EXPERIMENTAL INVESTIGATION THE IMPACT OF ELECTRIC DISCHARGE ON ICE ACCRETION

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Abstract: In this paper, a thermal method for anti-icing the suspension overhead insulators which could limit the power loss are proposed and tested. A certain kind of semiconducting room temperature vulcanized (RTV) silicone rubber was used to configure the surface resistivity of the insulator. By applying this material to the bottom side of the insulator, the surface discharge at the upper surface was increased when there is water and ice on the upper surface. And the power loss is limited when the upper surface is dry. The anti-icing effect of this method on insulator strings for 110 kV transmission line was tested in a climate chamber, and the results showed that the formation of ice on the coating was completely prevented.

1 INTRODUCTION

Icing on transmission line insulators has caused serious accidents[1-7]. The irregular shape of insulators makes it difficult to develop automatic de-icing devices. Most efforts to eliminate ice on insulator strings have been focused on passive methods, such as modification of the surface characteristics. Thus hydrophobicity was once believed to be able to inhibit the formation of ice by weakening the adhesive force between the ice and the insulator surface, but it has since been found that the hydrophobicity and the hydrophobicity transfer property is weakened below the freezing point [8] and experiments have shown little effect in preventing ice accretion on the silicone rubber surfaces [9].

Thermal methods have been considered for deicing. For example, heating ACSR (Aluminum Conductor Steel Reinforced) conductors by the Joule heat generated by electric current has proved to be an effective and practical method for preventing ice accretion on the conductor surface[]. The idea of introducing Joule heat by lowering the surface resistance of high voltage insulator was proposed a long time ago [10]. The use of resistive glazes was first applied around the high voltage electrode to prevent potential distortion along the insulator string under contamination conditions which would lead to local arcing and consequent radio interference. Application of conducting glaze to the whole insulator has been proved to have obvious surface heating effect that could improve performance under contaminated conditions but did not last well [11, 12].

Liao et al. [13] extended the idea of using the thermal method to anti-icing and formulated a partially-conducting RTV silicone rubber (SiR) for insulators by adding conducting particles such as carbon black and carbon fibers. The anti-icing properties of this material are due to its combination of hydrophobicity and surface heating. The time it takes for water droplets to freeze is extended because the leakage current heats up the insulator's surface and the hydrophobicity discourages water droplets from forming surface films so that they tend to run off the insulator[20]. The results showed that this partially-conducting RTV SiR coating can significantly reduce the rate of ice accumulation as compared to insulators with an ordinary RTV SiR coating or without any coating.

One practical aspect of using thermal method for anti-icing is to limit the power loss which could compromise the life span and economic efficiency. In this paper, the preliminary investigation on practical usage of the semiconducting RTV SiR was presented. The semiconducting SiR was applied to the bottom side of the insulator to configure the surface resistance of the insulator to eliminate the power loss when there is no precipitation. The anti-icing performance was compared in a climatic chamber.

2 SURFACE CONDUCTIVITY CONFIGURATION

Semiconducting RTV rubber coating, which acts as a resistor paralleled to the impedance of insulator, generates heat and makes the surface temperature above the ambient temperature by introducing certain amount of energy loss. This is a trading off between the loss of energy and loss caused by outages of transmission and distribution systems.

Some work [21] has been done to investigate the effect of surface conductivity configuration on anti-icing performance. The present paper should be considered as a follow-up of the previous work, and the specimens used in this paper was paint as follows.

Figure 1: coating applied to the pin area

Surface discharge, such as arc and corona, could heat the insulator surface and defer the ice accretion. By applying the semiconducting coating to the bottom side of insulators, the surface discharge is introduced under certain precipitation conditions to improve the flashover performance. The basic idea of applying the coating only to the bottom side of the insulator is to restrict the energy loss. A conductive path will be formed when the upper side of the insulator was wetted by moisture or precipitation. So the surface will not be heated at sunny days and thus the energy loss is decreased.

