THE ELECTRIC FIELD & POTENTIAL DISTRUBUTION OF COMPOSITE INSULATOR WITH SERIES CONNECTION OF GLASS INSULATOR

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Abstract: In this paper, a novel improvement method to modify the electric field and potential distribution of the composite insulator is proposed by connecting one plate of glass insulator to the high voltage end of the composite insulator. As the electric field and potential distribution is responsible for the flashover process under the normal condition and ice condition, the electric field and potential distribution along the insulator are calculated under the both conditions to judge whether this method works. The calculation result shows that when one plate of glass insulator is connected to the composite insulator, the max electric field and potential along the insulator are reduced under the normal condition, and the potential is also reduced under the ice condition, but the variation tendency of the voltage potential along the insulator is similar with the standard composite insulator.

1. INTRODUCTION

The composite insulator is characterized with low weight, small structure size, high mechanical strength, good anti-pollution performance, and installation convenience, and thus has gained increasingly population all over the world. However, due to the geometry configuration of the composite insulator, as well as the fitting structure and the dielectric properties of the silicone rubber material, there unavoidably exists a high electric field area near the both ends of the composite insulator. Comparing with the composite insulator, the traditional glass insulator has a higher capacity due to the lager dielectric constant of the glass and a better anti-arc performance. Therefore, a novel method is proposed by connecting one plate of glass insulator to the end of the composite insulator. This paper will discuss the advantage of this method from the view of the electric field and potential distribution under the normal condition and the ice condition.

2. RESULTS AND DISCUSSION

In this paper, the 3-dimensional 110kV tower-conductor-insulator model is constructed with the implement of COMSOL Multiphysics 3.4 under the normal condition. The glass insulator is connected to the high voltage end of the composite insulator as Fig.1 shows.

Under the ice condition, the effect of tower and conductors on the electric field distribution can be omitted due to the presence of accreted ice. Therefore the calculation is based on the two-dimensional axisymmetric model. The calculation is classified into two cases: dry ice and wet ice. The electric field distribution is calculated under the normal condition and ice condition.

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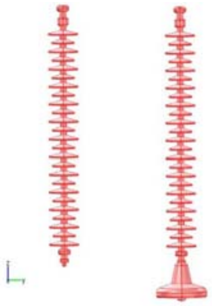

Figure 1: The insulator model

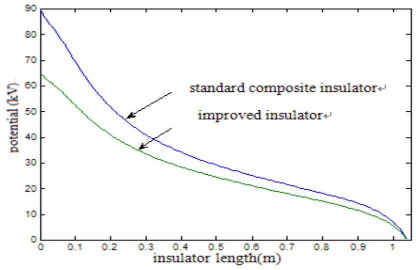

Figure 2: The potential distribution along the insulator

Table 1: The calculation result.

n	0	1
Max electric field strength （kV/mm）	0.29	0.229
Voltage drop, %	45.78	38.51

3. CONCLUSION

According to the calculation, when one plate of glass insulator is connected to the high voltage end of the composite insulator, the max electric field and potential along the insulator are reduced under the normal condition, and the potential near the high voltage end is also reduced under the ice condition, but the variation tendency of the voltage potential along the insulator is similar with the standard composite insulator.

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***Abstract*—In this paper, a novel improvement method to modify the electric field and potential distribution of the composite insulator is proposed by connecting one plate of glass insulator to the high voltage end of the composite insulator. As the electric field and potential distribution is responsible for the flashover process under the normal condition and ice condition, the electric field and potential distribution along the insulator are calculated under the both conditions to judge whether this method works. The calculation result shows that when one plate of glass insulator is connected to the composite insulator, the max electric field and potential along the insulator are reduced under the normal condition, and the potential is also reduced under the ice condition, but the variation tendency of the voltage potential along the insulator is similar with the standard composite insulator.**

Keywords-composite insulator; glass insulator; electric field calculation; potential calculation;

