INFLUENCE OF ICE THICKNESS ON DC FLASHOVER VOLTAGE OF ICE COVERED INSULATOR STRING

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Abstract: Icing flashover voltage is found to be influenced by ice thickness of insulators. In this paper, the icing flashover voltage of icecovered insulators with various ice thickness is studied under dc test condition. The ice thickness is represented by a icing measuring system with a rolling test stick contain. Through tests, features of different ice covered statues are observed with voltage energizing, and the relation between the ice thickness and icing flashover voltage are also studied. All test results show that the icing flashover voltage go decline if the ice thickness increase; when the ice thickness reach certain value, the flashover voltage becomes saturation.
Keywords: DC; insulator; Ice thickness; flashover voltage

I. INTRODUCTION

In the past few years, a great many outages caused by flashover of iced insulator strings of trandmisson lines have taken place in China. Most areas of China, like Hubei, Hunan, Jiangxi, Henan provinces and Three Gorge area in central China, Yunnan, Guizhou, Sichuan provinces in southwest China, Hebei, Shanxi provinces and Beijing-Tianjin-Tangshan region in north China, Qinghai and Ningxia provinces in northwest China, have the records of outages caused by flashover on ice-covered insulators.

Failures caused by ice accretion has seriously threatened the safe operation of electric power system in China, and caused a huge economic losses. In January 2008, 19 provinces in China, including Hubei, Hunan, Jiangxi, Guangxi province, have been affected by the rare in history disastrous weather of frozen rain and snow, which led to the power supply gap up to 70 million kilowatts and made 19 provinces restrict power consume. Taking the Chenzhou city of Hunan province as an example, about 443 electric power towers collapsed, which made the whole city a power “solitary island”.

Many studies on flashover performance of insulator strings covered with ice have been made around the world.It has been found that thickness of ice is a significant important factor that influences flashover voltage of the ice-covered insulator.Both the drop of resistance and nonuniform distribution of voltage caused by ice accretion are the major factors to the drop of flashover voltage.

II. TEST SPECIMENS AND TEST BASIS

2.1 Test facilities and test samples

The experimental investigations were carried out in the artificial climate room in the China Electric Power Research Institute. The artificial climate room has a diameter of 4 m and a height of 7 m, which is shown in Figure 1. It mainly consists of refrigeration system, vacuum-pumping system, and spraying system. The air temperature in the artificial climate room can be adjusted form -19℃ to 0℃ by the refrigeration system which meets the requirements of ice accretion test under different temperature. The air pressure in the room can be set as low as 50 kPa, which can simulate the atmospheric conditions at high altitude area.

Figure 1: Artificial climate test room.

The power supply was a ±600 kV thyristor-controlled dc source which is shown in Figure 2. It mainly consists of control unit, column type voltage regulator, silicon-controlled voltage regulator, step-up transformer, rectifying circuit and measuring systems.The voltage and leakage current signals transfered through cable will be collected and analysed by computer which is available for monitoring and recording the real-time datas.

The type of specimen is XZP-210 porcelain insulator. The geometric parameters of the test insulators are shown in Table 1 and the profile of the XZP-210 is shown in Figure 3.

Figure 2: ±600 kV DC power supply.

Table 1: Geometric parameter of the test insulator.

Type	Diameter (mm)	Creepage distance (mm)	Height (mm)	Mechanical strength (kN)
XZP-210	320	545	170	210

Figure 3: Profile of the XZP-210 insulator.

2.2 Test basis

The icicles are formed on the surface of the test insulators in a serious conditon, which may bridge the gaps between the insulator sheds.That will lead to the nonuniform distribution of voltage and consequently, a high voltage drop along the air gaps without icicles.

A important parameter in the ice test is the amount of ice accretion which can be measured by the weight or thickness of ice.In the paper, thickness measurement is adopted.Due to the nonuniform of ice coated on the insulator and the difficulty of measurement of ice thickness, a set of thickness measurement device has been established before test.

