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Overview of Power Outage in the Niigata Kaetsu Area Caused by a Snowstorm

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***Abstract*—The outage occurred in the Niigata Kaetsu area on December 22, 2005. The outage was a result of ground faults and short circuits that occurred simultaneously at many locations on transmission lines under the most severe weather conditions that are rarely encountered. After confirming the performance of the cap and pin insulator against the wet-snow accretion containing sea-salt by field tests, we plan to replace the long-rod insulators on single circuit with cap and pin insulators on double circuit transmission lines where long-rod insulators have conventionally been used. Using a different type of insulator on each circuit will allow establishing a more reliable power network against various severe weather conditions. As a galloping countermeasure, for bundle-conductor transmission lines, we plan to install loose spacers based on verification in simulations and the results and accomplishments thus far obtained from our testing. For single-conductor transmission lines, we plan to install phase-to-phase spacers.**

I. Introduction

A power outage occurred mainly in the Northern part of Niigata Prefecture, served by Tohoku Electric Power Company around 08:10 on December 22, 2005, with a maximum of about 650 thousand households affected.

Tohoku Electric Power, helped by electric works companies inside and outside the Prefecture and other electric power companies, made a lot of effort to recover the facilities. All outages were restored at 15:10 on December 23, or 31 hours after the occurrence of the outage.

Tohoku Electric Power assigned a total accumulative number of 2,500 workers to a seven-day restoration work in the period of December 22-28.

This paper describes the causes of this power outage in the northern part of Niigata Prefecture and countermeasures for recurrence prevention.

II. Overview of Accidental Power Outage

Fig. 1 shows an outline of the power transmission system in the Niigata Kaetsu area at the time of the accidental power outage.

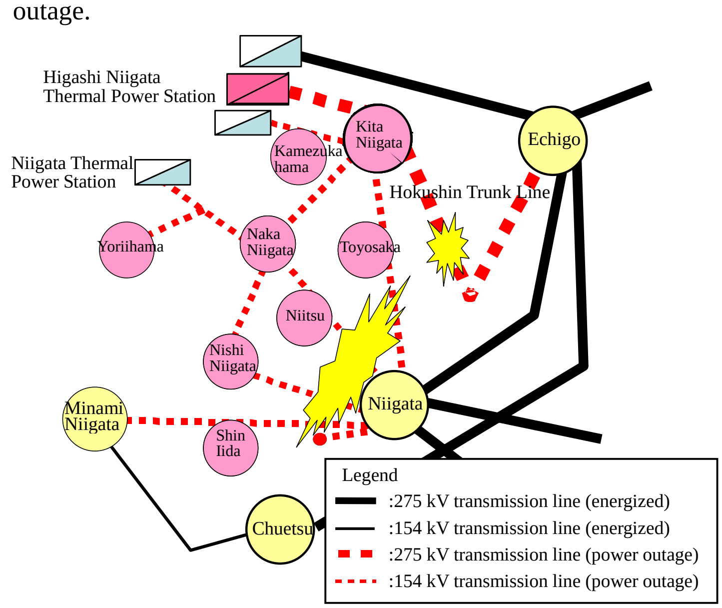


Fig. 1. Power transmission system at the time of power outage

The Niigata Kaetsu area is normally supplied with electric power via multiple routes of 154 kV transmission lines with two extra high voltage substations: Niigata and Kitaniigata Substations as bases for power supply.