3 EXPERIMENTAL

3.1 General setup

The experiments were conducted in a climate chamber at China electric power research institute(CEPRI) [13]. The inner space of the climate chamber is of a cylinder shape with diameter of 4 m and height of 5 m. The schematic diagram of the inside arrangement was shown in figure 2. Two insulator strings consist of seven pieces could be hung in parallel in the middle of the climate chamber. Two set of nozzles were placed near each insulator string to form a uniformly distributed spay at the specimens. The icing conditions at each insulator string are symmetrical.

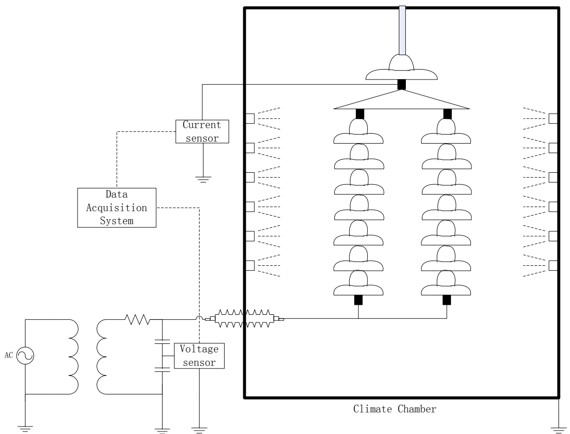

Figure 2: Schematic diagram for the HV circuit and monitor system

The applied voltage and leakage current was monitored and recorded by a data acquisition system sampled at 0.5 M/s. The peak values of the voltage and current were recorded and used in the figures to present the discharge on the insulator surface.

3.2 Specimens

The porcelain insulator used in this experiment was shown in the following table.

Table 1: Insulator configuration

Shed diameter (mm)	Shed spacing (mm)	Leakage distance (mm/unit)
280	146	335

The specimens were two strings, each consisted of seven insulators. One string was coated with the semiconducting RTV SiR coating to the bottom side of each insulator as described in Section 2 according to IEEE standard [23].

Table 2: coating parameters

Coating parameter	value
Volume resistivity	3×106 Ω·cm
Coating thickness	Less than 0.5 mm
Applying method	brush

One string without any coating was used for cooperation. The RMS value of the service voltage for the specimens was 63.5 kV, corresponding to 110 kV transmission line.

3.3 ICE DEPOSIT METHOD

This study was focused on the wet regime of growth, and the conditions in Tab. 1 were chosen to form freezing rain. Wet regime of growth produces a kind of opaque, high density that is about 0.9 g/cm3 and has strong adhesive force on the surface of insulator. This kind of ice causes most serious accidents in power systems.

Table 3: Experimental conditions

Ice deposit parameter	value
type	Glaze
Ambient temperature	-8 oC
Water droplets diameter	100 μm
Water conductivity	100 μs/cm
Distance from nozzle to specimen	0.7 m

The water was sprayed periodicity for 15 s every 2 min. Water Conductivity was adjusted to 100 μs/cm, which was recommended in the IEEE Std 1783 [19]. The thickness of ice accumulated on the insulator strings was measured by a monitoring cylinder.

The artificial icing experiment consisted of three stages. The insulators was cooled and energized for 2 hours, then water was spayed for 2 hours and the voltage and leakage was recorded. Picture of the specimen was taken after another 30 minutes to strength the ice.

4 RESULTS AND DISCUSSION

4.1 Ice appearance

After 2 hours icing, the appearance of the ice on both insulator strings was shown in the following figure. Ice thickness on the monitoring cylinder was 3.1 mm.

The space between insulators of the left string without coating was completely bridged by icicles. Icicles at the side opposite the nozzles were a bit shorter. For the strings with semiconducting coating, there was no icicles, and no ice covering on the surface of the insulator. The ice formation on the right string was completely prevented.

Figure 3: Icing on clean surface

4.2 Leakage current

The Leakage current recorded was the sum of the two specimens since there was only one channel for the current at the data acquisition system. The leakage current of the string without coating during icing was monitored in another test and shown in the following figure. The current ranged from 1 to 4.5 mA, and showed no periodicity.

