The movement characteristics of the charged haze particulates in the ionized field and its influence on the contamination of insulator

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***Abstract*—The haze-prone areas are usually the places with limited transmission line corridors and large power loads. The performance of overhead transmission lines is under threat of the haze. The charged haze particulates will affect the electric field of the HVDC transmission line and insulator contamination, which would enhance the probability of flashover. Based on the influence mechanism of haze on ionized field, this paper studies the movement characteristic of charged haze particulates in the ionized field. Then the motion principle of haze under different ionized field levels are investigated in terms of simulation and experiment. The results show that the insulator contamination will be straighten under haze weather and the motion rule isn't the same for different ionized levels.**

***Index Terms*—High-voltage direct current (HVDC), ionized field, movement characteristic, insulator contamination**

INTRODUCTION

The haze-prone areas are usually the places with limited transmission line corridors and large power loads. The haze particulates around the HVDC transmission lines will be charged due to the ionized field and affect the electric field of transmission lines, especially in the north of China, the air pollution index is usually over 300 μg/m^3.In addition, the movements of the haze particulates will change because of the electric field and the insulators' pollution characteristics could be affected. Simultaneously, the haze particulates will be charged under ionized field and drop on the insulator, which enhance the surface contamination and may cause insulator flashover, or even electrical accident [1]. Therefore, in the paper, the movement characteristic of charged haze particulates is investigated, and its influence on insulator contamination has also been studied by experiment. Results indicate that the movement characteristic of haze particulates is greatly affected by the electric field and the insulator contamination becomes serious for higher ionized field level. Besides, the motion rule isn't the same for different ionized field levels.

I. MOTION CALCULATION MODEL OF HAZE PARTICULATES

A. Theoretical Method

The movement characteristic of charged particulates is determined by polarization force, electrical force, viscous force and gravity and so on [2]. Therefore, in order to analyze the influence of haze weather on insulator contamination, the electric field distribution of transmission lines and insulator is calculated at first in consideration of the influence of haze particulates. As the Kaptzov based ionized field calculation method would result in problem of convergence rate and calculation accuracy when take insulators into account, especially when effect of fog particles on space charge density is considered. To obtain the electric field of insulators under haze weather and influence of space ion, the paper proposes a Deutsch based calculation method.

It is known that the composite electric field of insulator can be derived as follows [3]:

$$\boldsymbol{E}_s = A\boldsymbol{E} \quad (1)$$

where A is scalar function without dimension; $\boldsymbol{E}$ is the nominal electric field of insulator. Besides, the scalar function A can be calculated through (2).

$$A'(x, y) = E_s'(x, y) / E'(x \quad (2)$$

where $E_s'(x, y)$ and $E'(x, y)$ are the composite electric and nominal electric field of transmission line without considering insulators, respectively. In addition, the $E_s'(x, y)$ is calculated by improved MLPG meshless method [4].

B. Physical Model and Boundaries

To study the movement characteristic of haze particles and its influence on insulator contamination, the listed symmetry model is built. The voltage is applied on electrode 1, and particles fall through the upper inlet, of which radius is 5μm and the relative permittivity is 5. In addition, the voltage of electrode 2 is set as zero. The electric field of insulator can be changed by adjusting the applied voltage on electrode 1.

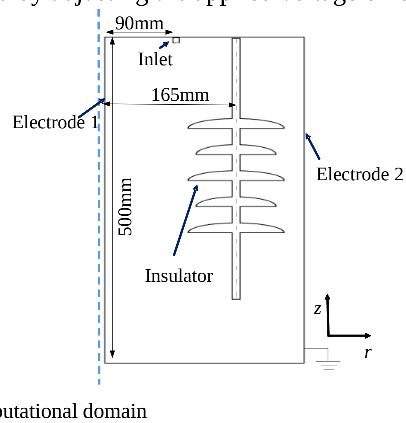


Fig. 1. Computational domain

Meanwhile, the fluid flow particle tracking module is brought into the model to study the particle motion. The gravity and electric force of hazes are considered in the model so as to consider the movement of particles under ionized field. To improve the calculation ability, it is assumed that the particle will be absorbed on the surface of insulator once it arrives at the insulator, and the speed is set as zero when the particles move to the boundary of calculated area.

II. Movement Characteristic Analysis

A. Results analysis

The motion characteristic of charged haze particulates can be achieved according to the above descried method. Fig.2 shows the movement characteristic of charged haze particulates under different electric field levels.

