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DEVELOPMENT OF FLASHOVER VOLTAGE TEST METHOD FOR SNOW ACCRETED INSULATORS
- PRELIMINARY TEST WITH 33 KV CLASS INSULATOR SAMPLES -

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Abstract: As the preliminary attempt to develop a 154 kV class full-scale snow test procedure to be used for evaluation of various insulator designs, flashover voltage tests of snow accreted insulators were carried out with 33 kV class insulator samples. The test procedure consisted of four steps, 1) generation of artificial snow with defined conductivity, 2) accretion of packed snow on the insulator, 3) increase of liquid water content of the accreted snow, 4) voltage application. The voltage tests showed that the level of flashover voltage was comparable with the service voltage during the Niigata field outage, and the results were also repeatable. The test method was preliminary verified for the full-scale transmission class insulators.

1. INTRODUCTION

In December 2005, Japan experienced a major outage in the Niigata Kaetsu area which lasted for up to 30 hours and was caused by snow accretion on insulators. During the event, porcelain long-rod insulators on several 154 kV and 66 kV lines were completely covered by wet and packed snow of relatively high conductivity [1].

To develop a 154 kV class full-scale snow test procedure to be used for evaluation of insulator designs, flashover voltage tests of snow accreted insulators were carried out with 33 kV class insulators.

2. TEST PROCEDURE AND RESULTS

The proposed test required generating snow with well defined conductivity, density, etc. The target values of the snow parameters were shown in Table 1.

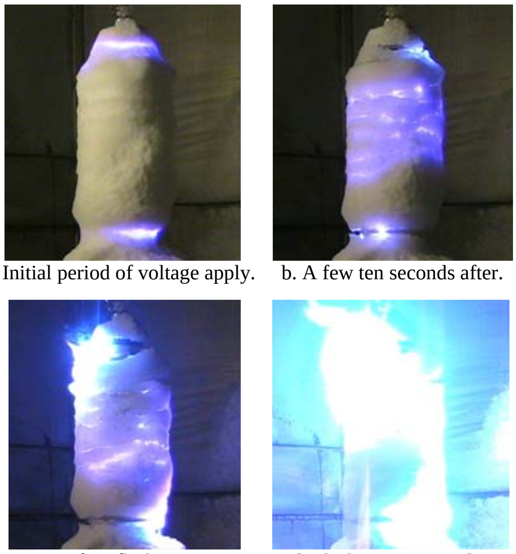
The test procedure consisted of four steps, 1) generation of artificial snow with defined properties, 2) accretion and packing of snow on the insulator, 3) increasing the liquid water content of accreted snow, and 4) voltage application of the snow-accreted insulators.

During the snow generation, the water with defined conductivity was sprayed into a large climate chamber cooled to -9 °C, and fine ice particles were collected as the artificial snow. The resulting snowflakes were blown onto the insulators until the snow accreted and filled the gaps between the sheds. After spraying the water with controlled conductivity on the accreted snow surface, voltage tests were performed in a temperature range from +1 to +2 °C.

As the results, the target values for wet and packed snow were reached and verified on 33 kV insulators. Typically, three phases of discharge activity were identified during the voltage test (Fig. 1). The flashover voltage was comparable to the service voltage during the Niigata outage and the results were also repeatable.

Table 1: Target values of snow parameters.

Parameter	Target value
Size of snowflakes	0.1-0.2 mm
Shape of snow	Cylindrical and half covered
Snow density	0.5 g/cm^3 and higher
Liquid water content	20-30%
Snow conductivity	About 0.2 mS/cm



a. Initial period of voltage apply. b. A few ten seconds after.

c. Before flashover. d. Flashover occurred.

Figure 1: Photographs of discharge activity during voltage test.

3. CONCLUSIONS

Flashover voltage tests of snow-accreted insulators with defined properties were carried out using 33 kV class insulators. Based on the test results, the test procedure is feasible for testing of 33 kV insulators covered by wet and packed snow. The test method was also verified on a preliminary basis for the full-scale 154 kV class insulators of various types and working positions.

4. REFERENCES

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- Preliminary Test with 33 kV Class Insulator Samples -

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***Abstract*— As the preliminary attempt to develop a 154 kV class full-scale snow test procedure to be used for evaluation of various insulator designs, flashover voltage tests of snow accreted insulators were carried out with 33 kV class insulator samples. The test procedure consisted of four steps, 1) generation of artificial snow with defined conductivity, 2) accretion of packed snow on the insulator sample, 3) increase of liquid water content of the accreted snow, 4) voltage application. During the snow generation, the water with defined conductivity was sprayed into a large climate chamber cooled to -9 °C, and fine ice particles were collected as the artificial snow. The resulting snowflakes were blown onto the insulator sample until the snow accreted and filled the gaps between the sheds. After spraying the water with controlled conductivity on the accreted snow surface, voltage tests were performed at a controlled temperature in the range from +1 to +2 °C. Target values for wet and packed snow with defined conductivity were reached and verified on 33 kV insulators. Preliminary voltage tests showed that the level of flashover voltage was comparable with the service voltage during the Niigata field outage, and the results were also repeatable. The test method was preliminary verified for the full-scale transmission class insulators of various types and operating orientations.**

Keywords-component; insulator, wet snow, packed snow, sea-salt, flashover

I. INTRODUCTION

In December 2005, Japan experienced a major outage in the Niigata Kaetsu area which lasted for up to 30 hours and was caused by snow accretion on insulators. During the event, porcelain long-rod insulators on several 154 kV and 66 kV lines were completely covered by wet and packed snow of relatively high conductivity (Fig. 1). The observed conductivity was attributed to salt transported from the sea by the strong wind. The large amounts of wet snow mixed with the sea-salt reduced insulation strength of the insulator strings and caused flashovers [1].

