Insulation Properties of Long Rod and Line Post Insulators for 33 kV Transmission Line in Wet-Snow Storm on January 2004

Noriyoshi Sugawara and Kazuhiro Hosono*
Kitami Institute of Technology, 165 Koen-Cho, Kitami, Hokkaido, 090-8507, JAPAN
sugawara@hvoltage.elec.kitami-it.ac.jp
*Asahikawa Branch of Hokkaido Electric Power Co.,Inc. 3-1 Tokho, Asahikawa, Hokkaido, 078-8343 JAPAN
sgm02373@epmail.hepco.co.jp

***Abstract*—Snow-storm from 13th to 16th January 2004 in Okhotsk region in Hokkaido island of Japan damaged all traffic and stopped electricity. Long rod and line post insulators for the 33 kV transmission line were accumulated with wet-snow including sea-salt. The spaces between sheds were filled up with this wet-snow and then the insulator was a cylinder with a shed diameter. Therefore, the leakage distance was the same as flashover distance and the insulation properties decreased greatly. Flashover events might be caused by supplying salt-water film on the surface of wet-snow accreted on insulator. According to the experiments with simulated wet-snow between shads using material which absorbs water, dc surface resistance of long rod insulator in tension situation was approximately 10 times lower than that in suspension situation using salt water of a conductivity of 20 mS/cm which was an electrical conductivity of wet-snow collected in the area along the Sea of Japan where the outage of distribution lines occurred. Artificial wet-snow-storm was also simulated..**

I. INTRODUCTION

The snow-storm for several days can damages seriously the lifeline for people in cold region. The ice- and snow-storm accidents happened in several countries. Especially, on January 1998 the ice-storm accidents (freezing rain accidents) due to the extraordinary ice storm in the 20 Century happed in the northeast regions of USA (North region of New York State, Vermont State, New Hampshire State, Maine State) [1] and the East regions of Canada (Ottawa, Montreal and its neighboring). The damages of transmission and distribution lines for Hydro Quebec were an enormous amount of money [2].

The frequency of large damages of accidents due to snow-storm per year in Hokkaido of Japan is 2.1 times per year which is 2 times frequency against the storm due to Typhoon and rain-storm [3]. Recently, snow-storms came from 13th to 16th January 2004, from 27th to 28th January 2002 and from 1st to 4th February 2001 [4].

A strong snow-storm was produced by two low-pressures which moved along Japan island in the Sea of Japan and in the Pacific Ocean in parallel. The snow-storm hit Okhotsk region from 13th to 16th January 2004. The low-pressure, one of them, which moved in the Pacific Ocean, grew by 964 hPa as a Typhoon at sea in the East of Nemuro City on 14th January with the result that warm air blew to the low-pressure as warm as air in the beginning of March. This strong low-pressure moved slowly to the East of Hokkido holding the strong power, and then this wet-snow–storm was maintained for 4 days [4] and damaged the civic life in Okhotsk region [5], [6].

In this paper, we report the characteristics of this wet-snow-storm, which damaged electrical facilities in Okhotsk region and the insulation properties of long rod and line post insulators covered with wet-snow included sea-salt for 33 kV transmission line which was installed along the coast of Okhotsk Sea. These insulation properties were studied in the experiment with artificial wet-snow-storm and mock-ice and -snow.

II. CHARACTERISTICS OF OKHOTSK WET-SNOW-STORM IN JANUARY 2004

Two low-pressures moved for North in parallel along Japan island as shown in Fig.1. The low-pressure of 1016 hPa produced at sea in the West of Japan island in the morning of 12th ceased at sea in the West of Sohya region in the night of 13th through at sea in the West of Hokkaido island in the noon of 13th in growing. In the same period, another low-pressure of 1008 hPa produced in Kii Peninsula in the morning of 13th moved to in the offshore of Sanriku in