The thickness measuring device is a rotating cylinder, which is 600mm long and has a diameter of 30mm. The device can rotate in a constant rate(about 1r/min).The ice thickness on the cylinder can be regarded as the thickness on the test insulator. To eliminate the influence of different test position, the device is fixed near the test insulator.The rotating cylinder and thickness measurement of ice are shown respectively in Figure 4 and Figure 5.

Figure 4: The rotating cylinder.

Figure 5: Thickness measurement of ice.

As in the natural environment, the insulator surface will gradually accumulate the contamination. So the test object is precontaminated by solid layer method.The ESDD is 0.05 mg/cm^2 and the NSDD is six times to ESDD, i.e. 0.3 mg/cm^2.

Conductivity of the applied water is 100μS/cm which is in accordance with conductivity of rain in icing flashover prone area（about 80~120μS/cm）.

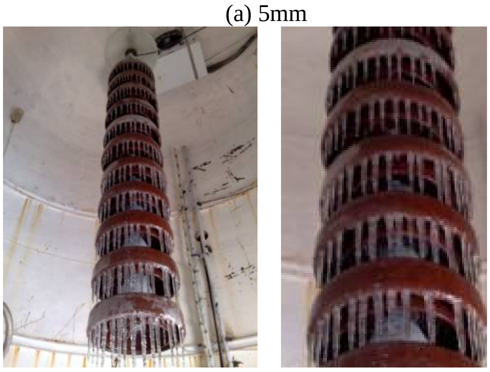
III. INFLUENCE OF ICE THICKNESS ON THE FLASHOVER VOLTAGE

3.1 Test condition with various ice thicknesses

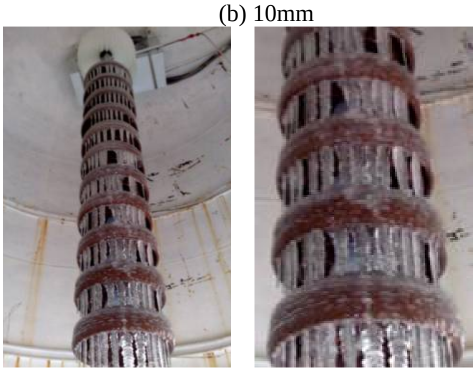
A string consisted of 11 pieces of XZP-210 insulators and the ice thickness is 5mm, 10mm, 15mm, 25mm, 28mm respectively. The Insulator Strings with various ice thicknesses are shown in Figure 6.

It can be found in Figure 6 that with the ice thickness of 5mm and 10mm, the insulator sheds were bridged incompletely by icicles. Especially with the ice thickness of 5mm, the air gap was still very large. with the ice thickness of 15mm, the insulator sheds had been bridged by icicles already. The insulator sheds are bridged completely by icicles along with no air gap between sheds with the ice thickness of 25 mm and 28mm.

