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Formation of Capped Snow over 66 kV Long-rod Insulators and Leakage Current

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***Abstract*—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 of capped snow accumulated over 66 kV polymer insulator strings and the time variation of leakage current were observed in winter from December 2005 to January 2006 at the snow-test site located in the Yonezawa Substation, Tohoku Electric Power Co. The time variation of capped snow was observed continuously with a VTR camera. Capped snow on the polymer insulator was relatively lower for a shorter period than porcelain one due to hydrophobic property of the surface. The leakage current was monitored by a system measuring both peak value of leakage current and the lead angle of the current waveform led to the applied voltage. The phase angle of the leakage current indicates clearly the condition of the capped snow.**

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.

Since the surface of polymer insulator has a hydrophobic property, the effect of water repellency on the formation of capped snow over the polymer insulator strings is needed to be investigated. Once capped snow forms over insulator strings, leakage current would flow more or less through the capped snow due to electrical conductivity. Snow melts partially to form a number of air gaps. Thus, partial arc discharge inevitably occurs at the air gap surrounded by snow wall. The electrical discharge occurring along the surface of the polymer insulator may deteriorate the surface property. Therefore, the performance of the polymer insulator covered with capped snow should be understood deeply.

In addition, snowfall on insulator strings might bring into a severe problem. If the capped snow on the insulator tends to keep relatively longer period, thereby the occurrence frequency of partial discharge would be higher. Since the particle discharge generates nitrate oxide in the capped snow to increase the conductivity, which brings the higher risk to develop flashover along the insulator [1-2]. 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 from snow involving partial discharge contains dense nitrate oxide ions and electric conductivity inevitably increases [3]. Therefore, 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.

The leakage current flowing through the capped snow would be affected by the height and electrical property of snow, or occurrence of partial discharge. To grasp the condition for natural growth of capped snow on polymer insulators, the leakage current was monitored continuously. The peak value of the leakage current and the phase angle of the leakage current leading to applied voltage to the insulator were measured during the snow season. This paper describes the growth of the capped snow of the porcelain and polymer insulator and the time variation of leakage current.

II. EXPERIMENTAL

A. Insulators

The capped snow was observed 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 used; 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 polymer insulator, Type A, has 27 alternative sheds. The length and the leakage distance are 1172 mm and 3516 mm, respectively. The length of the polymeric insulator denoted by Type B is 1180 mm and the leakage distance is 3540 mm. The diameters of a shed and a drum are 126 mm and 16 mm, respectively.

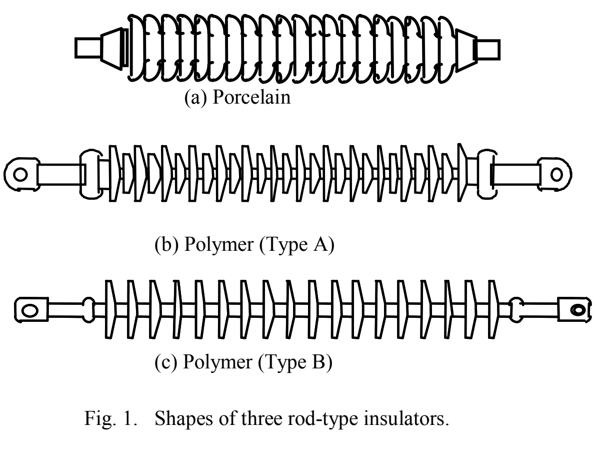


Fig. 1. Shapes of three rod-type insulators.