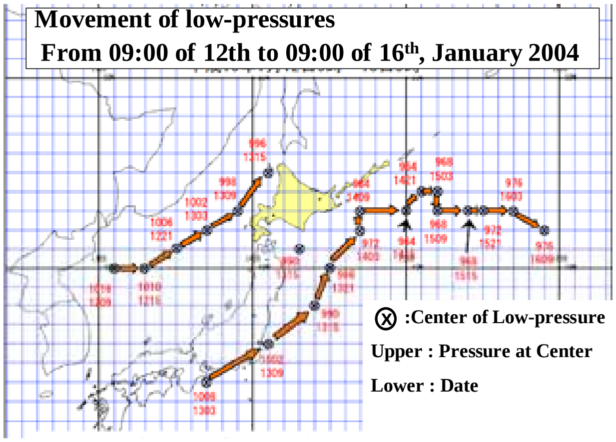


Fig.1 Movement of Low pressures during 12th to 16th [4]

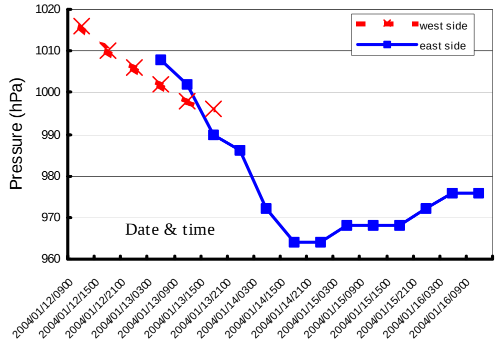
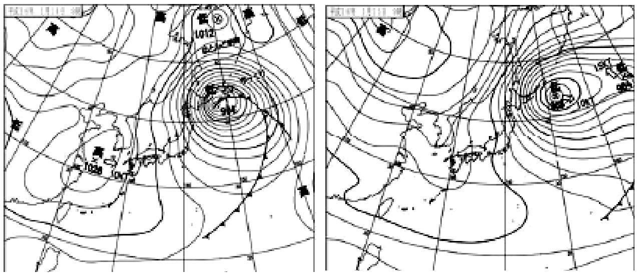
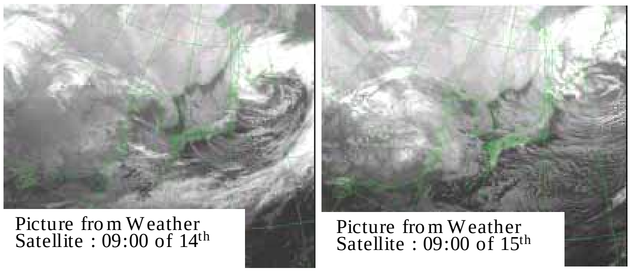


Fig.2 Development of Low pressures



Weather map at 09:00 of 14th

Weather map at 09:00 of 15th



Picture from Weather Satellite : 09:00 of 14th

Picture from Weather Satellite : 09:00 of 15th

Fig.3 Weather satellite pictures and weather maps [4]

growing. This low-pressure was growing in the result of blowing of humid warm air from the South as warm as air in the beginning of March and moved at sea in the East of Nemuro in the morning of 14th , and grew by the low-pressure of 964 hPa rapidly. The growth of low-pressures as a function of time is as shown in Fig.2. Both low-pressure grew in the movement. The low-pressure in the movement in the Pacific Ocean grew greater than that in the Sea of Japan. The power of the low-pressure increased up to the 964 hPa as a typhoon power for the 12 hours movement from the offshore of Sanriku at 21 hours of 13th to the offshore of Nemuro at 9 hours of 14th. And then the low-pressure moved slowly for East against the strong high-pressures in the chain of Aleutian and Bering Sea [4].

The pictures from the weather satellite and weather map from 09:00 of 14th to 09:00 of 15th are in Fig.3. It is seen that the cloud in low-pressure rotated in the counterclockwise and wind blew from the sea of Okhotsk to the inland. In this season, January, floating ice could not yet reached the coast of Okhotsk regions. Therefore, waves produced by strong wind made sea bubbles and this strong wind blew these sea bubbles. These flying sea bubbles adhered to wet-snow flakes. The wet-snow included sea-salt adhered on the structures of electrical facilities. Consequently, the insulation properties covered with these wet-snow included sea-salt decreased the leakage distance of an insulator and then decreased the insulation. Moreover, these wet-snow increased the amount of weight of transmission line and induced galloping phenomena of a transmission line.