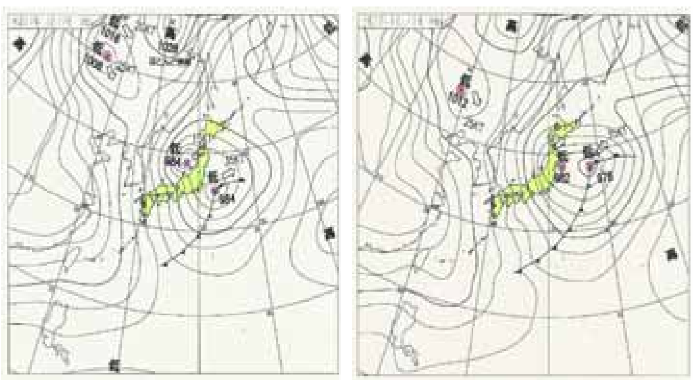
On December 22, 2005, there were faults on the 275 kV double circuit Hokushin Trunk Lines because of galloping frequently since around 06:40. At 08:12, when the single circuit of 275 kV Hokushin Trunk Line was out of service, there was a fault on the other circuit of 275 kV Hokushin Trunk Line. In addition, at 08:17, there were events on multiple 154 kV transmission lines because they were damaged by wet-snow accretion containing sea-salt. As a result the multiple transmission routes through which power was supplied from the Niigata Substation were cut off, which caused a long power outage in a wide area.

III. CAUSES OF EVENTS

A. *Meteorological conditions at the times of events*

Fig. 2 shows the distribution of atmospheric pressure on December 22, 2005. It was in a “twin cyclone (Futatsudama Teikiatsu) pattern” of a “large-scale cyclone” going along the south coast of the Honshu Island and a “meso-scale cyclone” going over Niigata. The meso-scale cyclone developed its lowest central pressure of to 984 hPa near Sado Island at 15:00 on December 22, and then passed over the southern part of the Tohoku region and went over the Pacific Ocean at 21:00 that day.

On the west side of the large- and meso-scale cyclones, a “meso-scale cyclone developed during a cold-air outbreak” with active cumulonimbus clouds had small-scale spiral turbulence and moved slowly east. As a result of analysis of precipitation data charts from the Radar-AMeDAS system, it was observed that a spiral “meso-scale cyclone developed during a cold-air outbreak” lying north of Sado Island.

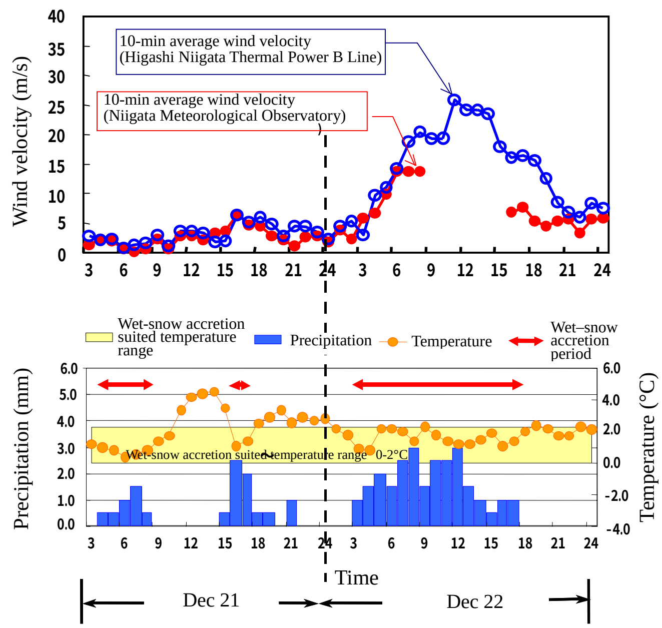


Dec 22 15:00 Dec 22 21:00

Fig. 2. Meteorological conditions at the time of power outage (surface weather charts)

Fig. 3 shows the meteorological conditions at that time as observed at the Niigata Meteorological Observatory. On December 22, it began to snow around 03:00, and then there were strong winds with a 10-minute average velocity of more than 10 m/s between 06:00-08:00 as the cyclones passed. The Niigata Meteorological Observatory lacks the wind-velocity data for 09:10-15:00 because of the power outage. It can be assumed that there were similar strong winds blowing for a long time during those hours by estimating the lacked data from the meteorological data at the Higashi Niigata Thermal B Line on the basis of the time between the former and the latter. The temperature was about 0°C-2°C, which is known to be suitable for wet-snow accretion, during 03:00-17:00, when wet snow could very easily accrete on power lines.