TABLE 1. SPECIFICATION OF INSULATORS TESTED

Specification	Porcelain	Polymer Type A	Polymer Type B
Voltage (kV)	66/77	66/77	66/77
Length (mm)	875	1172	1180
Insulation Length (mm)	711	1040	945
Shed Number	17	14/13*	18
Shed diameter (mm)	160	117/83*	126
Drum diameter (mm)	80	23	16
Leakage distance (mm)	2625	3516	3540
Weight (kg)	22	5.2	4.8

*Alternative shed

B. Observation method

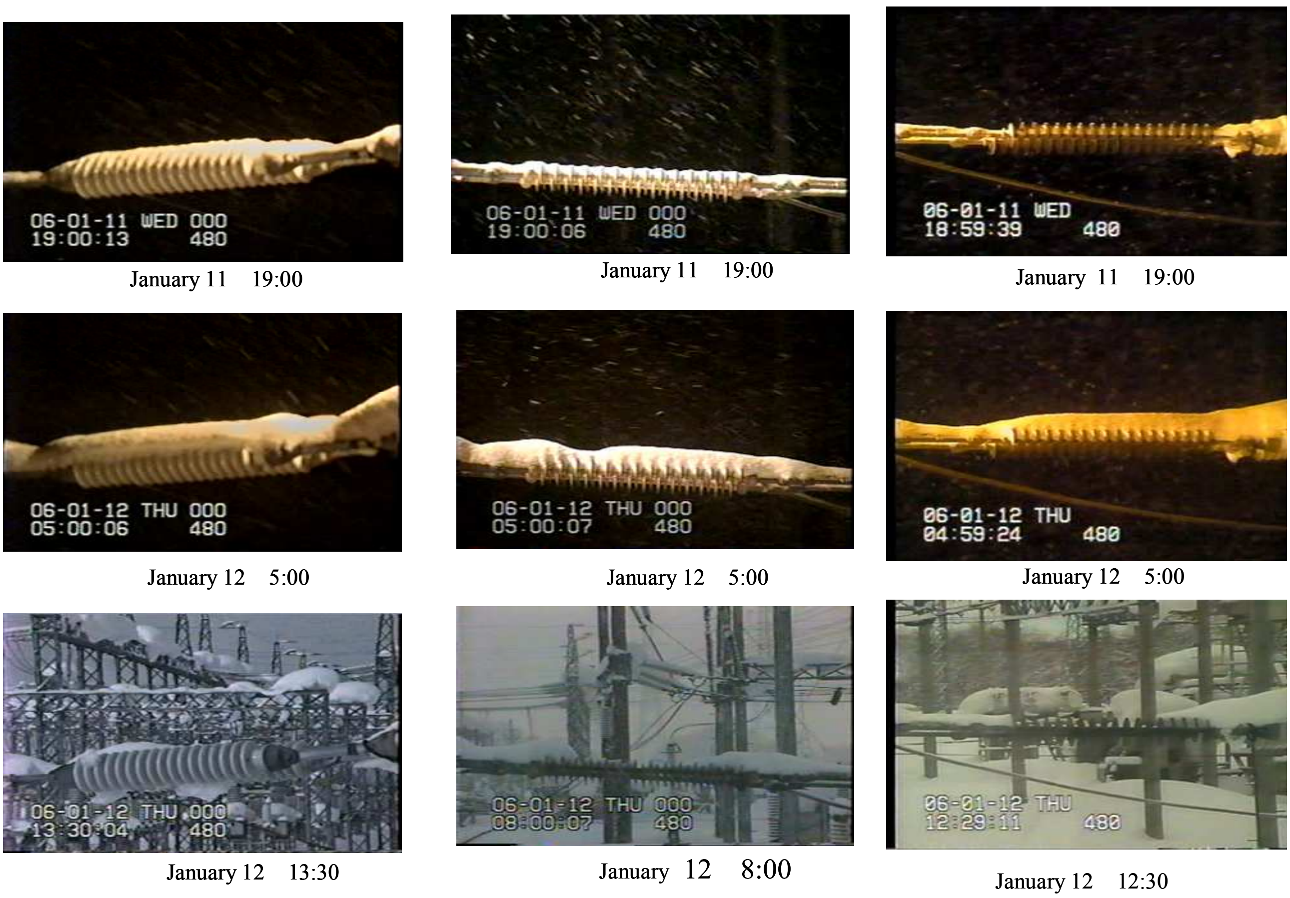
The tension parallel string of two insulators of each was installed between the poles. Since the nominal voltage of insulators tested was 66 kV, the ac voltage relative to the ground of 38 kV with 50 Hz was applied to the insulators. The time variations of the shape of the capped snow were taken with a VTR camera at a speed of one frame/s. The height of capped snow formed along each insulator was measured from the pictures on the display, where the height of capped snow was defined as the height measured from the upper edge of the shed.

