Study on Variation of Melting Water Conductivity During Melting Period

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Abstract: **in this paper, variation of melting water conductivity is studied. The relationship between melting water conductivity and freezing water conductivity in icing flashover tests is discussed. Saline solution is used to form ice cylinder to study the distribution of salt in an ice sample. Furthermore, the melting period of ice-covered insulators is simulated to find out the variation of melting water conductivity. The influence of ESDD of pre-contaminated insulators and freezing water conductivity on maximum melting water conductivity is also studied.**

I. INTRODUCTION

One of the most substantial problems with outdoor insulation in cold regions is icing flashover. Power outage due to the flashover of ice-covered insulators has been reported a lot around the world. Thus icing flashover has caught many attentions. The flashover of an ice-covered insulator is an extremely complex phenomenon resulting from the interaction between the following factors, electric field, wet and polluted ice surface, air gaps at the ice surface, environmental conditions, and the complex geometry of an ice-covered insulator [1]-[5].

Flashover always occurs at the moment when the surface conductivity is at its maximum value during melting period [3][4]. However, it is difficult to find out the highest surface conductivity, while it is easier to obtain the maximum value of melting water conductivity dripping from ice-covered insulators. Besides, few standards about icing flashover test methods can be used by now. The results in this paper will help to improve test methods and enact standards of icing flashover tests. Moreover the study will contribute to propose an icing flashover mechanism.

In this paper, the relationship between melting water conductivity and freezing water conductivity in icing flashover tests is discussed. And an ice cylinder was made by saline solution to find out the distribution of salt after freezing. Furthermore, studies on melting water conductivity dripping from insulators were carried out. These insulators were clean or pre-contaminated in different ESDD, and sprayed by freezing water with different conductivity.

II. ICE SAMPLES

To find out the distribution of salt in ice frozen by saline solution and the variation of melting water conductivity, two types of ice samples were formed.

Ice sample 1# was formed in a metal can, which shaped ice into a cylinder with a diameter of 12.5 cm, 7cm high. The water is saline solution, and its conductivity is 100μS.

Ice sample 2# were formed on ceramic and glass insulators, includingXWP-300, XP-70, and FC210P. These insulators are clean or pre-contaminated in ESDD/NSDD (equivalent salt deposit density/non-soluble deposit density) of 0.05/1.0 mg/cm^2, or 0.2/1.0 mg/cm^2. Water of conductivity of 100μS or 200μS was sprayed to insulator surface. The thickness of ice on insulators was about 5 mm.

Both the two types of ice samples were formed in natural environment. The outdoor temperature during freezing was -7 to -10℃, and room temperature during melting is 15 to 20℃.

The two types of ice samples are shown in Figure 1 and 2.

Figure1Ice Sample1#

Figure2Ice Sample 2#

III. TEST RESUALTS AND DISCUSSION

A. Melting water conductivity in icing flashover tests

Melting water conductivity in icing flashover tests was analyzed. In 2010, icing flashover tests were carried out and the melting water was collected. Its conductivity was shown in Figure3. The ESDD/NSDD of the test objects was 0.05/1.0 mg/cm^2, and the freezing water conductivity was 100μS.

As shown in this figure, the melting water conductivity is much greater than the freezing water conductivity. The average value is 2406μS, which is 24.06 times the freezing water conductivity. It is demonstrated that the salt on the surface of insulators has moved to the surface of ice. Usually, insulators for outdoor transmission lines are contaminated in China. Even the conductivity of freezing drips floating in air is low; the surface conductivity of ice-covered insulators during melting period is high enough to lead to a low icing flashover voltage.

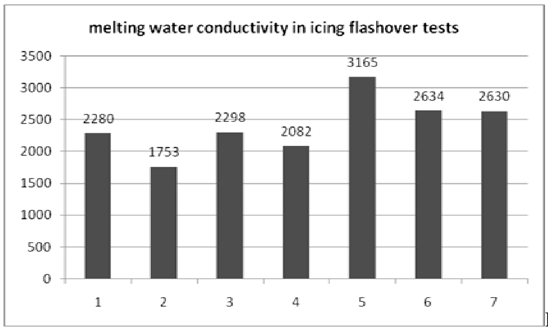

Figure3 melting water conductivity in icing flashover tests

B. Ice Sample 1#

Ice sample 1# was shaped in a metal can placed outside for days until it was totally frozen. The can was held away from ground by two rubber bars to make sure the atmospheric conditions around it are similar.

