Observation of Capped Snow Accumulated over 66kV Polymer-Insulator Strings

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Abstract—The performance of a polymer insulator used in a transmission line passing through a snowing region relates deeply to formation of capped snow and occurrence of partial discharge along the insulator surface. The growth and collapse of capped snow accumulated over 66 kV polymer insulator strings was observed from December 2002 to February 2003 at the snow-test site located in the Yonezawa Substation, Tohoku Electric Power Co. The capped snow was photographed by a video camera continuously and the time variation of the height of capped snow was analyzed from the video pictures. The polymer insulator was covered with lesser snow for shorter period than porcelain one owing to hydrophobic surface. There is slight difference in growth of capped snow between two polymer insulators.

I. INTRODUCTION

The non-ceramic or polymer insulators have been widely used because of excellent performance in polluted condition and light weight. However, the long-term reliability and the performance under the natural severe climate condition have been uncertain, thus polymer insulator has still rarely used in Japan except used as a phase spacer. For the transmission line passing through a snowing area, it is important to confirm the electrical performance of the polymer insulators under the condition of capped snow in winter.

In a capped snow on insulator strings in a transmission line, because snowfall has an electrical conductivity more or less, leakage current flows through the capped snow and snow melts partially to form several air gaps in it. Thus, partial arc discharge inevitably occurs at the melt area which forms air gap surrounded by snow wall. The electrical discharge occurring along the surface of the polymer insulator deteriorates the surface property. Therefore, the performance of the polymer insulator under the capped snow condition should be understood deeply.

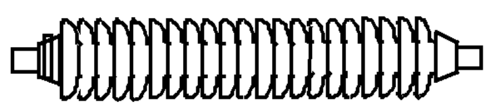
In a porcelain insulator would have a severe problem when capped snow forms on it. The capped snow tends to keep relatively longer. This means that the occurrence frequency of partial discharge would higher, thus the concentration of the nitrate oxide in the capped snow to increase the conductivity, which has the higher risk to develop flashover along the insulator[*]. When insulator was covered with contaminated snow by sea salt or industrial pollutant, leakage current would be large. The magnitude of the leakage current flowing [1]. The partial arc discharge in the capped snow happened to develop to a flashover event in the case when the melt water from snow retain in the capped snow. Melt water by electrical discharge contains nitrate oxide ions and electric conductivity inevitably increases. Occurrence frequency of electrical discharge would be important factor in breakdown process of capped snow as well as degradation of the surface of a polymer insulator [3].

Since the surface of polymer insulator has a hydrophobic property, capped snow may hardly grow on the polymer insulator strings. However, once capped snow accumulated along the surface, partial arc discharge occurs more or less. As a result, the surface of polymer insulator would be inevitably deteriorated. The objectives of this paper are to grasp the natural growth of capped snow on polymer insulators as well as porcelain insulator installed at a practical model of transmission tower.

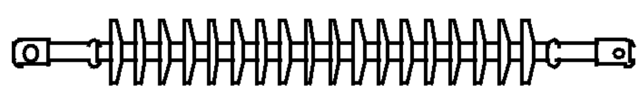
II. EXPERIMENTAL

The capped snow was observed carried out at the test site of the snow laboratory in the substation of Tohoku Electric Power co., Inc. in Japan. Three kinds of long-rod insulators with an operating voltage of 66 kV were tested; two kinds of polymer insulators and a porcelain insulator as shown in Fig. 1. The specification of each insulator was summarized in Table 1.

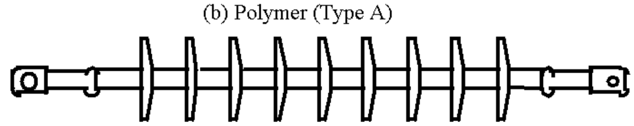
The length of the polymeric insulator denoted by Type A in Fig. 1(b) is 1180 mm and the leakage distance is 3540 mm.



(a) Porcelain



(b) Polymer (Type A)

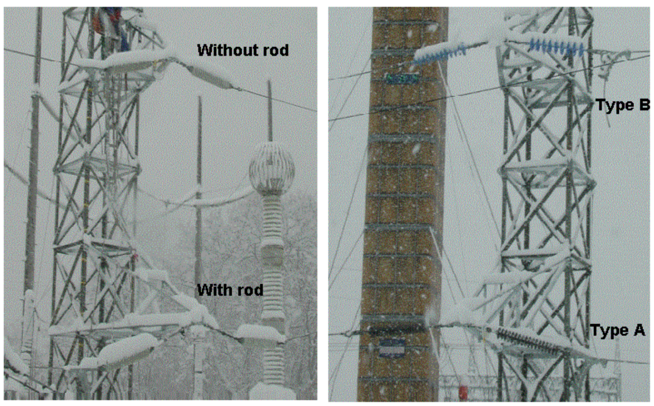


(c) Polymer (Type B)

Fig. 1 Shapes of three rod-type insulators.

