTION

Corona discharge along HVDC transmission lines generates ions, which can be expelled to the ground by the DC electric field and deteriorate the ground level electrical environment. If these ions accumulate on some ungrounded objects, the electric potential of these object will increase and may cause hazard results [1].

Many simulation methods have been developed to predict the ground level ion flow field under HVDC transmission lines, but only a few works on how to reduce the ground ion flow field have been published. In 1989, Amano and Sunaga conducted experiments on the grounded wires which were parallel with HVDC transmission lines, and proved that these wires can decrease the ground level ion flow field [2].

This work investigats the possibility of reducing the ground level ion flow field by using wire mesh, which is a common used construction material. Both the simulations and experiments about the shielding effect of the wire mesh to the ion flow field are included, and the suggestions on the selection and arrangement of wire mesh used for shielding ion flow field are proposed.

II. SIMULATION METHOD

The existing methods for ion flow field simulation are generally in two categories, which are FTM and mesh-based methods. The FTM is a based on the Deustch's assumption, which sloving the ion flow field along the electric field lines [3]. The mesh-based methods, like FEM and FVM, preserve certain advantages, such as inclusion of the recombination of different species of ions and are independent of the Deustch's assumption [4]. However, the task of present work is to model the thin wire structure that is placed in the open domain, and the problem is naturally three-dimensional (3D). Solving such a problem through mesh-based methods is too demanding in terms of computation cost. Moreover, because the wire mesh is not large enough to involve the bipolar ion flow field, the recombination of different species of ions can be neglected in the present problem. Therefore, in this work, the 3D FTM, along with some adaptations, is chosen to solve the ion flow field with the presence of wire mesh.

The monopolar ion flow field problem is governed by the Poisson's equation and the charge conservation law, which are as follows:

$$\nabla^2 \varphi = -\rho / \varepsilon_0 \tag{1}$$

$$\nabla \cdot \left(\rho k E_s \right) = 0 \tag{2}$$

where φ is the electric potential, ρ is the positive or negative charge density, E_s is the electric field, ε_0 is the dielectric constant of the vacuum and k is the ion mobility.

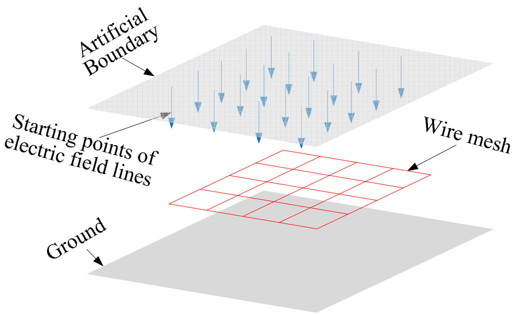


Fig. 1. Illustration of artificial boundary.

The boundary conditions of the present problem are as follows:

(1) The electric potential of ground plane and wire mesh are zero.

(2) To reduce the computation cost, the artificial boundary is used in this work. The artificial boundary shown in Fig. 1 is the plane parallel to the wire mesh, and its electric potential and charge density are assumed not to be influenced by the presence of wire mesh. The height of artificial boundary can be determined by trial and error method. The electric potential and charge density of the artificial boundary is determined by 2D ion flow field simulation method [5].

(3) Besides the ground plane and the artificial boundary, there are still four faces that enclosing the 3D computational domain. However, the electric potential and charge density of these four faces are not required to be given in 3D FTM. The detail of 3D FTM developed in this work will be presented in the full paper.

In FTM, the charge density and electric field are solved along electric field lines in 3D. The starting points of these electric field lines are located at the artificial boundary. These electric field lines develop from its starting points toward the ground plane, and some of the electric field lines will end at wire mesh while others will eventually reach the ground plane. The number of electric field lines that reach the ground plane decreases substantially due to the presence of wire mesh, and the distribution of the endpoints become nonuniform.

III. VERIFICATION

The arrangement of indoor tests is shown in Fig. 2. The DC wire is suspended between two epoxy crossbars, which is a steel strand wire, 3mm in diameter and 4m in length. The wire mesh used in the test is supported by stretching wires, which have relatively small influence on the ion flow field compared with other support structures. The size of the wire meshes are 1m×1m, while the mesh openings can be 0.125m, 0.25m or 0.5m. The wire diameter of the meshes can be 1mm or 1.6mm. The ion current density is measured by a Wilson plate, whose sensing surface is 0.5m×0.5m and the guarding ring is 5cm in width. The Wilson plate is placed right under the center of the wire mesh.