I. INTRODUCTION

As the main insulation structure of the OHL, the performance of the insulator is responsible for the safety operation of the whole power grid. In recent years, the emergence of the composite insulator has greatly improved the outer insulation performance of the OHL. The composite insulator is characterized with low weight, small structure size, high mechanical strength, good anti-pollution performance, and installation convenience, and thus has gained increasingly population all over the world. However, due to the geometry configuration of the composite insulator, as well as the fitting structure and the dielectric properties of the silicone rubber material, there unavoidably exists a high electric field area near the both ends of the composite insulator. With the increase of the potential level of the transmission line and the structure length of the composite insulator, this electric field distortion is consequently becoming severer. High electric field induced partial discharge will lead to rapid degradation of the insulating material[1]. And the electric field distortion is also responsible for the ice accretion of the insulator and its flashover process. According to existing studies, the faults caused by ice-covered have been reported[2,3], raising worldwide research interest in the related area[4-8]. At present, the installation of corona rings is commonly used on composite insulators to settle these problems[9]. Corona rings have obvious effect on improving the electric field distribution, but limited effect on improving overall voltage distribution. Meanwhile, the installation of corona rings will reduce the dry arcing distance between two poles of composite insulators, and lower the lightning withstand level of transmission lines. And there is still no uniform standard for the manufacture and implement of corona rings both at home and abroad, leading to difficulties in the actual practice. Comparing with the composite insulator, the traditional glass insulator has a higher capacity due to the lager dielectric constant of the glass and a better anti-arc performance. Therefore, a novel method is proposed by connecting one plate of glass insulator to the end of the composite insulator. The improvement concerning the degradation is obvious due to the material properties; therefore, this paper will discuss the advantage of this method from the view of the electric field and potential distribution under the normal condition and the ice condition.

II. MODEL CONSTRUCTION

In this paper, the 3-dimensional 110kV tower-conductor-insulator model is constructed with the implement of COMSOL Multiphysics 3.4 under the normal condition, including the composite insulator, one plate of glass insulator, one tower, conductors, and grounding wires. The glass insulator is FC-100/146, and its diameter, structure height, creeping distance are respectively 255mm, 146mm, and 320mm. The composite insulator is FXBW3-110/70, and its diameter, structure height, creeping distance are respectively 150/115mm, 1190mm, and 3200mm. The glass insulator is connected to the high voltage end of the composite insulator as Fig.1 shows.

Under the ice condition, the effect of tower and conductors on the electric field distribution can be omitted due to the presence of accreted ice. Therefore the calculation is based on the two-dimensional axisymmetric model. The calculation is classified into two cases: dry ice and wet ice, and the simulation factors for the dielectrics are listed in Tab.1. The conductivities of rubber and air are set as zero and the simulation is based upon the assumption that under the dry ice condition, the leakage current conducts along the ice layer, whereas under the wet ice condition, the leakage current conducts along the water film.

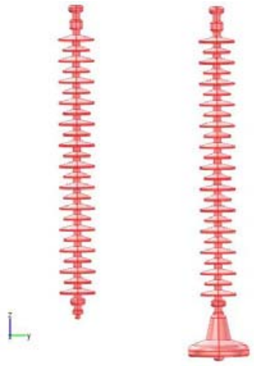


Fig.1 The insulator model

Tab. 1 The simulation factors

	rubber	ice	Water film	air
relative permittivity εr	3.0	70	81	1.02
conductivity （μS/cm）	0	1	300	0
thickness （mm）	—	Variable	0.15mm	—

Similar with the polluted insulator, there also exists an area with intensive electric field strength on the ice-covered insulator, which is the air gap. The conductivity of the ice layer is far larger than that of the air gap, therefore the air gap bears most of the voltage drop, and always leads to the ignition of the arc. This paper calculates the potential distribution with different air gap position and length. The thickness of the ice layer and the water film is respectively 10mm, and 0.15mm. The calculation model is showed in Fig. 2.