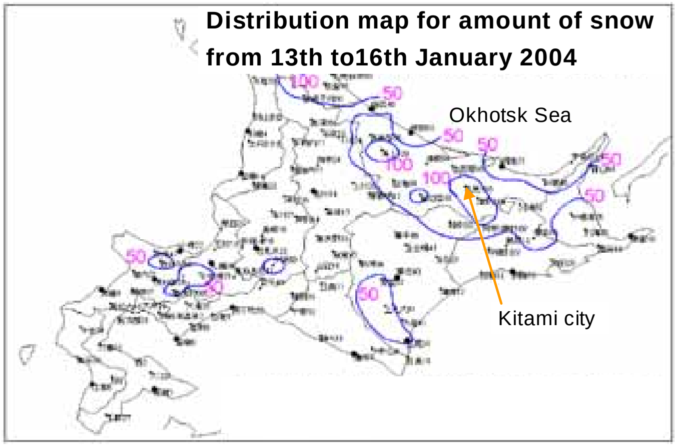


Fig.4 Amount of snow from 13th to 16th [4]

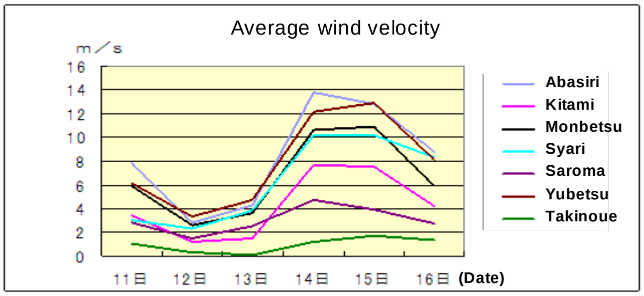


Fig.5 Average wind speed at main cities in the snow storm [5]

All Hokkaido regions, especially, were hit by strong snow storm from the night of 13th to the early morning of 16th. From Fig.4, Kitami city, Takinoue and Nakatonbetsu towns had the record snow depth as shown in Fig.4.

Wet-snow and rain in a result of these low pressure were in the Southwest regions of Hokkaido from the early morning of 13th, and then developed to the North regions. Strong snow-storm hit the coast regions of Okhotsk from 14th as shown in Fig.5. The record snow depth in Kitami city resulted in strong snow-storm from 14th to the early morning of 16th as shown in Fig.4. The maximum instantaneous wind velocity in Abashiri city was 32.8 m/s (Northwest) at 16:10 of 14th [5]. These strong snow storm damaged railway, ferry, airline and road, and then all traffic was stopped.

III. INSULATION PROPERTIES OF INSULATORS UNDER WET-SNOW-STORM

A. Insulators covered with wet-snow in field

Panzer transmission pole structure, long rod insulator and station post insulators covered with wet-snow for 33 kV

Fig.6 Transmission pole and insulators covered with snow after snow storm

transmission line which faults happened, are shown in Fig.6. Wet-snow accreted on surfaces of these structures from the direction of seaside. For long rod insulator, wet-snow filled spaces between sheds up as shown in Fig.7 as compare with an ordinary long rod insulator as shown in Fig.8. Picture of Fig.7 was taken after flashover events, therefore accreted snow on both end fitting metal of the long rod insulator was melted by arc, and then the metal appeared. The relationship between coast of Okhotsk Sea and 33 kV transmission line was shown in Fig.9. This transmission line has been installed near windbreak forest along the coast. The shortest distance between the transmission line and the coast is about 500 m as shown in Fig.10.

Fig.7 Long rod insulator covered with wet-snow

Fig.8 Clean long rod insulator as above

Fig.9 Transmission line map along the coast

Faults as a result of wet-snow accretion included sea-salt and weather data are shown in Fig.11. Several outage faults occurred from 1:00 of 15th to the early morning of 16th at temperature from –0.5ºC to –2.5ºC and a wind velocity of about 10 m/s and under the conditions of increasing of snow depth in the direction of seaside. After these faults, transmission line could transmit electricity simultaneously. This means that wet-snow accretion on an insulator deceases the insulation and then flashover appears, consequently accreted snow on insulator is melted by arc heat and then the insulation recovers. The temperatures in the faults were below zero degree, because of freezing point of salt water being lower than zero degree. The insulation of wet-snow covered insulator decreased with decreasing of temperature as a result of increasing of conductivity of water film on snow and ice because of the excretion of salt nuclei from ice crystal when salt water freezes [7]. Moreover, it is clear that the increase of snow depth under wet-snow-storm supplied water included sea-salt with snowflakes on insulators continuously, and then this supply made high conductivity water film on ice and snow of the insulator.

