RESEARCH ON SHED CRACK OF COMPOSITE INSULATORS USED IN STRONG WIND AREA

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ABSTRACT

Composite insulators promoted development of ultra-high voltage transmission lines and study of the composite insulators is very important at the high voltage engineering. Strong wind area is very special environment at China or the worldwide. Not only the tower strength, conductor galloping and external insulation selection should be considered, but also the insulator structure and the shed materials need to be designed carefully. The sheds cracks of the composite insulators at 750kV AC lines in Xinjiang province is very new topic. It is found that when the wind speed is higher than 30 m/s, the biggest sheds of the tested insulator would vibrate at high frequency and great amplitude. The vibration of the sheds caused the sheds root load stress concentration, which is periodically. Even the stress was lower than the tensile strength of the HTV rubber, the stress fatigue would break the sheds root and the cracks would appear. To restrain the resonance between fluid and the shed, the shed structure parameter and the material used to make insulators sheds should be improved.

1. INTRODUCTION

Composite insulators fabricated by the HTV(High Temperature vulcanized Silicone Rubber) are now used more and more at ultra high voltage transmission lines, and they are lighter, more stronger, anti-pollution on flashover than glass and porcelain insulators. At the end of 2011, 5 million composite insulators were used in China and one third of the insulators are composite insulators that will be used in the new ultra high voltage transmission lines[1-3]. It's very important to study technique of the fabrication, test and maintance the composite insulators.

Now the injection process, end-fitted metallic hardware, acid resistant insulation core, shed structure parameters are well researched and improved about the composite insulators[4,5]. Besides the inner insulation fault which often shortens the service time of the composite insulators, the ageing resistance and anti-weathering properties of the silicone rubber also affect the working life of the composite insulators. The sheds made of HTV were different produced by different company and in different place (such as desert, coast, mountain, and plain) they exhibited great differences to adapt the environment. In China it's very important to evaluate the service life of the composite insulator sheds. In this paper we will study the shed crack problem caused by the strong wind (>40m/s).

In one internal report given by Xinjiang Electric Power Company, when they maintained the 750kV AC lines between Urumqi and Trupan in 2011, there were many composite insulator sheds cracked as can be seen in figure 1. These composite insulators met demands of Chinese Standard and the standard of State Grid, while in other place they served very well. These damaged insulators were used in strong wind areas called Sanshili and Baili wind area where the wind speed can be larger than 40 m/s and the largest speed can be up to 50m/s. These areas

Gobi Desert and none can live there, so these cracked sheds couldn't be damaged by persons. The only reason for the shed crack should be the strong wind. According to the local weather reports, in these two strong wind area the average 10 minutes maximum wind speeds would be 37.6 m/s and 33 m/s respectively between March and June[6]. As seen in figure 1, the big shed's root cracked and the middle shed and the little shed were well. The sheds structure is shown in the figure 2. The sheds spacing was 140 mm, and the sheds diameters were 210, 130 and 175 mm. The total length of this type of insulator was 7150 mm.

This is a new research topic with the insulators sheds cracked by the strong wind, different with the traditional topics such as conductors galloping and tower design. This research will help the electric power company maintenance the transmission lines safety and to guide the line design and the composite insulator structure design.

Fig. 1 shed crack of the composite insulator at 750kV Urumqi-Turpan Lines

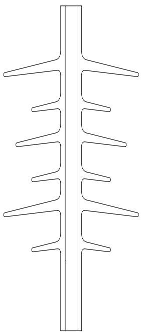


Fig. 2 the composite insulator sheds structure

2. WIND TUNNEL EXPERIMENT

To explain the problem we carried out the experiment in the wind tunnel at Beihang University. The wind speed could be up to 100 m/s in this wind tunnel. We arranged the insulator as shown in figure 3 and the insulators used in the experiments were cut down from the real insulators supported by the same company with whose products had been used in the 750 kV AC line. The wind tunnel was closed as a ring and the part for this experiment was open with 1 m high and 1 m wide. The wind could blow uniformly in the tunnel. The wind speed in the wind tunnel could be controlled continuously and in the experiment we changed the wind speed continuously from 0 m/s to 60 m/s. Per 5 m/s we will stay for 3 minutes to record a video of the insulator. When found the insulator shed started vibrating we would stop at that wind speed and record this speed. Then when wind speed was up to 60 m/s we would depress the wind speed until the shed stop vibrating. The wind speed when the insulator sheds started vibrating was called upgoing wind speed while the wind speed when the insulator sheds stop vibrating called down wind speed.

The ends of the composite insulator were both fixed and the insulator had an angel with the horizontal plane. This angle called suspending was very important in our study and we changed several angels in the experiments.