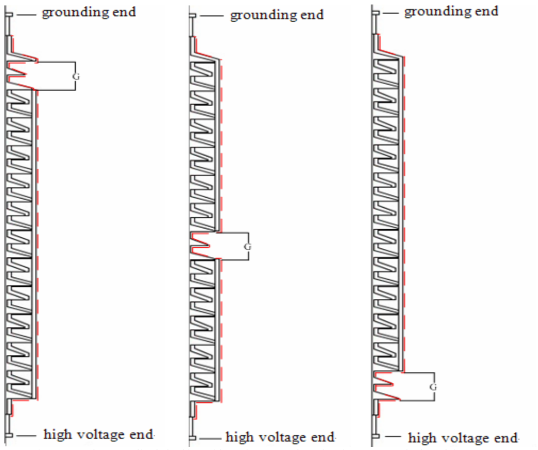


Fig. 2 The e-field distribution calculation model of ice-covered composite insulator with various air gap lengths

III. RESULTS & DISCUSSION

The electric field distribution is calculated under the normal condition and ice condition. The results are listed as follows.

A. *Normal Condition*

The electric field distribution and the voltage drop along the insulator are showed in Fig. 2 and Fig. 3.

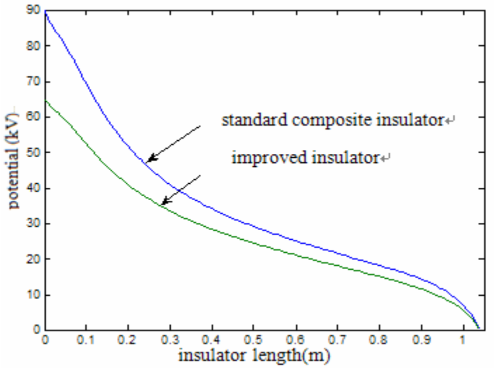


Fig. 3 The potential distribution along the insulator

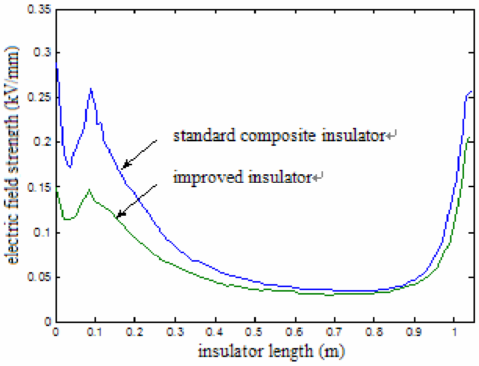


Fig. 4 The e-field distribution along the insulator

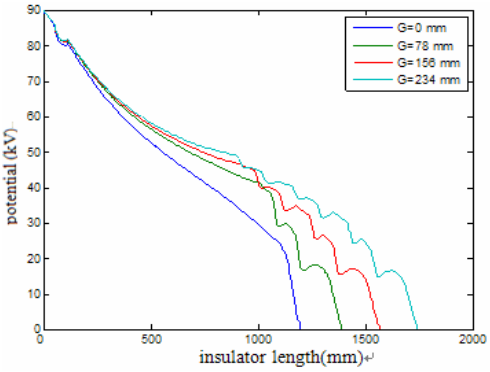
It can be judged from Fig. 3 and Fig. 4 that when one plate of the glass insulator is connected to the high voltage end of the composite insulator, the electric potential and the electric field strength are reduced. The nearer to the high voltage end is, the reduction is more significant. The max electric field strength and the voltage drop at the point of 1/5 length of the whole insulator away from the high voltage end are given in Tab. 2.

Tab. 2 The calculation result

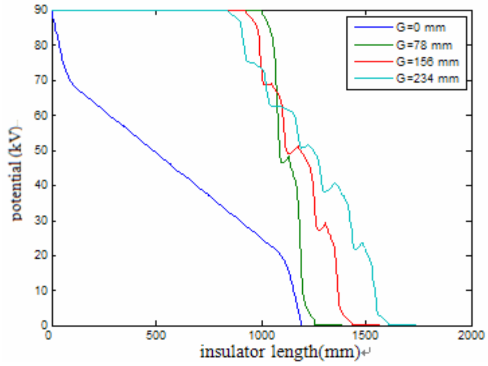
n	0	1
Max electric field strength （kV/mm）	0.29	0.229
Voltage drop, %	45.78	38.51