After the ice cylinder was formed, it was cut into two halves. And then they were separately cut into 6 and 9 pieces, as shown in Figure4. The 15 pieces of ice, marked as 1,2,…,15, were placed separately in beakers and then melt. When all the ice pieces were completely melt, the conductivity of the melting water were measured and corrected to 20℃. A and A' are the same line, so it is with B and B'.

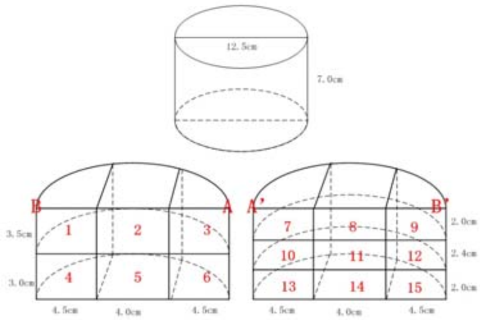

Figure4 Cutting Ways of Ice Sample 1#

The conductivity is shown in Figure5.

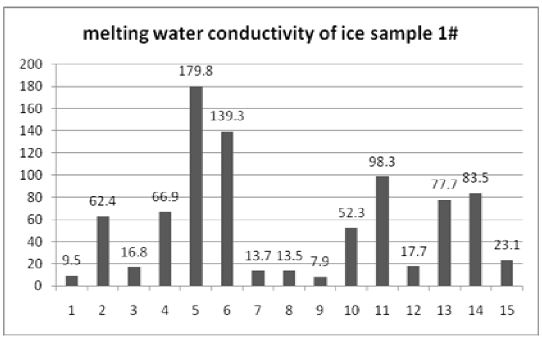

Figure5 Melting Water Conductivity of Ice Sample 1#

It shows that the conductivity inside is much higher than others. In the left half, the highest conductivity is 18.9 times the lowest, and as to the right half, it is 12.4 times.

When the ice sample was formed, the surface of the saline solution froze first and the salt in the solution filtered into the liquid fraction so that at the surface of the sample contained less salt than that inside. The conductivity of bottom is also a little higher probably because of gravity of salt.

During the period of freezing, salt was filtered greatly. The distribution of salt in ice is very uneven. The highest melting water conductivity is 1.8 times the freezing water conductivity.

C. Ice Sample 2#

Ice samples 2# were melt in room. The volume of melting water for measurement is about 50 to 80ml. According to the room temperature during melting, 10 or 20 minutes later the first measurement was carried out. Then melting water conductivity was measured every time interval.

Variation of the melting water conductivity is shown in Figure6to 8.

- Clean insulators

The conductivity of melting water reaches its maximum value which is much greater than that of freezing water, and then decreases gradually to a very low level compared with the conductivity of freezing water. As explained before, the surface of the water freezes first and the salt in the solution filtered into the liquid fraction so that the ice at the surface of the sample contained less salt than that inside. During melting period, the ice on the surface melt fist, so the conductivity of melting water decreases gradually.

Even for clean insulators, the maximum value of melting water conductivity is 4.3 times the freezing water conductivity. Salt tends to move to the surface during freezing.

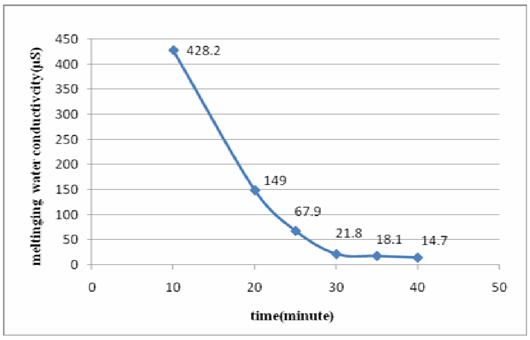

Figure6 Variation of Melting Water Conductivity Dripping from Clean Insulators. Freezing Water Conductivity is 100 μ S

- Pre-contaminated insulators

Figure7 shows the result of an insulator with ESDD 0.2mg/cm^2. The freezing water conductivity is 100 μ S. The maximum value is about 26 times the freezing water conductivity.

