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EVALUATION OF SNOW ACCRETION PROPERTIES OF INSULATORS BY FIELD OBSERVATION AND ARTIFICIAL TEST

-FOCUSING ON PACKED AND WET SNOW CONDITION-

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Abstract**:** Snow accretion properties of insulators were evaluated by field observation and artificial test. In the field observation, we carried out remote observations of snow accretion on insulators over the two sequential winters at Niigata, Japan. During eleven events of snow accretion, gaps between the sheds of insulators were bridged with relatively large amounts of snow. Most accretion events occurred during periods of low wind velocity, with only one case occurring during a period of strong winds. During this remarkable event, the gaps between the sheds of long rod insulator were covered with the packed snow to some extent, but they did not bridge completely between the sheds as a result of insufficient precipitation.

During artificial snow accretion tests, a wind tunnel was used to deposit snow particles onto the insulators using snow taken from outside of the facility. Snow accretion properties of the insulators were evaluated by observation of the accreted snow shape and the amount of snow usage untill snow bridged between the sheds. Wind velocity was varied from 5 to 15 m/s In the case of 5 m/s, snow accreted readily on the sheds. In the case of higher wind velocity, snow accreted to the part of rod and caps with packed and wet conditions. At the higher wind velocities, larger amounts of snow was needed for bridging between the insulator sheds.

1. INTRODUCTION

In 2005, Japan experienced a major outage in Niigata Kaetsu area due to snow accretion on insulators. During the event, porcelain long-rod insulators on several 154 kV and 66 kV lines were completely covered with wet and packed snow. The reduced insulation strength of the insulator strings caused sequential flashovers. This flashover phenomenon was quite different from the well-known one caused by ice accretion or snow covering the insulator strings. Knowledge related to the effect of wet snow is very limited, as these conditions are quite rare [1,2].

The authors have reported the phenomenon of wet and packed snow accretion of various types of insulators in artificial snow accretion tests [3]. This paper presents an evaluation of snow accretion properties of porcelain long rod, cap & pin insulators by both field observation and artificial snow accretion tests focused on packed and wet snow conditions.

2. RESULTS AND DISCUSSION

Eleven events of snow accretion during which the gaps between insulator sheds were bridged were recorded by field observation over the two winters. While these all occurred during periods of weak wind, only one case of accretion during strong wind was also observed. In this latter event, the strong wind kept blowing with snow fall and eventually caused wet and packed snow accretion on the insulators. Although the rod regions of the long-rod insulator were covered with packed snow to some extent, the gaps between the sheds were not bridged completely as a result of less precipitation than was recorded during the failure of 2005.

During artificial snow tests, in the case of the 5 m/s wind velocity, large amounts of snow accreted on the windward side of the upper part of sheds despite less snow usage. In the cases of 10 and 15 m/s, snowflakes frequently run strike the caps regions of the cap & pin insulators and the rod regions of the long-rod insulator which resulted in packed and wet snow accretion to these elements. In addition, the case of 10 and 15 m/s wind velocity with the cap & pin insulators, sheds were not bridged within the two hour measurement period.

Satisfactory agreement was obtained between the appearance of snow accretion during field observation and artificial tests. During the artificial tests, the cap & pin insulators showed superior performance in preventing snow accretion which bridged between sheds as a result of their larger shed spacing, as was observed in field data.

(a) Shapes of snow accretion with strong wind
(b) Shapes of snow accretion with weak wind

Figure 1: Contrast on shapes of snow accretion between strong and weak wind.

3. CONCLUSION

Continuous field observation of snow accretion and artificial tests was performed in parallel in order to determine snow accretion of the insulators with a focus on packed and wet snow conditions. The results showed that shed spacing of the insulators and wind velocity affected to the snow accretion properties.

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Evaluation of Snow Accretion Properties of Insulators by Field Observation and Artificial Test -Focusing on Packed and Wet Snow Condition-

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Keywords-Insulators; Packed and Wet Snow Accretion; Field Observation; Artificial Test

I. INTRODUCTION

In 2005, Japan experienced a major outage in Niigata Kaetsu area due to snow accretion on insulators. During the event, porcelain long-rod insulators on several 154 kV and 66 kV lines were completely covered with wet and packed snow of relatively high conductivity derived from sea salt. The reduced insulation strength of the insulator strings caused sequential flashovers. Since conductor galloping of 275 kV transmission lines also contributed to the outage, it lasted for up to 30 hours. This flashover phenomenon was quite different from the well-known one caused by ice accretion or snow covering the insulator strings.

While large amounts of research has been performed on ice accretion and snow covering on insulators [1-7], knowledge related to the effect of salt-containing wet snow is very limited, as these conditions are quite rare [8,9].