It is reported that in the coast of Japan of Sea, the insulation properties of 33 kV transmission line under wet-snow-storm depends on the kind of insulators [8]. Faults were less with the increase of shed number for line post insulator, and using 250 mm suspension insulator. The insulation properties of insulator covered with snow and ice were affected by the situation of ice and snow accretion that also was affected by the shape of insulator [9],[10].

B. Experimental results

Two experimental methods carried out as follows as simulating the insulation decrease of long rod and line post

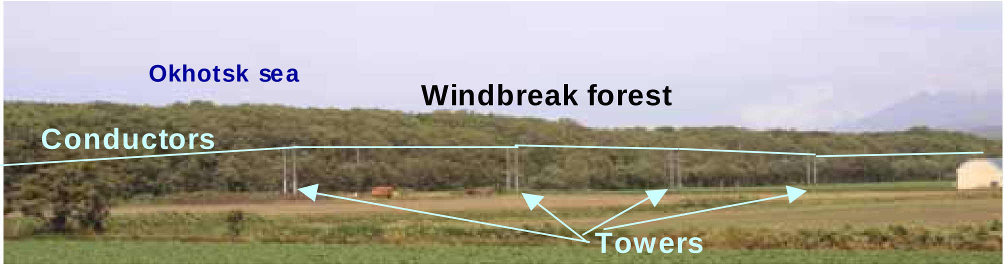


Fig.10 Transmission line and windbreak forest along the sea

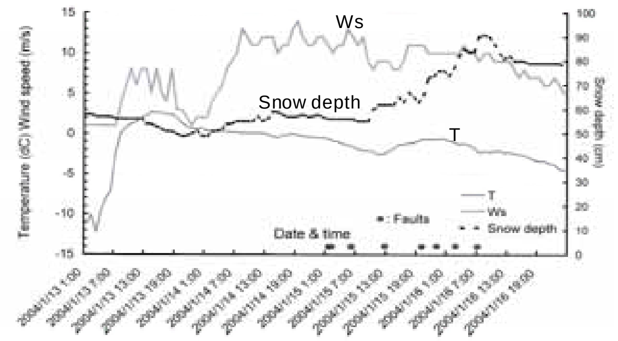


Fig.11 Weather data at faults

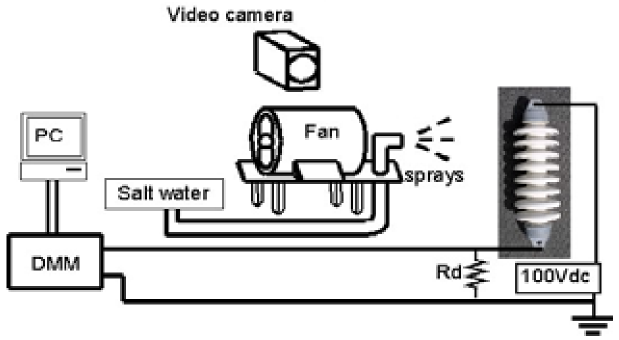


Fig.12 Experimental setup with mock-ice and -snow

insulators covered with wet-snow under storm. Experimental setup was shown in Fig.12. DC leakage resistance (surface resistance: Rs) was measured with +100 Vdc power supply as the surface resistance of an insulator. Wind velocity was 10 m/s at the position of insulator. Both specimen insulators are long rod with ribs (LR) and line post (LP) insulators for 33 kV transmission line.