While extensive research has been performed on ice accretion and snow covering on insulators [2-13], knowledge related to the effect of salt-containing wet snow is very limited, as these conditions are quite rare [14, 15].

In order to increase the reliability of the networks of Japan, CRIEPI recently initiated a comprehensive project related to ice and snow issues at overhead lines [16]. Part of this project was to develop a 154 kV class full-scale snow test procedure to be used for evaluation of insulator designs. The first step in this was to verify a proposed test using 33 kV class insulator samples. This paper provides information about the procedures for generation and accretion of wet and packed snow with well defined properties onto 33 kV class insulators in laboratory and the results of the flashover voltage tests.

Figure 1. Example of packed snow on horizontally mounted long-rod insulator strings.

II. FLASHOVER VOLTAGE TEST PROCEDURE FOR SNOW-ACCRETED INSULATORS

The proposed test required generating snow with well defined conductivity, density, etc. The target values of the snow parameters were, snowflake size of 0.1-0.2 mm, snow density of 0.5 g/cm^3, liquid water content of 20-30%, and snow conductivity: 0.2 mS/cm, as shown in Table I. The snow conductivity was the same as observed after the blackout at Niigata Kaetsu in 2005.

The test procedure consisted of four steps, 1) generation of artificial snow with defined conductivity, 2) accretion of packed snow on the insulator, 3) increase of liquid water content of accreted snow, 4) voltage application.

A 33 kV class porcelain long-rod support insulator was applied for the tests. The effective length, creepage distance and number of insulator sheds were 585 mm, 1020 mm and 10, respectively. All the tests were performed using the test facilities of STRI AB in Ludvika, Sweden.

TABLE I. TARGET VALUES OF SNOW PARAMETERS.

Parameter	Target value
Size of snowflakes	0.1-0.2 mm
Shape of snow	Cylindrical and half covered
Snow density	0.5 g/cm^3 and higher
Liquid water content	20-30%
Snow conductivity	About 0.2 mS/cm

A. *Artificial Snow Generation*

During the generation, water with conductivity of 0.2 mS/cm was sprayed into a large climatic chamber of 18 m diameter and 23 m height. By maintaining a temperature of -9 to -10 °C, fine ice particles were generated as the artificial snow (Fig. 2). Snowflake size was mostly 0.1 to 0.2 mm, and the visual appearance was very similar to natural snow. The conductivity of the artificial snow was approximately 0.2 mS/cm, as expected, but liquid water content was still zero.

B. *Accretion of Packed Snow*

For the snow accretion and voltage tests, the artificial snow was moved to another test chamber, 3x3x5 m, which was maintained between +1 to +2 °C. The snowflakes were blown onto the insulator by a blower, a small handheld vacuum cleaner operating in reversed mode, i.e. blowing instead of sucking, until the snow accreted and filled the gaps between the sheds. The distance between the blower and the insulator was about 300 mm, and the wind velocity at the insulator was approximately 15 m/s.

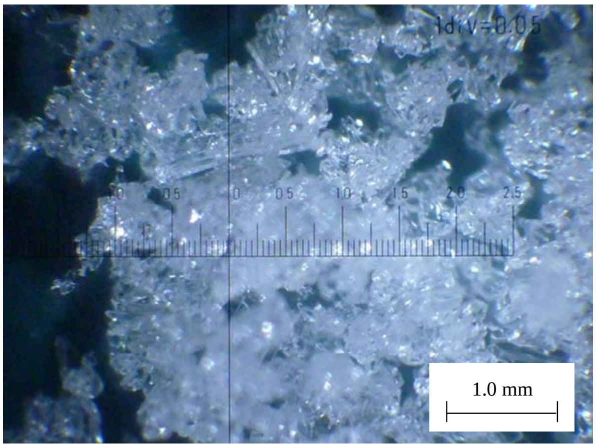


Figure 2. Appearance of the artificial snow.

Fig. 3 shows the photographs of insulators with well packed accreted snow on the insulators at a density in the range of 0.5-0.6 g/cm^3. Cylindrical snow accretion, as observed in the Niigata case, was formed by rotating the insulator on a turn table during accretion. Thickness of the accreted snow at the shed surface was about 20 mm. To check the influence of inhomogeneous snow coverage, insulators were covered by snow blowing from one direction. This resulted in coverage of approximately half of the insulator surface, and such insulators were also prepared for the voltage tests (Fig. 3b).

a. Cylinder like accretion. b. Half part accretion.