TABLE 1. SPECIFICATION OF INSULATORS EXAMINED

Specification	Porcelain	Polymer Type A	Polymer Type B
Nominal Voltage (kV)	66	66	66
Total length (mm)	1025	1180	1220
Effective length (mm)	861	945	1005
Number of Shed	21	18	9
Shed diameter (mm)	160	126	170
Drum diameter (mm)	80	16	22
Creapage distance (mm)	2140	3540	2600
Weight (kg)	26	4.8	4.3



(a) Porcelain insulator (b) Polymeric Insulator

Fig. 2 The arrangement of insulators at the arm of a transmission tower model.

The diameter of a shed and drum are 126 mm and 16 mm respectively. The number of sheds is 18. In contrast, the polymer insulator, Type B, has the wider shed and the number of sheds is 8. The length and the leakage distance are 1220 mm and 2600 mm, respectively.

The tension string of a single insulator was installed at the arm of a simulated model with an arm size same as a practical transmission tower as shown in Fig.2. Since the nominal voltage of insulators is ac 66 kV, the voltage relative to the ground of 38 kV with 50 Hz was applied. The time variations of the shape of the capped snow were taken with a VTR camera one frame every 4 s. The height of capped snow formed along each insulator was measured on the picture on the console and the time variation of the height was obtained. The height of capped snow was defined as the height measured from the edge of the shed.

III. RESULTS AND DISCUSSION

A. Formation of capped snow

Fig. 3 shows the capped snow formed on a porcelain and polymer insulator at the same instance 1:00 am January 24, 2003. The capped snow formed uniformly at a height of 180 mm above the surface of the porcelain insulator, while that on Type A polymer insulator reached 30mm. In the polymer insulators, there was snow packed between the sheds. Since polymer insulators have a wide distance between thin sheds, it would be hard for snow accumulate at the drum.

(a) Porcelain

(b) Polymer (Type A)

(c) Polymer(Type B)

1:00 am January 24, 2003

Fig.3 Capped snow formed on long rod insulator

Fig. 4 shows an example of the time variation of the height of capped snow formed at the porcelain and polymer insulators. The height of capped snow on porcelain insulator rapidly increases faster than that on polymer ones. During accumulation of snowfall onto the insulator, the height of the capped snow varied with time due to snow sintering, climate condition, melting by leakage current flowing through it, partial or entire dropping.

The height of capped snow on the three types of insulators was shown in Fig 5. The plots connected by a solid line denote that the capped snow formed during a same snowfall. The difference in height tends to be large when the capped snow reached above 100 mm on the porcelain insulator, while the capped snow lower than 100 mm, there is no large difference by the insulator type.

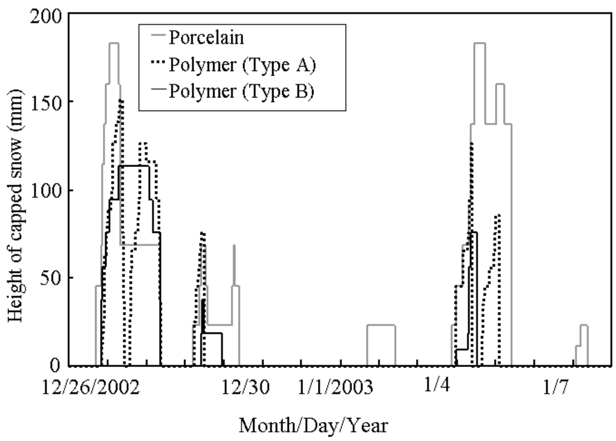


Fig. 4 Time variation of the height of capped snow on a porcelain and two kinds of polymer insulator

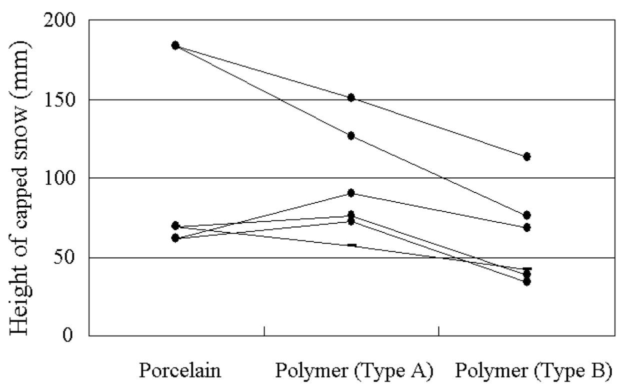


Fig. 5 Comparison of the height of capped snow formed on three different insulators during same snow fall