B. *Ice Condition*

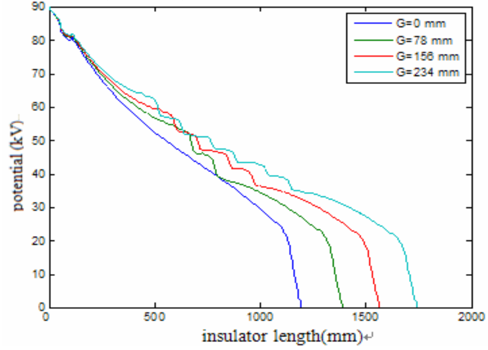
The potential distribution along the insulator with different air gap positions and lengths under the condition of dry ice and wet ice are calculated and showed in Fig. 5 and Fig. 6. G stands for the gap length.



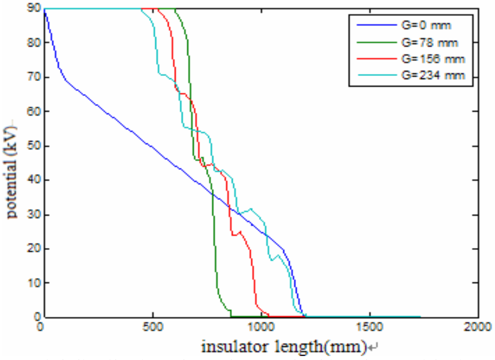
a.The potential distribution along the standard insulator with air gap near the grounding end under dry ice condition



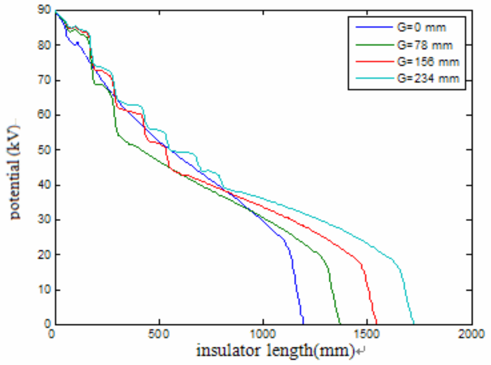
b.The potential distribution along the standard insulator with air gap near the grounding end under wet ice condition



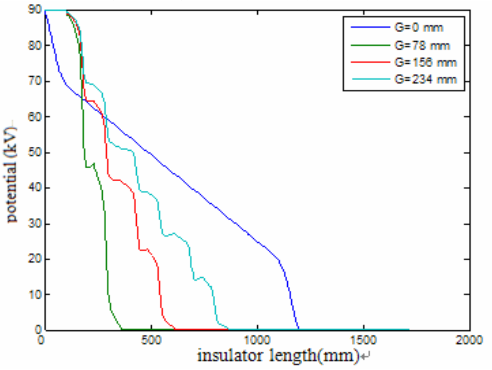
c.The potential distribution along the standard insulator with air gap in the middle under dry ice condition



d.The potential distribution along the standard insulator with air gap in the middle under wet ice condition

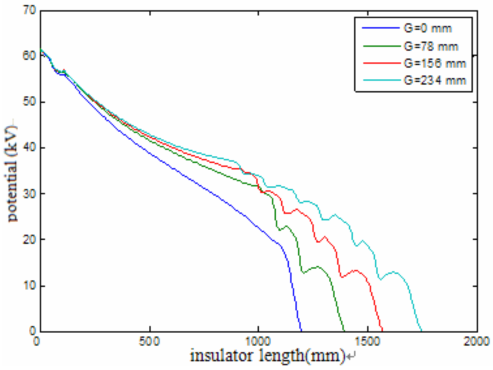


e.The potential distribution along the standard insulator with air gap near the high voltage end under dry ice condition

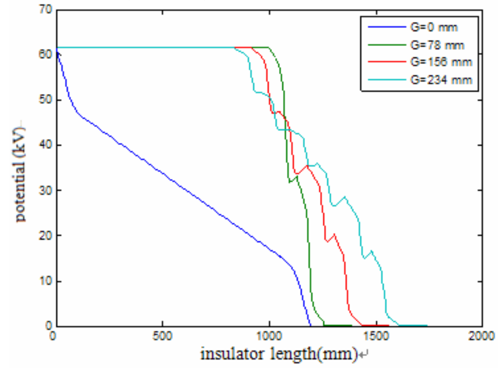


f.The potential distribution along the standard insulator with air gap near the high voltage end under wet ice condition