The leakage current was detected by a 2kΩ resister connected between the insulator and the ground. The leakage current flowing through the insulators and the applied voltage were logged in a PC via an A/D interface. By the PC program, the waveforms of leakage current and applied voltage were sampled with a rate of 9,000 samples per second. The positive and negative peak values of the leakage current were obtained in every cycle and were stored in a data file. In addition, the lead angle of the leakage current to applied voltage was detected by calculating the time difference of the zero crossing of the waveforms of leakage current and applied voltage. The resolution of the lead angle is 2 degrees due to sampling period of 112μs. The lead angle was obtained by averaging the data for every 10 minutes.

III. RESULTS AND DISCUSSION

A. Formation of capped snow and leakage current

Fig. 2 shows the time variation of capped snow formed on a porcelain and polymer insulator from January 11 to 12, 2006. The capped snow formed uniformly at a height of 60 mm above the surface of the porcelain insulator, while that on Type



(a) Porcelain (b) Polymer Type B (c) Polymer Type B

Fig. 2. Capped snow formed on three kinds of long rod insulators.

A and Type B polymer insulators reached 70mm and 75 mm, respectively. Although polymer insulators have a wide distance between thin sheds, snow accumulated between the sheds and the capped snow forms uniformly along the insulator. During accumulation of snowfall onto the insulator, the height of the capped snow varied with time due to not only snow fall but also snow sintering, melting by climate condition, and leakage current flowing through it.

On the porcelain insulator, capped snow gradually moved toward the side, before the capped snow drop off from it and it took longer time for capped snow to drop off. The water layer existing along the glassy plain surface of porcelain would act as an interface to keep snow. On the other hand, the hydrophobic property of the surface of polymer insulator act important role for dropping of capped snow. The capped snow on the polymer insulator dropped earlier than that on porcelain one. There was a few dropping of capped snow at midnight or early in the morning under the condition of low air temperature due to strong wind.

The time variation of the height of capped snow on the three types of insulators was shown in Fig 3. The height of capped snow on porcelain insulator tended to be higher than that on polymer ones due to narrow spacing and thick shed.

