# Evaluation of Flashover Voltage Property of Snow Accreted Insulators for Overhead Transmission Lines, Part III - 154 kV Full-scale Flashover Voltage Test of Snow Accreted Insulators -

**Hiroya Homma, Kohei Yaji, Teruo Aso, Masato Watanabe, Gaku Sakata**
Central Research Institute of Electric Power Industry (CRIEPI)
2-6-1 Nagasaka, Yokosuka, Kanagawa 240-0196, Japan

**Andreas Dernfalk** and **Igor Gutman**
STRI AB
Box 707, SE-77180 Ludvika, Sweden

## ABSTRACT

**In December 2005, Japan experienced a major outage in Niigata Kaetsu area due to a large amount of wet snow mixed with sea-salt accreted on several transmission line insulators. To clarify the causes of the snow-induced outage and increase reliability of the networks, a 154 kV class full-scale snow test procedure to evaluate various insulator designs was developed, and artificial flashover voltage tests of snow accreted insulators were carried out. High voltage flashover tests showed that the flashover voltage of both long-rod and cap & pin insulators was decreased with the increase of snow conductivity. Also, cap & pin insulators showed significantly higher flashover voltage than long-rod insulators. Thus substitution of long-rod insulators with cap & pin insulators appears to be reasonable as a countermeasure against snow induced flashovers.**

Index Terms - **Insulator, wet snow, packed snow, sea-salt, flashover.**

## 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, packed snow of relatively high conductivity. The observed conductivity was attributed to salt transported from the sea by 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 the effect of insulator ice and snow accretion on flashover characteristics [2-15], knowledge related to the effect of salt-containing wet snow is very limited, as these conditions are rare [16, 17]. In order to increase reliability of Japanese networks, CRIEPI initiated a comprehensive project related to the effect of ice and snow accretion on overhead lines [18]. Part of this project was to develop a 154 kV class full-scale snow test procedure to evaluate insulator designs.

*Manuscript received on 17 Jan. 2014, in final form 25 May 2014, accepted 26 May 2014.*

As the first step, flashover voltage tests of snow-accreted insulators with controlled snow conductivity, liquid water content, density, etc. were carried out using 33 kV class insulators. The target values for wet and packed snow with defined conductivity were verified on 33 kV insulators. High voltage flashover tests showed that the flashover voltage was comparable to the service voltage for conditions presented during the Niigata outage, and the results were repeatable [19]. Based on these tests, the procedure was considered 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.

This paper discusses the procedures for generation and accretion of wet and packed snow with well defined properties onto 154 kV class insulators in laboratory and the results of the flashover voltage tests.

## 2 BLACKOUT IN NIIGATA KAETSU AREA

The details of the wet snow storm in the Niigata case have been reported in [1]. Some important elements of this event are described briefly below.

**DOI 10.1109/TDEI.2014.004563**

A strong low pressure system in Pacific Ocean moved from south to north along the east coast of Japan's main island, and another low pressure system in the Sea of Japan moved across the island on 22 Dec. 2005. The ambient temperature in the Niigata Kaetsu area, which is located in the northwest of the Japan's main island facing the Sea of Japan, stabilized in the range of 0 to +2 °C from 03:00 to 17:00 on 22 Dec. with heavy precipitation and wind. The total precipitation and the maximum 10 minutes average wind speed observed at Niigata Meteorological Local Agency was 26 mm from 03:00 to 17:00 and 14 m/s just before 09:00. The observation system of Tohoku Electric Power Co. recorded the maximum wind speed of more than 25 m/s at 11:00.

Cascading electrical failures on 154 kV and 66 kV transmission lines started just before 09:00 and resulted in numerous tripped lines. At about the same time, a couple of 275 kV transmission lines also tripped as a result of conductor galloping. A total of 30 transmission lines with 49 circuits tripped and induced a blackout over a large area.

Many porcelain long-rod insulator strings, which were used exclusively on 154 kV and 66 kV transmission lines, were packed with wet snow. Figure 1 shows an example of packed snow on insulator strings. The shape of packed snow on some insulators was cylindrical, while others were eccentric pennant into the wind direction. These shapes of snow on insulator strings are quite different from those which result from ice accretion or covered by snow without strong wind. The volume density of the packed snow ranged from 0.54 to 0.94 g/cm$^3$, and the maximum melted water conductivity was approximately 200 μS/cm at 25 °C.

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

The worst of the weather ended before the night of the 22 Dec., and restoration work was started at midnight. More than 2,500 electrical workers climbed the towers and removed the packed snow from insulator surfaces by hand. The restoration work was very difficult, as the wet snow was nearly transformed into ice at that time. After 31 hours from the start of the interruption, the electrical system was entirely restored.

During restoration work, many traces of power arcs on insulator surfaces and hardware were observed on both horizontally and vertically mounted insulators, including V-strings. They were found over a wide area, and many traces were located inland, 30 to 40 km from the Sea of Japan. The measured conductivities of the packed snow were the highest in this area. Apparently, the sea-salt was carried by the wind to the inland area.

After the outage, Tohoku Electric Power Co. completed replacement of the long-rod insulators of one transmission line circuit by cap and pin insulators in the Niigata Kaetsu area, and they are conducting the same countermeasures in other areas where the similar events could occur.

## 3 FLASHOVER VOLTAGE TEST PROCEDURE FOR SNOW ACCRETED INSULATORS

To clarify the causes of the snow induced flashover and increase reliability of the networks, a 154 kV class full-scale snow test procedure to be used for evaluating various insulator designs was developed.

Various research has been carried out on the effect of insulator snow accretion on flashover characteristics, and representative snow test procedures and evaluation methods have been established in IEEE standard 1783-2009 [20]. In the test procedure, natural snow gathered from the ground is mixed with salt with a snow blower. Then the snow is dumped into the snow pile jig mounted on the insulators to simulate the accumulation of snow on horizontal oriented insulators. However, storing and handling natural snow still presents some difficulties.

The proposed test required generation of snow with well defined conductivity, density, etc.. The target values of the snow parameters, such as snowflake size, snow density, liquid water content and snow conductivity, are shown in Table 1. The target snow conductivity was the same as observed after the blackout at Niigata Kaetsu in 2005 and during continuous field observation in the same geographic region from 2007 to 2011 [21].

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 in the accreted snow, 4) voltage application. A 154 kV class porcelain long-rod insulator and cap & pin suspension insulator string were utilized for the tests. The number of insulator sheds, connection length, creepage distance and dry arc distance of both insulators is shown in Table 2. All the tests were performed using the test facilities of STRI in Ludvika, Sweden.

**Table 1.** Target values of snow parameters.

| Parameter | Target value |
|---|---|
| Size of snowflakes | 0.1-0.2 mm |
| Shape of snow | Cylindrical |
| Snow density | 0.5 g/cm$^3$ and higher |
| Liquid water content | 20-30% |
| Snow conductivity, $\sigma_{25}$ | 200 and 700 μS/cm |

**Table 2.** Specification of test insulators.

| Insulator type | Long-rod | Cap & pin |
|---|---|---|
| Shed number / profile | 21 | Anti-fog |
| Shed diameter [mm] | 160 | 254 |
| Connection length per unit [mm] | 1,025 | 146 |
| Creepage distance per unit [mm] | 2,140 | 430 |
| Number of units | 2 | 13 |
| Dry arc distance [mm] | 1,774 | 1,960 |
| Total creepage distance [mm] | 4,280 | 5,590 |