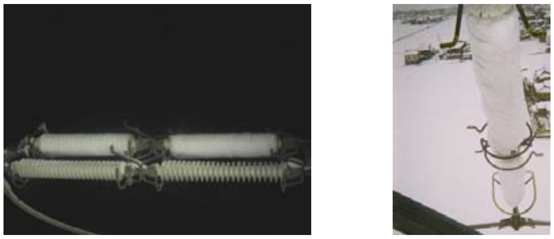
The Central Research Institute of Electric Power Industry, CRIEPI, initiated a comprehensive project, “The Research of Wet Snow Related Failures on Overhead Transmission Lines” in July 2007 to increase reliability of the transmission networks in Japan. As a part of project research, a Task Force on failures caused by wet snow packed with sea-salt on insulator strings deals with clarifying the mechanism of electrical failure and establishing effective countermeasures. The authors have reported the phenomenon of wet and packed snow accretion of various types of insulators in artificial snow accretion tests [10]. This paper presents an evaluation of snow accretion properties of porcelain long rod, cap & pin insulators by both field observation and artificial snow accretion tests focused on packed and wet snow conditions.

II. BLACKOUT IN NIIGATA KAETSU AREA

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 Niigata Kaetsu area, which is located in the north west of the Japan Main Island facing the Sea of Japan, stabilized in the range of 0 to +2 degree Celsius on 22 Dec. with heavy precipitation and wind [9].

Cascading electrical failures on 154 kV and 66 kV transmission lines started at just before 09:00 (AM) 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 at 154 kV and 66 kV transmission lines were packed with wet snow as shown in Fig. 1. The shape of packed snow on the insulators was cylindrical or eccentric pennant into the wind direction. The volume density of the snow ranged from 0.54 to 0.94 g/cm^3, and the maximum conductivity was up to 200 μS/cm.


(a) Strain assembly

(b) Suspension assembly

Figure 1. Example of packed snow on long rod insulator strings of 154kV transmission line.

III. FIELF OBSERVATION OF SNOW ACCRETION

A. *Overview of Field Observation System*

The field observation system, shown in Fig. 2, which employes CCD cameras and internet terminals, was installed on an existing transmission tower of a 154 kV transmission line in Niigata before the winter of 2009. The location is in the same area where the electrical failures occurred in 2005, an area with frequent wet snow and wind from the Sea of Japan. Since 2009, we have carried out remote observations of snow accretion on insulators under natural conditions over the two sequential winters.

Our research deals with porcelain long-rod, cap & pin, and some polymeric insulators, but this paper evaluates the properties of long-rod and cap & pin insulators, described in Table 1, and focuses on packed and wet snow conditions. The insulators were exposed without voltage application.

Data, including photo images of specimens, precipitation, wind velocity, temperature, and humidity are recorded every ten minutes through an internet link to the observation site.

B. *Result of Field Observation*

Eleven events of snow accretion during which the gaps between insulator sheds were bridged were recorded over the two winters. While these all occurred during periods of weak wind, only one case of accretion during strong wind was also observed. In this latter event, the strong wind kept blowing with snow fall and eventually caused wet and packed snow accretion on the insulators. Although the rod regions of the long-rod insulator were covered with packed snow to some extent, the gaps between the sheds were not bridged completely as a result of less precipitation than was recorded during the failure of 2005.

C. *Snow Accretion Propertiy with Strong Wind*

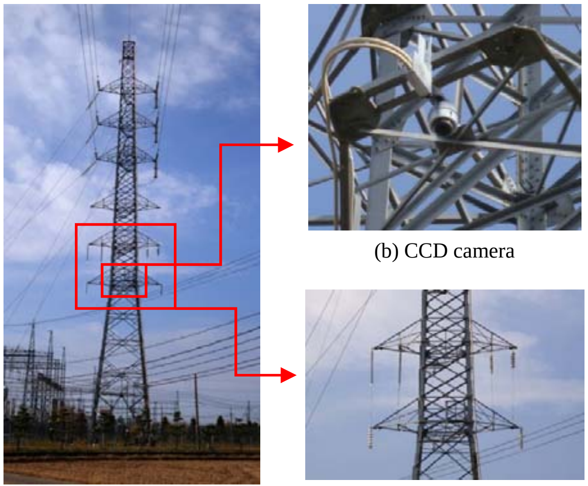
T Snow accretion with strong wind was observed on January 13, 2010. The rain, which had begun before dawn with strong wind, changed to snow at about 09:00, and the temperature dropped to the range of 0 to +2 °C which is within the temperature range which is suitable for snow accretion. The maximum wind velocity reached to 16.2 m/sec. and lasted intermittently with snow fall until the afternoon of that day. The cumulative precipitation from 08:40 in the morning to 14:00 in the afternoon was 9.5 mm.