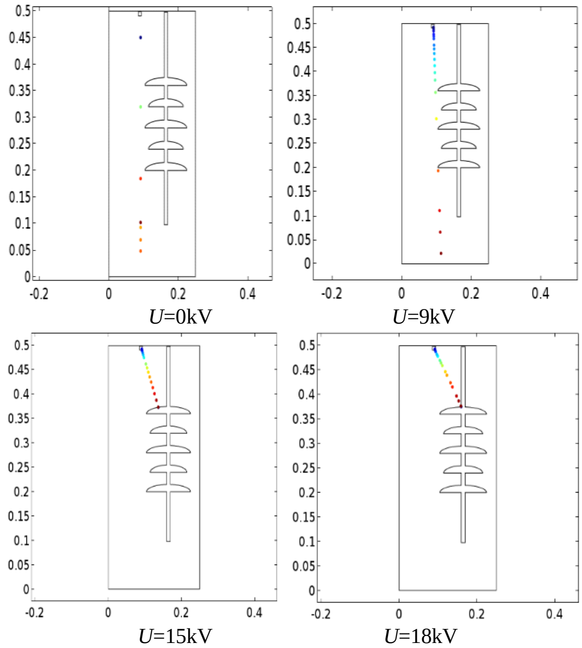
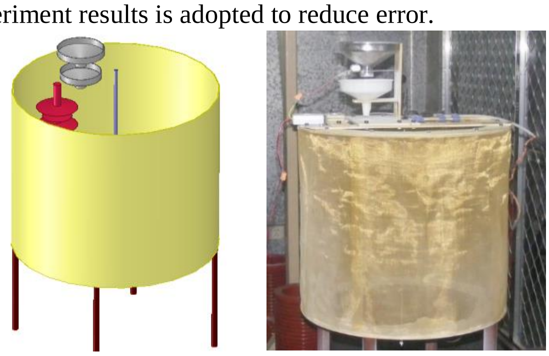


Fig. 2. The movement path of haze particulates at different voltage levels

It can be seen that the particulates fall down straightly due to the gravity force. Since when *U*<9kV, the haze particle motion is only determined by the polarization force and the haze particles move toward insulator slightly. However, the haze particulates would be charged when the *U*>9kV, due to the surface electric field is higher than the inception electric field. The motion of haze particulates is mainly affected by electrical force, and then move toward the upper insulator. It is obvious that with the increasing of electric field, the excursion extent of particulates becomes more intense. When the voltage is about 18kV, the charged particle drop on the center of insulator straightly.

B. Experimental and validation

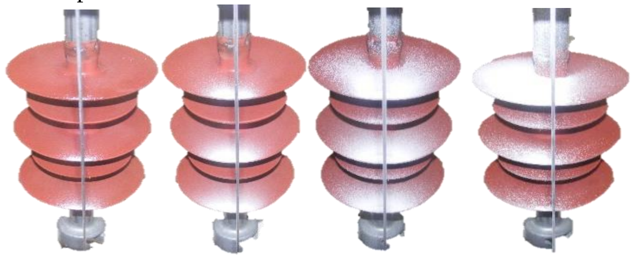
To verify the above conclusion and investigate the movement characteristic of haze particulates, the insulator contamination experiment platform is built, as shown in Fig.3, where haze particle is replaced by talcum powder. The weight of talcum powder on insulator is used to present the motion characteristic of particles. The mean weight value of talcum powder on insulator surface for three times experiment results is adopted to reduce error.



(a) Structure (b) Platform

Fig. 3. The structure and physical picture of the experimental set-up.

As seen from Fig.4 that the contamination on insulator surface is little when the applied voltage is less than 9kV, since the movement of particulates is mainly determined by polarization force, and the particles on insulator is less than 0.2g. However, when the voltage is over 9kV, more particulates drop on the insulator, when the voltage increases from 9kV to 18kV, the weight of talcum powder increases greatly, from about 0.3g to 1g. However, when the voltage increases continuously, the fallen particulates on insulator become less, because the particulates across the insulator. The experimental result accord with theoretical result well.



(a) 0 kV (b) 9 kV (c) 12 kV (d) 21kV

Fig. 4. The insulator talcum powder buildup at different voltages

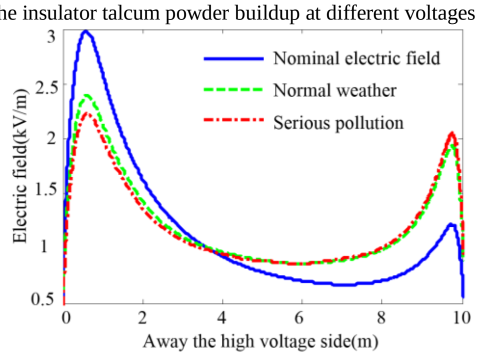


Fig.5.The influence of haze weather on the insulator contamination.

Fig.5 shows the electric field under different air quality cases, it can be seen that the electric field on low voltage side becomes larger while that on high voltage side becomes smaller due to the movement of space charge.

III. Conclusion

The paper studies the movement characteristic of haze charged particle and its influence on insulation surface contamination. The particle movement track under different voltage is discussed. Results indicate that the movement characteristic of haze particulates is greatly affected by the electric field, and the motion path of haze particle would deviate and exacerbate the surface contamination of insulator greater under higher ionized field level. Besides, the ionized haze would strengthen the electric field of low voltage side and weaken that on high voltage side.

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