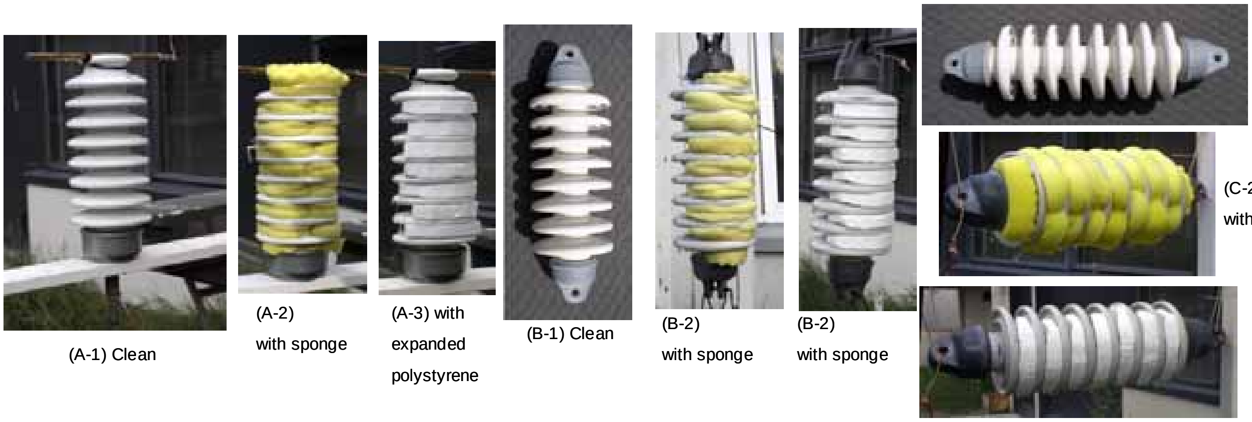
One of two experiments used mock-ice and –snow. Wet-snow accretion was simulated with sponge, and ice accretion was simulated with expanded polystyrene, filled spaces between shads. Measurement of surface resistance for insulators filled with mock-ice and –snow was done under spraying conditions of 20 mS/cm which is the conductivity of water melted snow and ice collected at fault area due to wet-snow-storm [11]. Ordinary specimen, ice and snow accreted insulators are shown in Fig.13. Two situations for long rod insulators were suspension and tension.

Rs of ordinary insulators as a function of time depending on the install situation are shown in Fig.14. The experiment was stopped at the constant value of surface resistance. Comparing Rs of LR in the situation of suspension (LR-s) with that of LP in Fig.14, Rs of LR-s is higher than that of LP with the effect of under ribs of LR sheds. Rs of LR in the situation of tension (LR-t) is lower than that of LR-s, because of wetting of surface of under ribs by spraying salt water.

Under the simulated conditions of wet-snow as shown in Fig.15, Rs of all specimen with sponge (mock-snow) decreased as a result of absorbing of spraying salt water. Furthermore, Rs of all specimen with expanded polystyrene (mock-ice) as shown in Fig.16 decreased as a result of salt water film on the surface of expanded polystyrene, while expanded polystyrene could not absorb salt water.

Results of 3 times experiment and their average for Rs under three kind conditions are shown in Fig.17. Rs under the conditions of wet-snow (mock-snow) were lower than those under ordinary and ice (mock-ice) conditions. This reason is that the conductivity and absorption of material inserted between sheds decreases the insulation. For LR, Rs of LR-s was higher than that of LR-t because of the presence of water line along the lowest position of sheds between end fittings of LR-t.

Another experiment carried out using natural snow and water spraying to produce wet-snow with wind velocity of 10 m/s in outside. Two kind of water are tap water of 162 μS/cm and salt water of 20 mS/cm. Spaces between sheds were filled with wet-snow produced with snow and water before wet-snow accretion using wind and water spraying as shown in Fig.18. After filled the spaces, Rs was measured during artificial wet-snow-storm. Situations after wet-snow accretion for LR-s and LR-t are shown in the figure. Rs properties using tap water for LR-s, LR-t and LP insulators are shown in


(C-1) Clean

(C-2) with sponge

(A-2) with sponge

(A-3) with expanded polystyrene

(B-1) Clean

(B-2) with sponge

(B-2) with sponge

(C-3) with expanded polystyrene

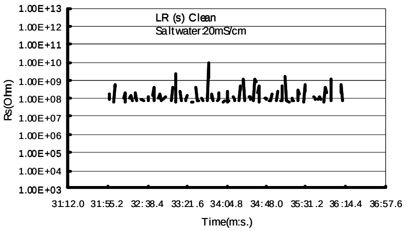
(A-1) Clean

(A) LP insulator

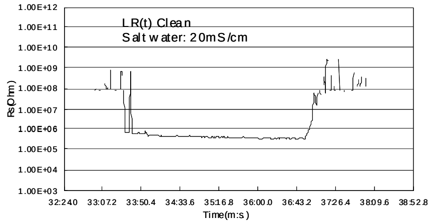
(B) Long rod insulator in suspension situation