Snow accretion to the insulators began immediately after snow fall began and developed somewhat by 10:00. As snowflakes hit the rod and cap regions of the insulators, snow accreted into a packed condition as shown in Fig. 3(a). Since some of the snow was blown away by the strong wind, the volume of snow accretion was limited. As a result, accreted snow never filled the gaps between the sheds of the insulator during the snow fall. Eventually, all snow accreted on the insulators blew off as a result of the high wind velocity.

D. *Snow Accretion Propertiy with Weak Wind*

When snow accretion occurred in the presence of weak wind, snow accumulated on the insulator sheds to be similar to snow covering on insulators. The volume of the snow accretion was greater than for the case of strong wind in spite of less precipitation. Fig. 3(b) is an example of the snow shape accreted during weak wind with a maximum velocity was 4.6 m/sec. and cumulative precipitation of 3.0 mm which was observed on January 24, 2009.

Through the entire observation period, the number of bridging events between the gaps of the insulator sheds by snow accretion was 11 for the long-rod insulator and 2 for the cap & pin insulators. The superiority of the cap & pin insulators against snow accretion is the result of the larger shed spacing.


(b) CCD camera

(a) Appearance of 154kV tower

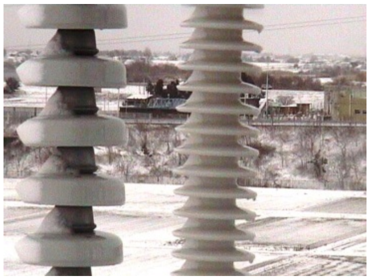
(c) Test insulators

Figure 2. Setup of field observation system.

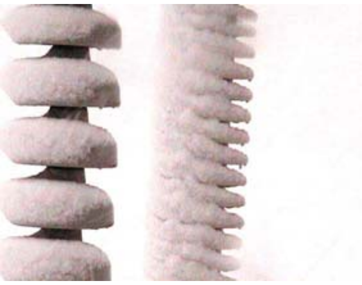
TABLE I. SPECIFICATION OF TEST INSULATORS

Items	Long rod	Cap & Pin 254 mm ×6
Total length	1,175	876
Creepage distance	2,470	2,580
Shed diameter	160	254
Core-rod diameter	80	-
Shed spacing	40	Applox.80

Unit (mm)



(a) Shapes of snow accretion with strong wind at 14:00, 13 January.
Maximum wind velocity was 16.2 m/sec.
Cumulative precipitation was 9.5 mm.



(b) Shapes of snow accretion with weak wind.
Maximum wind speed was 4.6 m/sec.
Cumulative precipitation was 3.0 mm.

Figure 3. Contrast on shapes of snow accretion between strong and weak wind.

IV. ARTIFICIAL SNOW ACCRETION TEST

A. *Test Facility and Procedure*

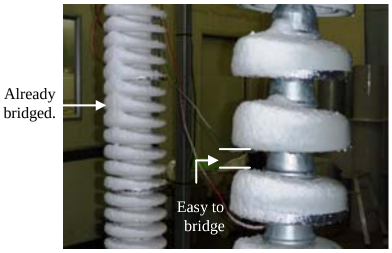
During artificial snow tests, a wind tunnel test facility of a cable manufacture, J-Power Systems Corporation, at Echigo-Yuzawa, Niigata was employed, as shown in Fig. 4. Natural snow taken from outside of the test facility was stored in a freezer. Artificial snow fall was made by dropping snow over the test insulators using a mesh screen. Hence the snow particles were blown onto the test insulators with the wind from the wind tunnel. Long-rod and cap & pin insulators of the same types as in the field were tested. Wind velocity was varied from 5 to 15 m/sec. Temperature in the test room and liquid water content of the snow was controlled to obtain desired wettability levels. Precipitation was also controlled during the tests. Test conditions are shown in TABLE II.

Snow accretion properties of the insulators were evaluated by shapes of snow accretion and the amount of snow usage untill snow bridged between the insulator sheds. Tests were continued until accreted snow bridged between the sheds or until more than 2 hours passed without bridging.

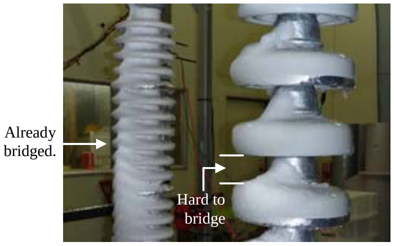
TABLE II. TEST CONDITIONS

Items	Values
Volume density of snow	0.2-0.3 g/cm^3
Water content of snow	5-8%
Temperature inside wind generator	0 to +2 degree Celsius
Wind velocity	5, 10, 15 m/sec
Precipitation	Approx. 5 mm/h

Figure 4. Set up of artificial snow accretion test.