The above-mentioned meteorological conditions means that with the 10-minute average wind velocity in a wet-snow accretion suited temperature range, the average wind velocity for the three hours when such a temperature range was recorded, and the cumulative precipitation during those three hours were all the largest values in the observation records in the past 30 years at the Niigata Meteorological Observatory. There was enormous precipitation in a wet-snow accretion suited temperature range while strong winds blew for a long time. Thus, the overhead transmission lines were subjected to unprecedented severe meteorological conditions.



Data source: Niigata Meteorological Observatory

Fig. 3. Meteorological conditions at the time of power outage (changes in wind, precipitation and temperature)

B. *Mechanism of event occurrence*

i) Wet-snow included sea-salt accretion on insulators:

To understand the mechanism of damage caused by salty snow, how the snow containing saline particles was carried inland was assumed from the meteorological data for December 22 because it was observed that samples taken from the snow accreted on the transmission line insulators had content similar to seawater components.

It was inferred that saline particles flying from the sea due to vaporization of the seawater or high waves soared on rising air currents produced an effect of strong cold air high in the sky. The saline particles, as well as dust, in the air were nuclei around which water gathered to make snow crystals, which in turn developed into snowflakes. The snow was carried inland, and fell when it was blocked by mountains. The snow was then wet because the ground temperature was comparatively high. (Fig. 4)

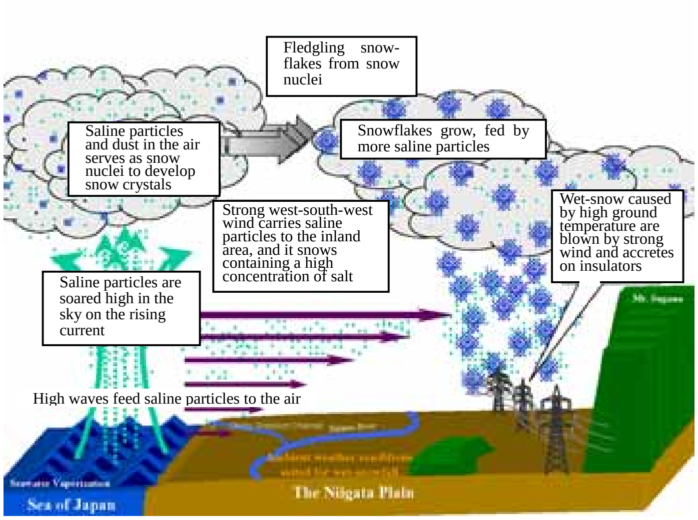


Fig. 4. Snowfall included saline particles

It was presumed that this snowfall had salt provided by additional saline particles carried by strong west-south-west winds.

This wet-snow included salt hit the insulators due to strong winds, and went deep into the ribs of the insulators. It then filled the insulator recesses to cover the ribs and froze. As a result the insulator dielectric strength lowered. (Fig. 5)

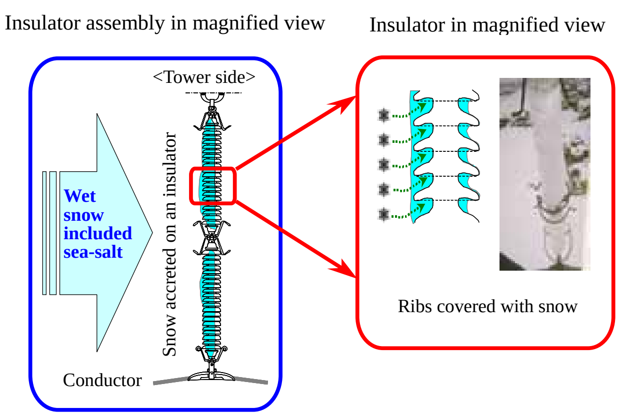


Fig. 5. Illustration of snow accretion on insulator

ⅱ) Galloping:

Generally, galloping events are most likely to occur under the conditions of a temperature of 0°C-2°C, wind blowing at a maximum instantaneous speed of 25 m/s-30 m/s and 10-minute average velocity of 5 m/s-10 m/s, and the angle between the wind direction and the line is more than 45 degrees. However, galloping is still considered accidental, and does not necessarily occur where all the above-mentioned conditions are met.