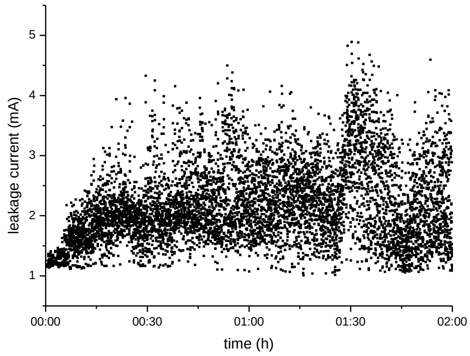

Figure 4: leakage current of one porcelain string without coating

The leakage current curves at the very beginning and after one hour of the icing progress were shown in the following figures. The current ranged from 3 to 30 mA, so it mainly came from the string with semiconducting coating.

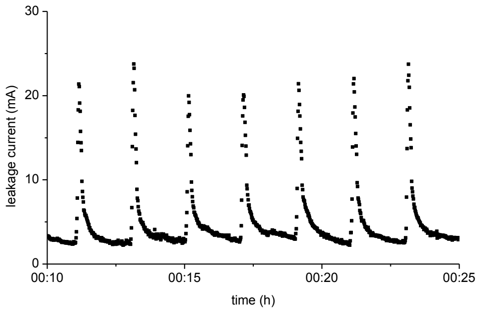

Figure 5: leakage current at the beginning

The average power of the discharge along the string at the beginning 20 min is 311 w, and it was sufficient to prevent ice formation under the test conditions.

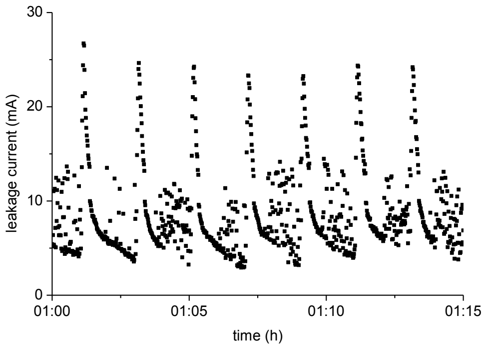

Figure 6: leakage current after one hour

The leakage current curve showed a lot of discharge after one hour. The peak value was about 25 mA, which is slightly higher than that in the previous figure. This was caused by the ice accumulation on the string without coating.

The leakage current showed a clearly periodicity which was consistent with the spray period of the icing water. The leakage current rose very quickly as the water being sprayed, then following a attenuation process. The period was about 2 min which is the same as the spray period.

4.3 potential distribution

The potential distribution was tested under service voltage by measuring the potential drop of each insulator along the string. The results of one coated and one uncoated string were shown in the following figure. The potential drops were converted to the percent of the service voltage.

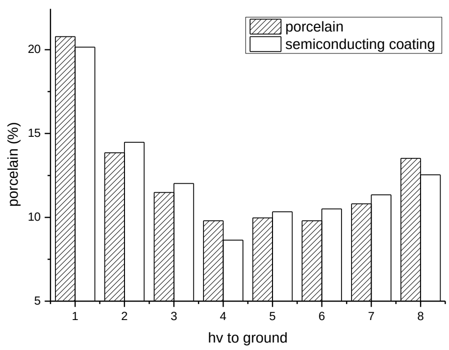

Figure 7: potential distribution

The results showed that the potential distribution was more uniform compared with that of the uncoated porcelain insulator string. The potential drop of the first and the last insulator of the coated string was smaller. The standard deviation of the potential was 1.95 kV for the coated string, compared to 2.05 kV for the uncoated case.

The semiconducting coating at the bottom side did not affect the potential drop of each insulator, and that was the reason for the good performance under fog and rain.

5 CONCLUSION

The surface conductivity of the insulator could be reconfigured by applying Semiconducting RTV SiR to introduce surface discharge which could raise the surface temperature under precipitation conditions. The power losses is controlled for other weather conditions.

For a seven piece string for service voltage 110 kV, the ice formation on the insulator surface was completely prevented with power loss of 311 w.

The surface discharge could be controlled by configuring the location and conductivity of the semiconducting coating. This method should be adjusted according to the natural icing conditions and the insulator used.

6 ACKNOWLEDGMENTS

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