(a) 5m/sec, Snow usage 7kg



(b) 10m/sec, Snow usage 48kg

(c) 15m/sec, Snow usage 58kg

Figure 5. Variation of snow accretion with various wind velocities.

B. *Result of Artificial Test*

Fig. 5 shows photographs of snow accretion at each wind velocity. The snow usage was 7, 48, and 58 kg for 5, 10, and 15 m/sec., respectively. The snow accreted on the windward side of the sheds.

In the case of the 5 m/s wind velocity, large amounts of snow accreted on the windward side of the upper part of sheds despite less snow usage. The shape of the accreted snow was like pennants toward the wind direction, as shown in Fig. 5(a).

In the cases of 10 and 15 m/s, snowflakes frequently run strike the caps regions of the cap & pin insulators and the rod regions of the long-rod insulator which resulted in packed and wet snow accretion to these elements. However most of snow which accumulated on the sheds was blown off by the strong wind, as shown in Fig.6. This demonstrates the reason for less snow accretion with strong wind. In the case of 10 and 15 m/s wind velocity with the cap & pin insulators, sheds were not bridged within the two hour measurement period. Fig. 7 shows a schematic process of snow accretion described above. Fig. 8 shows the amount of snow required to cause bridging between the insulator sheds as a function of wind velocity. Total precipitation prior to bridging increased with the wind velocity.

Satisfactory agreement was obtained between the appearance of snow accretion during field observation and artificial tests. During the artificial tests, the cap & pin insulators showed superior performance in preventing snow accretion which bridged between sheds as a result of their larger shed spacing, as was observed in field data.

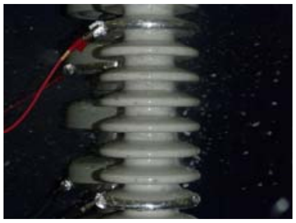
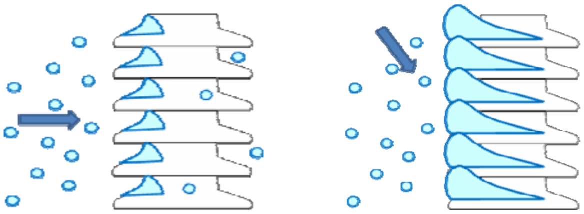


Figure 6. An example of snow flakes blown off the sheds by strong wind.



(a) High wind velocity

(b) Low wind velocity

Figure 7. Schematic of process to evaluate snow accretion as a function of wind velocity.

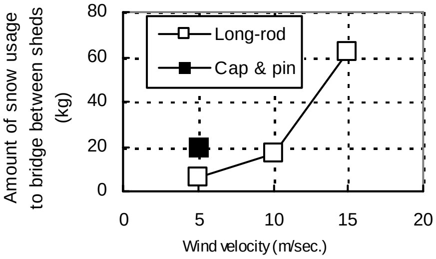


Figure 8. Amount of snow necessary to form accreted snow bridges between insulator sheds. In the cases of 10 and 15 m/sec. with cap & pin, shed bridging was not observed within 2 hours.

V. CONCLUSIONS

This paper presented evaluation of snow accretion properties of long-rod and cap & pin insulators with a focus on packed and wet snow conditions. Continuous field observation of snow accretion was performed in Niigata, Japan in order to determine snow accretion of the insulators under the natural conditions. Artificial tests were carried out in parallel to evaluate the properties of snow accretion as a function of wind velocity. The results showed that shed spacing of the insulators and wind velocity affected to the snow accretion properties. The results can be summarized as follows.

1) Eleven snow accretion events with shed bridging were observed through two winters. These were all caused by weak wind. In spite of relatively little precipitation, the gaps between the sheds could easily bridge with snow. Large amounts of snow accretion was confirmed on the aupper side of the sheds for both long-rod and cap & pin insulators.o change the default, adjust the template as follows.

2) One snow accretion event with strong wind was observed, which resulted in a packed snow condition. Although the cumulative precipitation during this event was 9.5 mm, the no insulator sheds were bridged as a result of the smaller amount of snow accretion under high wind conditions.

3) In the artificial tests, snow accretion was formed toward the wind direction in all cases. Snow usage until the bridging between the sheds increased with the wind velocity.

4) Satisfactory agreement was obtained for the appearance of snow accretion and other properties, such as the effect of wind velocity on snow accretion, between the field observation and the artificial tests.

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