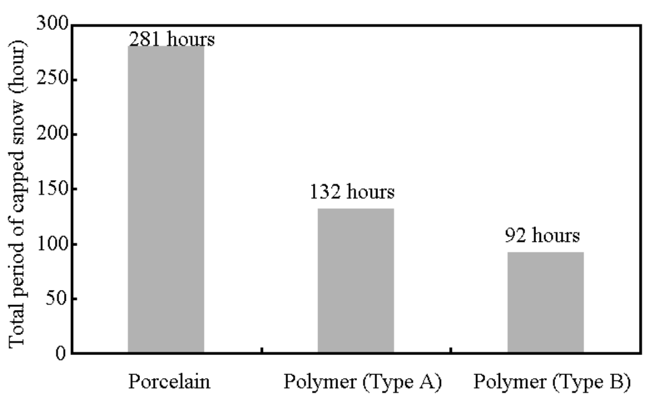


Fig. 6 The total time of capped snow on the insulator

The capped snow on the polymer insulator tends to drop off earlier than that on the porcelain one. This would be due to hydrophobic property of the surface of polymer insulator. Fig. 6 shows the total time which capped snow formed on the insulators during the observation period of 1480 hours, 70 days from December 13 to February 21. The period of capped snow for porcelain, A-Type and B-type polymer insulator is 289, 148, 125 hours, respectively. Porcelain insulator kept twice as long as polymer ones. This would result from the surface property as well as shape of the insulator.

There is a large difference in total period of capped snow between the types of polymer insulator. The Type B insulator has a fewer number of sheds and larger distance between them. On such insulator with sparse shed, snow hardly bridges the neighboring shed. As a result, the caped snow rarely grows above the shed. When polymer insulator is installed in the snowing region, the sparse-shed type insulator might be preferable, although the leakage distance tends to be short and there are rims under surface of the shed of the Type- B insulator.