Fig. 4 shows the time variation of maximum leakage

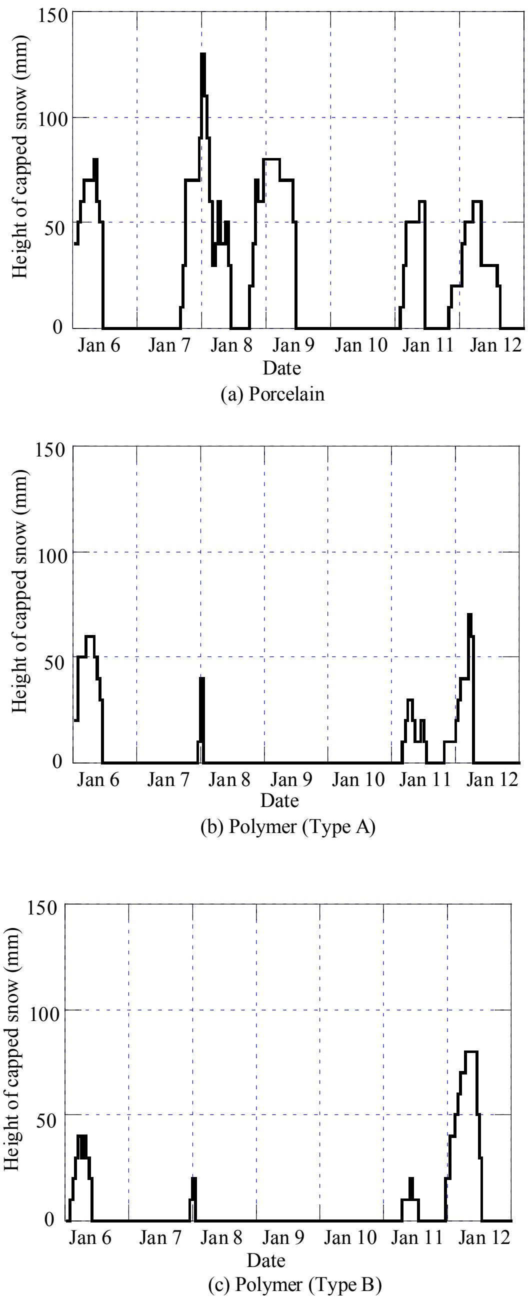


Fig. 3 Time variation of the height of capped snow on a porcelain and two kinds of polymer insulator from January 6 to 12, 2006

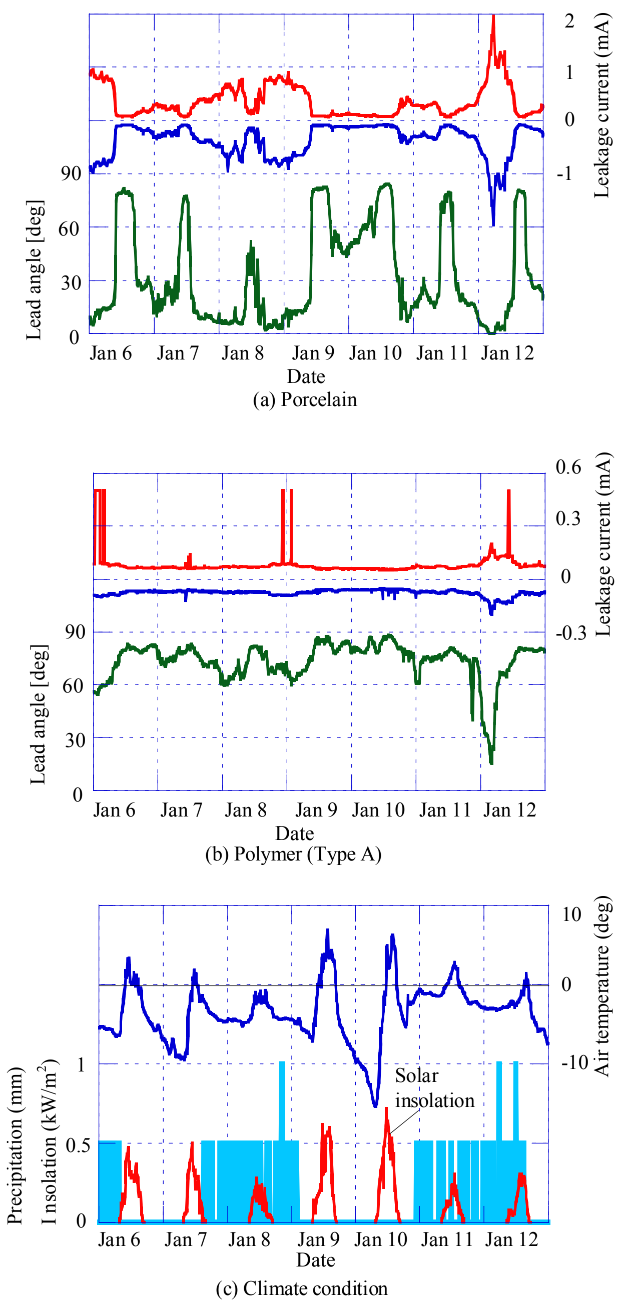


Fig. 4 Time variation of the leakage current flowing through capped snow on a porcelain and Type A polymer insulator

current and the lead angle of the current to applied voltage every 10 minutes as well as precipitation, air temperature, and solar insolation. The variation of leakage current for porcelain insulator was consistent with the formation of capped snow. During formation of capped snow, leakage current flowed more or less and the maximum value reached 2 mA, although it varied hardly with the height of capped snow. When snow remained at the insulator surface, the phase angle of the current drastically was decreased below 10 degrees. The leakage current flowed even without capped snow as seen in the night of January 6. This would be due to dew condensation. Thus, in case of porcelain insulator, leakage current also flows along the surface without capped snow.