Figure 3. Snow accreted insulators.

C. Increase of Liquid Water Content of Accreted Snow

Water of the defined conductivity was sprayed onto the accreted snow to increase the liquid water content to the range of 20-30% which resulted in a snow density of 0.7-0.8 g/cm^3. As the result, the target values for wet and packed snow with defined conductivity, density, etc. (Table I) were attained and verified for the 33 kV insulators.

D. Flashover Voltage Test

After spraying the conductivity-adjusted water onto the accreted snow surface, voltage tests were performed in the same test chamber with a temperature range of +1 to +2 °C. A 250 kVac, 500 kVA test transformer was used for the flashover tests. Applied voltage was increased rapidly up to the desired value at a rate 3 kV/s and thereafter kept constant until the insulator either flashed over or withstood in that the risk of flashover was deemed negligible based on monitoring of leakage current levels. If flashover occurred at the selected test voltage, the applied voltage was decreased about 10% for the next test.

III. Results of Flashover Voltage Tests with 33 kV Class Insulators

Fig. 4 shows the photographs of discharge activity at 34 kV during the voltage tests. Fig. 5 shows the time variation of applied voltage and leakage current observed for the same test.

Typically, three phases were identified during the voltage test. During the initial period of voltage application, small visible discharges appeared inside the accreted snow, and the leakage current increased with increased applied voltage. A few tens of seconds after voltage application, intensive discharges developed and distributed along the insulator. A number of air gaps formed in the snow as a result of melting, and maximum amplitudes in the range of 1.6 A were measured. Thereafter, a long arc grew along the surface and finally developed into a complete flashover after a few minutes.

The flashover voltage was comparable with the service voltage during the Niigata outage, and the results were also reproducible.

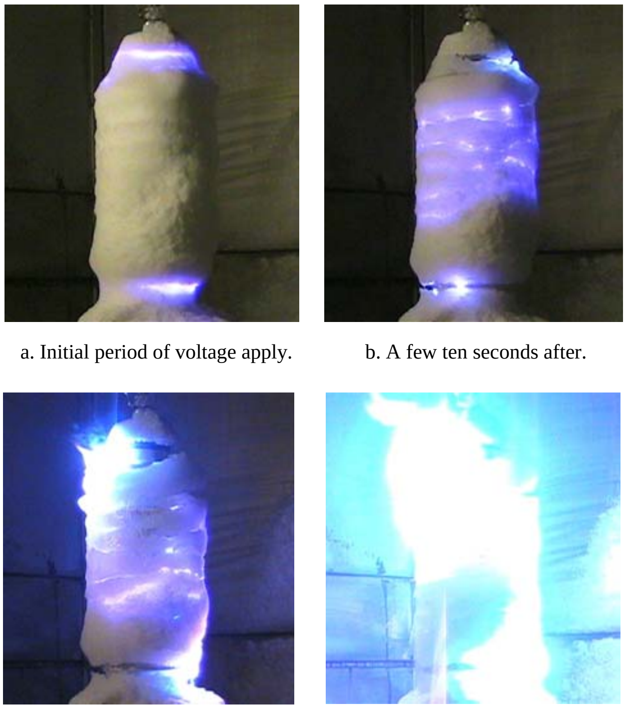
IV. Conclusions

Flashover voltage tests of snow-accreted insulators with controlled snow conductivity, moisture, density, etc. were carried out using 33 kV class insulator samples as a first step in developing a test for transmission class insulators of various designs.

The test procedure consisted of four steps, 1) generation of artificial snow with defined properties, 2) accretion and packing of snow on the insulator, 3) increasing the liquid water content of accreted snow in a controlled manner, and 4) voltage application of the snow-accreted insulators. The target values for wet and packed snow with defined conductivity were reached and verified on 33 kV insulators.

High voltage flashover tests showed that the flashover voltage was comparable to the service voltage during the Niigata outage, and the results were also repeatable.

Based on the test results, the test procedure is feasible for testing of 33 kV insulators covered by wet and packed snow with defined conductivity. The test method was also verified on a preliminary basis for the full-scale 154 kV class insulators of various types and working positions.



a. Initial period of voltage apply. b. A few ten seconds after.

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Figure 4. Photographs of discharge activity during voltage test.

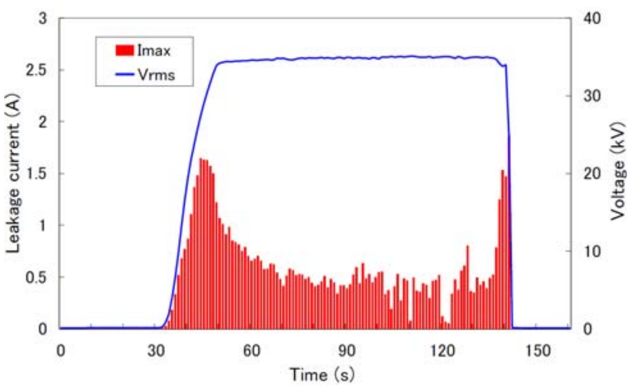

Figure 5. Time variation of voltage and leakage current during the test.

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