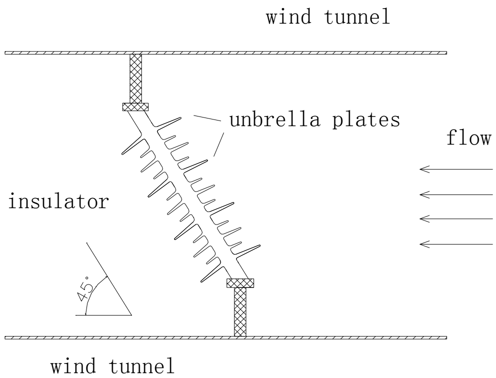
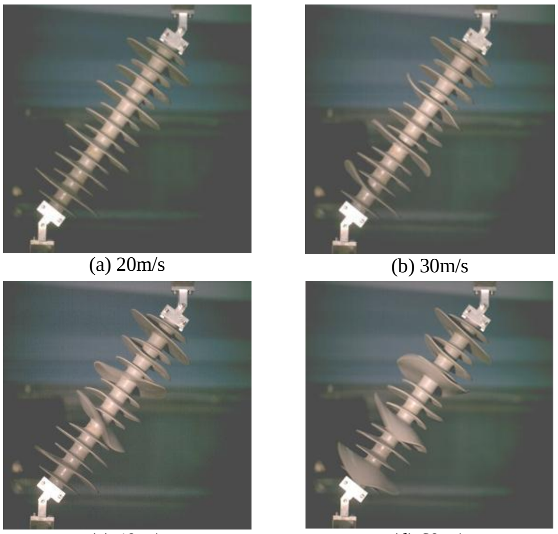


Fig. 3 Wind tunnel experiment

3 RESULT AND DISCUSS

(1) The sheds vibrating

The figure 4 showed one composite insulators was blow by the different speed wind in the wind tunnel. At different the insulator sheds showed different vibrating type. When the wind speed was at low speed (0~30m/s), the biggest sheds of the composite insulator would begin to warp and the edge of the sheds begin to vibrate at a low frequency and amplitude as shown in figure 4(a). The high definition camera could record this phenomenon clearly. While the wind speed is higher than 30 m/s shown in figure 4(b), the insulator shed would vibrate at a high frequency and amplitude and the edge of the biggest sheds would warp at a big angle. The sheds of middle size and smallest size wouldn't vibrate or warp at all. 3 of the 4 biggest sheds would vibrate except the one at the top right-hand corner. As the wind speed rose continuously from 30m/s to 60 m/s, the biggest sheds of the insulator vibrated more violently that the edge of the sheds touched the smallest sheds[6]. The sheds of middle size would also vibrate at a low frequency. As we measured according to the HD camera record, the vibrating frequency of the biggest sheds were 16~20 Hz. The biggest sheds would remain this type of vibrating as the wind speed was higher than 30 m/s.



(a) 20m/s (b) 30m/s

(c) 40m/s (d) 60m/s

Fig. 4 Dynamic process of insulator sheds at different wind speeds

(2) Simulation

To study the stress and wind distribution at the insulators sheds, we set up a composite insulator model in the Ansys software. The insulator size and parameters in the model were the same as figure 2. The insulator core was glass fiber reinforced plastic actually, but for calculating efficiency we set the core was made of aluminum. The materials of the sheds and housing was HTV rubber and the density was set as 1420 kg/m^3. The elastic modulus and Poisson's ratio of the rubber were measured by the tensile test. The computation domain was set as a cubic, and the air was idea gas whose density was 1.18 kg/m^3 and the input fluid velocity was 40 m/s.

Figure 5 and 6 showed the fluid distribution around insulator and stress distribution at the sheds. When the wind fluid blow around the insulator, there were some vortexes appeared at the edge of the sheds or near the insulator core. These vortexes would vibrate at some frequency which associated with the wind speed, shed structure and material modulus. When the vibration frequency of the vortexes was near the natural frequency of the shed vibrating, resonance would appear and the amplitude of the vibrating would be bigger. The resonance should be the real reason of the shed vibrating at big amplitude.

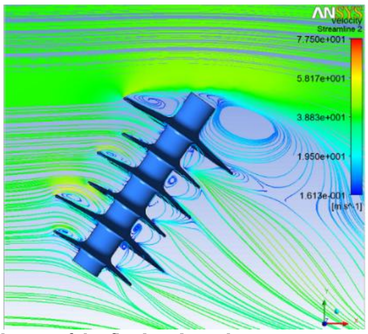


Fig.5 Simulation of the fluid and insulaor string at wind speed 20 m/s

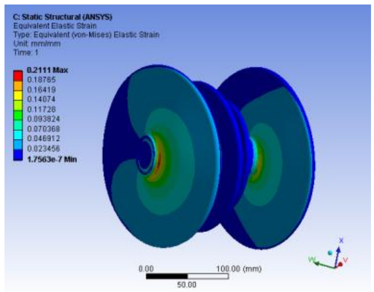


Fig. 6 Distribution of stress at composite insulator shed at wind speed 40m/s

As seen in figure 6, when the biggest shed vibrated at very big amplitude and periodically, the stress at the shed surface would distribute differently. Obviously the stress was max near the shed root and the maximum value of the stress appeared at the juncture of the shed and the housing. This maximum value of stress is lower than the tensile strength of the HTV rubber, so if the sheds begun to vibrate at a big amplitude the shed root wouldn't crack immediately. The cracks at the shed surface were due to the stress fatigue-the stress is bigger than the fatigue limit of the material.

4. CONCLUSION

(1) When used in the strong wind area, the composite insulators' sheds in this paper studied would vibrate at high frequency and great amplitude when the wind speed is bigger than 30 m/s. The vibration of the sheds would lead stress

concentration at the root of the sheds;

(2) The stress maximum value is smaller than the tensile strength of the HTV rubber, but is bigger than the fatigue limit of the material. The periodical stress at the shed surface would cause the micro cracks and then the micro cracks expanded to be cracks.

(3) To restrain the resonance between fluid and the shed, the shed structure parameter and the material used to make insulators sheds should be improved.

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