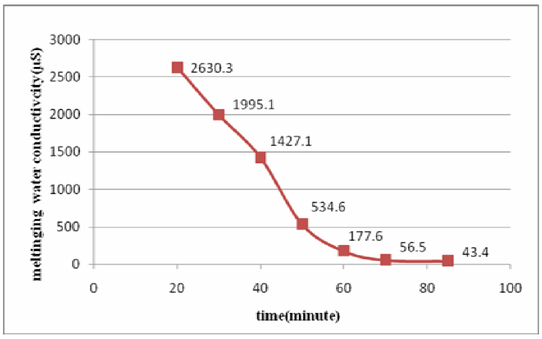

Figure7 Variation of Melting Water Conductivity Dripping from Pre-contaminated Insulators. ESDD/NSDD is 0.2/1.0 mg/cm^2, Freezing Water Conductivity is 100 μ S

Experiments on insulators with different ESDD, which are sprayed by freezing water of different conductivity, were carried out. At the same ESDD level, the maximum melting water conductivity of ice samples sprayed by 200 μ S conductivity freezing water is about 2 times that sprayed by 100 μ S conductivity freezing water. Other ice samples were all formed by 100 μ S conductivity freezing water, the maximum melting water conductivity of ice samples on insulators with ESDD 0.2mg/cm^2 is about 5 times that of ice samples on insulators with ESDD 0.05mg/cm^2, which is a little higher than the ratio of ESDD.

Besides, several melting results show that in the same conditions, the melting water conductivity decreases less slowly when freezing temperature is higher, as shown in Figure8.

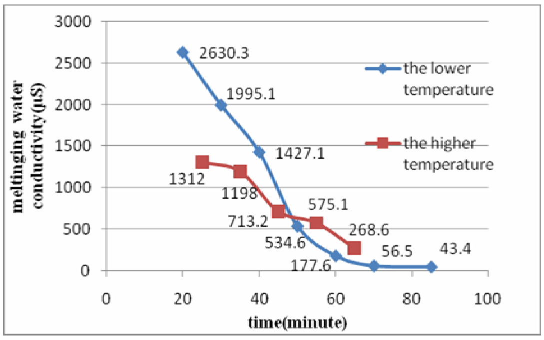

Figure8 Comparison At Different Freezing Temperature

The results indicate the complexity of variation of surface conductivity of ice-covered insulators and the difficulty to control. With surface conductivity increasing, icing flashover will decrease [5][6]. Based on these studies above, the maximum melting water conductivity always occurs at the beginning of melting and last for less than 10 minutes. As a result, voltage should be applied within 10 minutes once melting water begins dripping continuously.

IV. CONCLUTION

- The variation of melting water conductivity indicates that surface conductivity of ice-covered is complex and hard to control.

- The conductivity of melting water reaches its maximum value which is much greater than that of freezing water, and then decreases gradually to a very low level compared with the conductivity of freezing water.

- Since the maximum melting water conductivity always appears at the beginning of melting and last for less than 10 minutes, voltage should be applied within 10 minutes since melting water begins dripping continuously.

- During the period of freezing, salt was filtered greatly. The distribution of salt in ice is very uneven. In experiment, the highest melting water conductivity is 1.8 times the freezing water conductivity.

- During icing flashover tests, melting water conductivity is much higher than freezing water.

- If ESDD is the same, and the ratio of freezing water conductivity is 2, the ratio of melting water conductivity is also about 2. If the freezing water conductivity is the same, and the ratio of ESDD is 4, the ratio of melting water conductivity is about 5, a little higher than the ratio of ESDD.

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