(a) 5mm

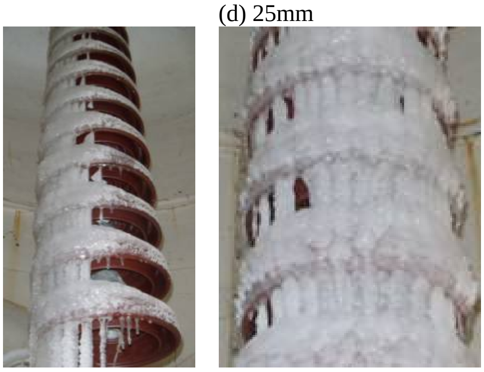


(b) 10mm



(c) 15mm

(d) 25mm

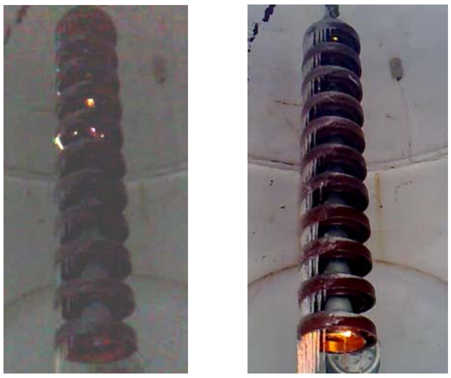


(e) 28mm

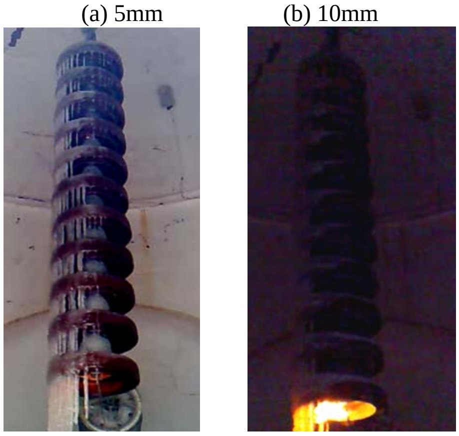
Figure 6: Insulator strings with various ice thicknesses

3.2 Discharge phenomena variance

Due to the different voltage distributions along the surface of insulator and ice coat, the ice thickness have an important effect on voltage distribution, which can be figured out according to different flashover process.As shown in Figure 7(a) arcs appear between the sheds in the middle of most insulator strings with the ice thickness of 5mm, which indicates that the insulator string form dominates the voltage distribution on insulator string surface and lead to well voltage distribution along with random position of arc. With the ice thickness of 10mm, arcs appear on the end of strings(high voltage end)as well as slight arcs on the top. With the ice thickness of 15mm and 25mm, arcs appear on the high voltage end of strings. Arcs will be more dramatic on insulator string with thicker ice coat.



(a) 5mm (b) 10mm



(c) 15mm (d)25mm

Figure 7: The Arcing Position of the Insulator String With Different Ice Thickness

3.3 Test results

In order to study the relationship between ice thickness and flashover voltage, ESDD and NSDD which are the most relevant parameters of insulator precontamination are kept constant (0.05 mg/cm^2 and 0.3 mg/cm^2 respectively). The insulator sting still consist of 11 pieces XZP-210 porcelain insulators. To avoid the influnce of results dispersion, several experiments have been done and the average value was taken. Meanwhile, in order to compare results under different ice thickness, flashover voltages under various ice thickness are calculated, taking flashover voltage under 5mm ice thickness as standard value. All test results are shown in Figure 8. The icing flashover voltage was represented by the per-unit value, of which the standard value came from the icing flashover voltage under the test condition with 5mm ice thickness.

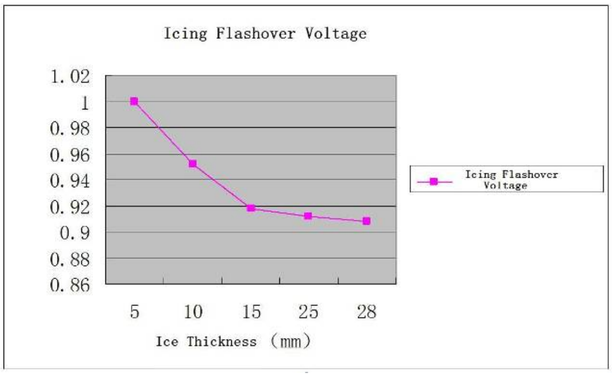


Figure 8: Relationship between icing flashover voltage and ice thickness.

The results available in Figure 9 show that an increase in ice thickness causes a decrease in flashover voltage of insulators.

It seems that the flashover voltage levels off when the ice thickness is up to 15mm along with completeness of bridging between insulator sheds.It can be concluded that 15mm ice thickness can be adopted as the ideal thickness of ice accretion test for evaluating the icing flashover voltage of insulators under heavy ice covered condiction.

IV. CONCLUSIONS

A ice thickness measuring device which can show the thickness of ice on the test insulator has been established in the test.

The condition of ice coated on the insulators and the distribution of voltage along the strings were quite different under various ice thickness. And the arc positions changed if the ice thickness was different.

An increase in ice thickness causes a decrease in flashover voltage of insulators. it seems that the flashover voltage levels off when the ice thickness is up to 15mm.It can be concluded that 15mm ice thickness can be adopted as the ideal thickness of ice accretion test for evaluating the icing flashover voltage of insulators under heavy ice covered condition.

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