The arrangement in Fig. 2 is simulated by the method developed in this work. The roughness factor of the DC wire is 0.74, while the ion mobility is determined by trial and error method. After comparing with the measured ion current density without presence of wire mesh, 1.2×10^{-4} $m^2/V/s$ and 1.9×10^{-4} $m^2/V/s$ are chosen for positive and negative ion mobility respectively.

The measured and calculated ion current density from indoor test is shown in Fig. 3, where the wire diameter is 1mm and the applied voltage are in the range of ±50kV to ±100kV. In Fig. 3, W is the mesh opening. The measured and calculated ion current density decrease with the decrease of mesh opening, which means smaller mesh openings lead to better shielding effect on ion flow field.

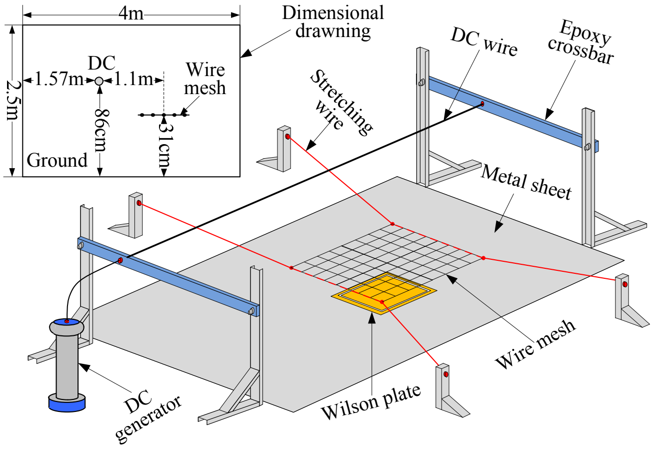
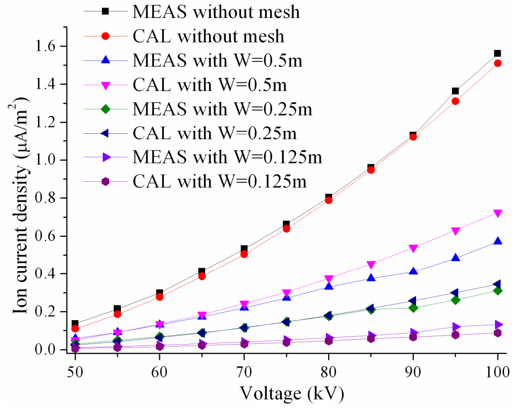


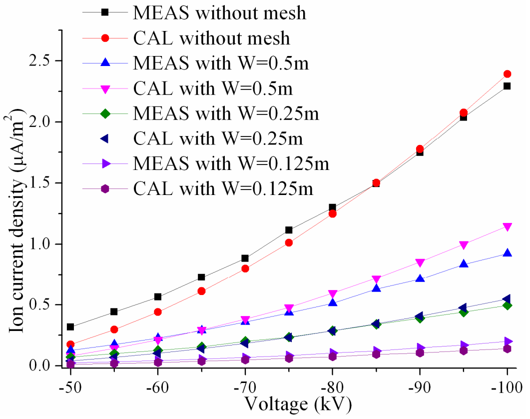
Fig. 2. Arrangement of indoor tests.

IV. CONCLUSIONS

A simulation method for shielding effect of wire mesh to ion flow field is developed, and it is verified by experiment results. The grounded wire mesh has significant shielding effect on the ion flow field under it. Reducing the mesh opening is helpful to improve its shielding effect. However, the ion flow field will quickly decrease to negligible level when the mesh opening is still relatively large, therefore finer wire mesh is not necessary in shielding of ion flow field. Increasing the wire diameter of the mesh is helpful in improving the shielding effect, but it is not a cost effective way in comparison with reducing the mesh opening.



(a) Positive polarity.



(b) Negative polarity

Fig. 3. Comparisons between the measured and calculated ion current density (only magnitude) with different mesh openings in indoor tests

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