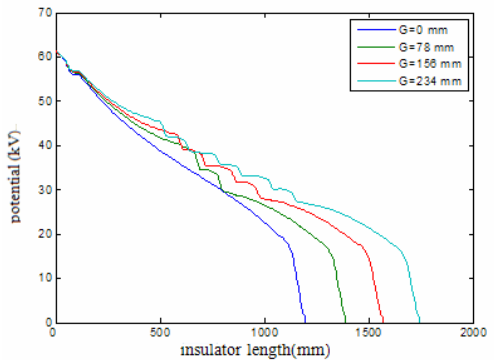
Fig. 5 The potential distribution along the standard insulator



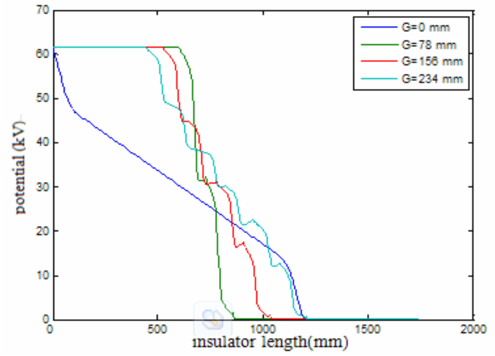
a.The potential distribution along the improved insulator with air gap near the grounding end under dry ice condition



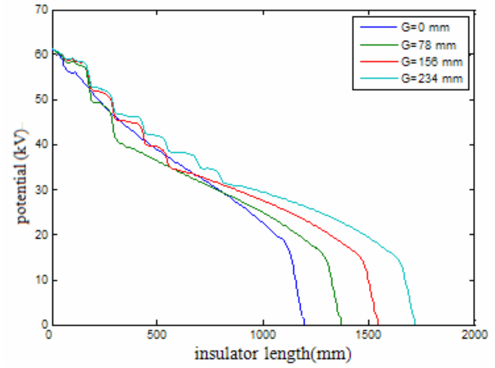
b.The potential distribution along the improved insulator with air gap near the grounding end under wet ice condition



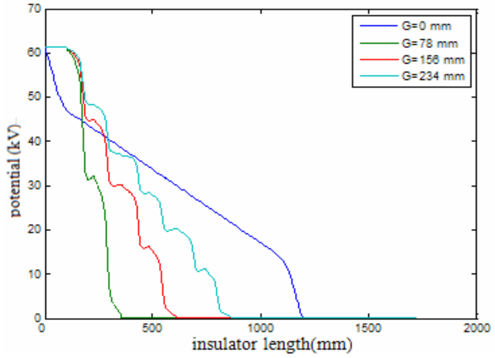
c.The potential distribution along the improved insulator with air gap in the middle under dry ice condition



d.The potential distribution along the improved insulator with air gap in the middle under wet ice condition



e.The potential distribution along the improved insulator with air gap near the high voltage end under dry ice condition



f.The potential distribution along the improved insulator with air gap near the high voltage end under wet ice condition

Fig. 6 The potential distribution along the improved insulator

It can be judged from Fig. 5 and Fig. 6 that when one plate of glass is connected to the high voltage end of the composite insulator, the electric potential near the high voltage end of the composite insulator is reduced. But the variation tendency of the voltage potential along the insulator is similar with the standard composite insulator, therefore with the smaller voltage near the high voltage end and similar variation tendency along the insulator, the average and max electric fields strength are reduced, which means that this improvement has advantage in suppressing the arc ignition.

IV. CONCLUSION

According to the calculation, when one plate of glass insulator is connected to the high voltage end of the composite insulator, the max electric field and potential along the insulator are reduced under the normal condition, and the potential near the high voltage end is also reduced under the ice condition, but the variation tendency of the voltage potential along the insulator is similar with the standard composite insulator. This result shows that the connection of one plate of glass insulator to the composite insulator can improve the electric field distribution along the insulator.

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