On the other hand, leakage current for polymer insulator reached 0.15 mA at most, except noise-like spikes appeared in the leakage current. The phase angle of the leakage current indicates the condition of capped snow over the insulator. When the leakage current with relatively small lead angle flowed through the capped snow, the conductivity of capped snow increased and partial discharge might occur. In contrast, when leakage current was flowing and the lead angle kept large, capacitive current would be dominant. The magnitude of the leakage current itself never means the occurrence of partial discharge in the capped snow or along the surface of the insulator.

Fig. 5 shows the distribution of drop-off time of the capped snow. The capped snow tended to drop from the insulators in the morning due to solar insolation or rise of air temperature. Capped snow on the type A insulator tends to drop off from 12 to 14 am. In contrast, the capped snow on the type B insulator Mainly dropped off from 10 to 12 pm. There was a slight difference in the drop-off time between the Type A and B.

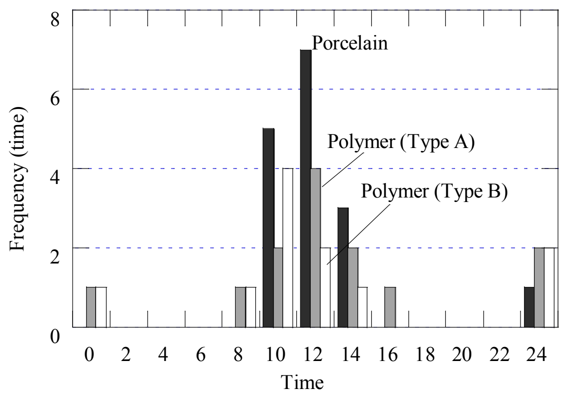


Fig. 5. The occurrence frequency of drop-off time of capped snow.

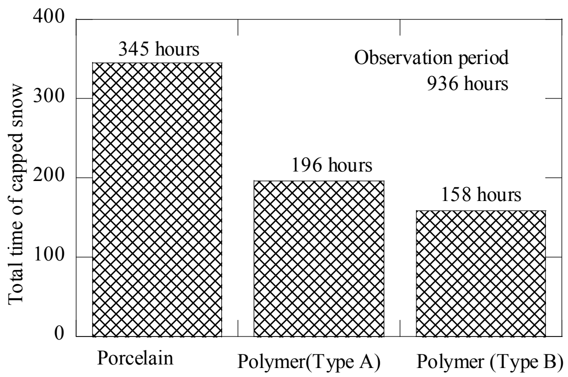


Fig. 6. The total time of capped snow on the insulators.

Fig. 6 shows the total time which capped snow formed on the insulators during the total observation period of 936 hours, 39 days from December 9, 2005 to January 27, 2006 except 11 days interruption. The period of capped snow for porcelain, A-Type, and B-type polymer insulator is 345, 196, and 158 hours and the rate of snow covered time of total time correspond to 37, 20, and 17 % of total time of observation period, respectively. Porcelain insulator kept twice as long as polymer ones. This would result from not only the surface property but also the shape of the insulator.

There is a little difference in total period of capped snow between the types of polymer insulator. The Type A insulator has 27 sheds with alternative diameter, while the Type B insulator has 18 sheds and the distance between the neighboring sheds is wider than that of type A. As a result, capped snow keep longer at the polymer insulator Type A than that of Type B.

The longer time of capped snow on the insulator surface increases a possibility to cause partial discharge. It is needed to know the occurrence and the extent of the partial discharge to estimate the degradation of the polymer insulator.

IV. CONCLUSION

In order to evaluate the performance of polymer insulators, the formation of capped snow under the natural condition was observed and the leakage current was measured. The height of capped snow on the polymer insulator strings was smaller than that on porcelain one and the leakage current was quite low. The current lead angle of polymer insulator varies at only heavy capped snow, while that of porcelain one varies drastically whenever capped snow formed along the insulator. The relationship between the magnitude of the leakage current and occurrence of partial discharge need to be studied.

V. REFERENCES

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