(C) Long rod insulator in tension situation

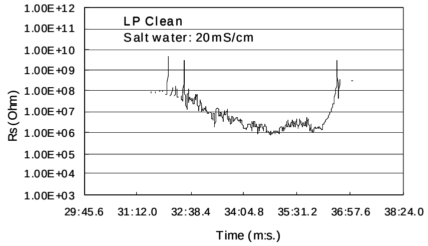
Fig.13 Long rod and LP insulators with mock-ice and -snow



(A) Long rod in suspension situation

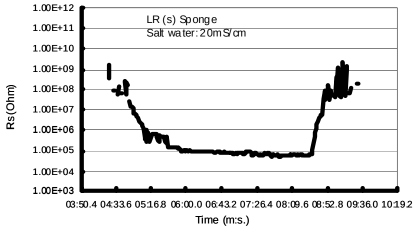


(B) Long rod in tension situation

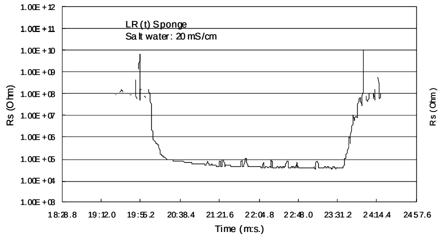


(C) Line post

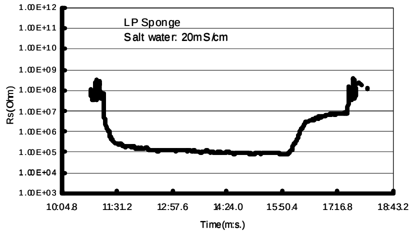
Fig.14 Surface resistance of insulators due to install conditions without mock-ice and snow



(A) Long rod in suspension situation

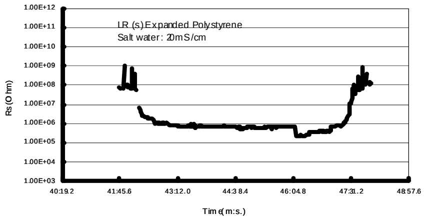


(B) Long rod in tension situation

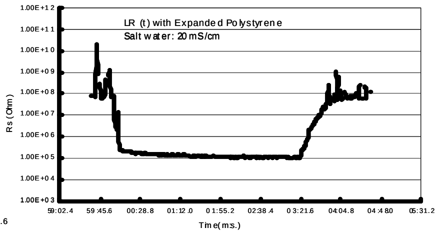


(C) Line post

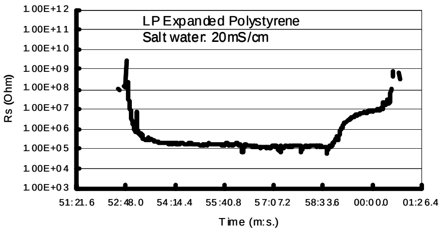
Fig.15 Surface resistance of insulators due to install conditions with mock-ice and snow with sponge blocks



(A) Long rod in suspension situation



(B) Long rod in tension situation



(C) Line post

Fig.16 Surface resistance of insulators due to install conditions with mock-ice and snow with expanded polystyrene blocks

Fig.19. The lowest Rs for LR-t was lower than that for LR-s, because of lower parts between end fitting metals of LR-t accreted with wet-snow absorbed much water as shown in Fig.18 (B). Furthermore, Rs for LR-s is higher than that for LP because of LR having under ribs. The same Rs properties between LR-s and LP are shown in Fig.20 using salt water spraying of 20 mS/cm. Especially, Rs using salt water spraying of 20 mS/cm for LR-t was lowest in all these experimental data as shown in Fig.20.