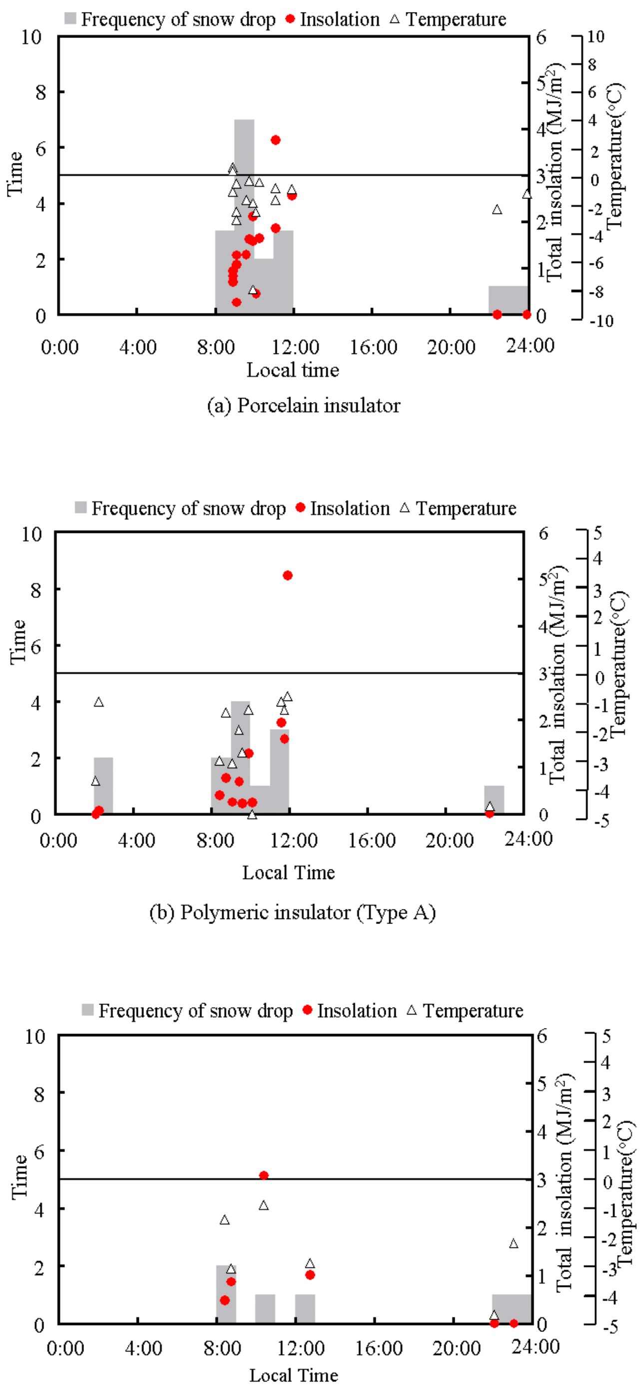
B. Factor for forming capped snow

Growth of capped snow is influenced by the climate condition, the geometric condition or surface property of insulator. Once capped snow formed along insulator, the time at dropping of capped snow might be determined by the surface condition. Water existing at the interface between capped snow and the insulator surface would be important role to keep caped snow on the insulator.

Air temperature and solar insolation inevitably affect the fall of capped snow on the insulator as shown in Fig. 7. This means that the snow melts partially and the snow contains some water. If melt water reached at the insulator surface, snow tends to drop off.

The insolation provides the melt water which helps the capped snow fall off from the insulator. On the porcelain insulator, snow gradually moves toward the side, before the capped snow drop off from it. Eventually the snow falls down. However, it takes long time for capped snow to drop off than that on the polymer insulator. This would be due to some resistance or friction of snow against the surface of the porcelain insulator. The water layer existing along the glassy plain surface of porcelain would act as glue. On the other hand, the surface of polymer insulator has hydrophobic property and the water tends to form water droplet not water film. The water never act as glue between snow and the polymeric surface.

The time of drop of capped snow mostly ranges from 8 am to noon. Fig. 7 shows no information on height of capped snow and history of growth. These factors relate climate condition. However, most falling time is in the morning. This means if some electrical event, such as partial corona, flashover event tends occur in the morning, because, the melt water flow down and capped snow tends to contain much water. Thus the conductivity of the whole capped snow increased and the melting process increased. If the snow has a property to sustain water like sintering snow, the snow changed to sherbet snow. This snow has high potential to lead to breakdown. New snow gradually changes into sintering snow through sintering process. It takes a few days. On the insulator equipped with transmission tower, snow could change to sintering snow. However, the temperature and insolation help the capped snow drop off. Especially, the hydrophobic property of the surface of polymer insulator act important



(a) Porcelain insulator

(b) Polymeric insulator (Type A)

(c) Polymeric insulator (Type B)

Fig. 7 The occurrence frequency of drop off of capped snow and its occurrence time with air temperature and Total insolation from sunrise.

role to drop capped snow. There was a few dropping of capped snow at midnight or early in the morning under the condition of low air temperature without solar insolation. They would result from strong wind.

IV. CONCLUSION

In order to evaluate the performance of polymer insulators, the formation of capped snow under the natural condition was examined using by tree insulators installed at a transmission tower model. The height of capped snow on the polymer insulator strings lower than that on porcelain one. Since the leakage current indicates one of measure for deterioration of the surface of polymer insulator, the magnitude of the current and occurrence of partial discharge need to be studied.

V. REFERENCES

[1] Y. Higashiyama, K. Asano, M. Johsho and S. Tachizaki, “AC Breakdown Process of Snow Sample Simulating Capped Snow on Insulator Strings”, Proc. of 7 th Int. Workshop on Atmospheric Icing of Structures, Chicoutimi, Canada, 1996, pp. 327-332

[2] Y. Higashiyama, T. Sugimoto, K. Asano M. Johsho and K. Sato, “Electrical Breakdown of Heavily Polluted Capped Snow on Insulators Strings”, Proc. of 8th Int. Workshop on Atmospheric Icing of Structures, Reykjavik, Iceland, 1998, pp. 199-203.

[3] Y. Higashiyama, J. Shida, K. Asano and M. Johsho, “Condensation of Ions in Snow Fall during AC Voltage Application and Increase of Conductivity”, T. IEE Japan 114-A, 9, 1994, pp. 653-654 (in Japanese)

[4] Y. Higashiyama, T. Sugimoto and M. Johsho, “Leakage Current Flowing Through Capped Snow Artificially Formed on Non-Ceramic Insulator”, Proc. of 9th Int. Workshop on Atmospheric Icing of Structures, Chester, England, 2000.

[5] Y. Hiagshiyama, M. Josho and M. Sakata “Observation of Capped Snow over 275kV Polymer-Insulator Strings” Proc. of 10th Int. Workshop on Atmospheric Icing of Structures”, Bruno, Czech, 2002