These results shows that the higher liquid water content, the higher volume density and the higher conductivity of wet snow included sea-salt decrease the insulation properties of insulators covered with wet snow in the storm which have the higher liquid water content, the higher volume density and the higher conductivity than those of dry clean snow [12].

IV. CONCLUSIONS

Surface resistance properties for wet-snow filled long rod and line post insulators decreased with increasing the conductivity of spraying water, and depending on install situations for long rod insulator. Surface resistance for long rod in tension situation was lowest than those for long rod in suspension situation and line post insulator. This lowest value may occur flashover of long rod in energizing transmission line in wet-snow-storm included sea salt.

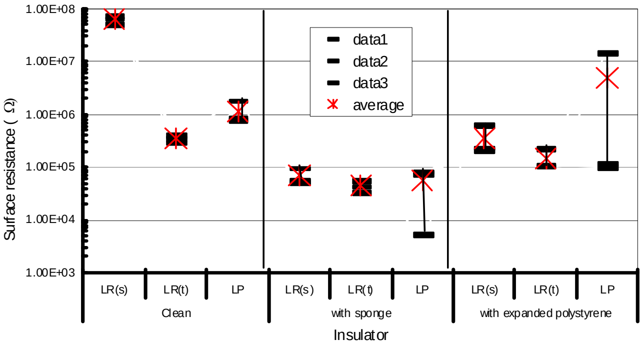


Fig.17 Surface resistance due to ice and snow accretion situations depending on install conditions

We are planning flashover experiment under artificial wet-snow-storm conditions in cold room to estimate the lowest withstand voltage under these worse weather conditions.

V. REFERENCES

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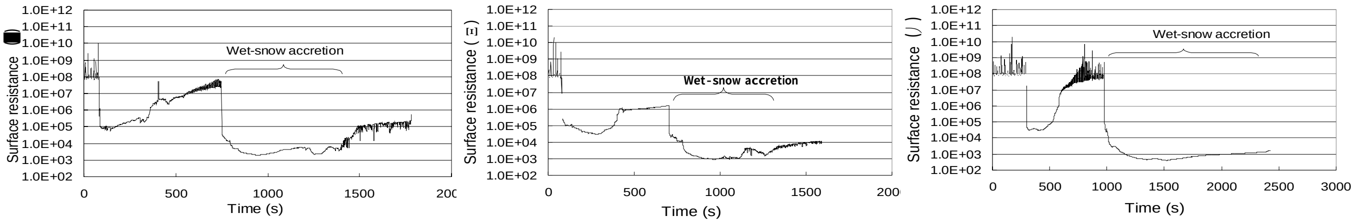
(A) LR in suspension situation

(B) LR in tension situation

Fig.18 Artificial wet-snow accretion situations before and after experiment

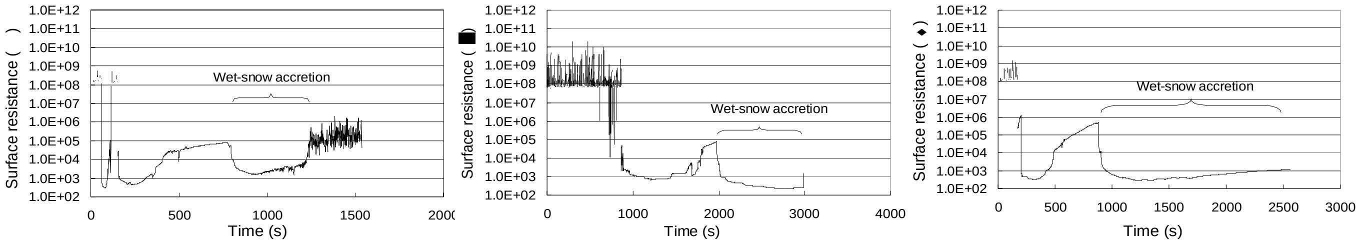


(A) Long rod in suspension situation

(B) Long rod in tension situation

(C) Line post

Fig.19 Surface resistance of insulators covered with artificial wet-snow using tap water spraying (162 µS/cm)



(A) Long rod in suspension situation

(B) Long rod in tension situation

(C) Line post

Fig.20 Surface resistance of insulators covered with artificial wet-snow using salt water spraying (20

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