Phase-to-phase short-circuits in this power outage event were located where there were rice paddy fields spreading both toward the wind and downwind, without anything to block the wind. It was determined that those events had been caused by galloping because the meteorological observation data met the conditions for occurrence of galloping, because the conditions of the events suggested it, and because irregular swings of conductors (galloping) had been actually observed by patrol teams.

IV. COUNTERMEASURES AGAINST RECURRENCE OF POWER OUTAGE EVENT

A. Countermeasures on transmission lines:

ⅰ) Countermeasures against wet-snow included sea-salt accretion:

It is presumed that, in the power-outage event, wet-snow accretion completely covered the ribs of long-rod insulators and induced degraded insulation. The cap and pin insulator has sheds with larger spaces between them than those of the long-rod insulator, and there is a larger difference between the outer diameter of its sheds and that of its connections than with the long-rod insulator. In view of those features, the long-rod insulators on single circuits of double circuit transmission lines were replaced with cap and pin insulators. Cap and pin insulators were combined with long-rod insulators to rely on the features of both types of insulator and to improve the reliability of the lines against severe meteorological conditions. (Fig. 6)

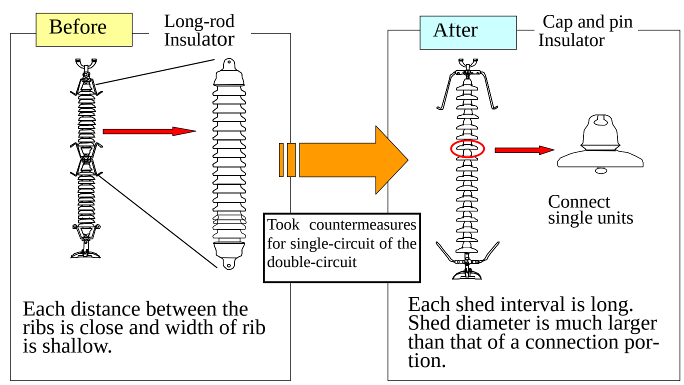


Fig. 6. Change of type of insulator

To verify the validity of this countermeasure against wet-snow included sea-salt accretion, an outdoor artificial snow accretion field test was conducted on the assumption of an environment with a snowstorm at the Kitami Institute of Technology. The field test was conducted by letting natural snow fall through a sifter and blowing it on sample insulators with winds generated by means of a wind tunnel.

The result of this artificial snow accretion test was that, on a long-rod insulator, wet-snow accretion grew to fill the insulator recesses with wet-snow and the metal at both ends of the insulator was bridged. On the other hand, on a cap and pin insulator, no bridge was produced, as it was on the long-rod insulator, although wet-snow accreted on sheds and the cap. It took two or three times as long for a bridge to be produced on the cap and pin insulator as on the long-rod insulators. Thus, it was confirmed that the cap and pin insulator is more resistant to wet-snow accretion than the long-rod insulator.

In view of the result of the above-mentioned field test, a voltage withstand test on long-rod and cap and pin insulators where wet-snow accreted 20 mm thick from the outer diameter evenly around them, i.e., wet-snow accretion in a cylindrical shape with the ribs covered with wet-snow for the long-rod insulator, but wet-snow accretion with which an undulated shape was seen for the cap and pin one, at the Yonezawa Snow Hazard Testing Facility of Tohoku Electric Power.

The withstand voltage test with a nominal voltage of 154 kV indicated that the AC withstand voltage at a conductivity of 300 μS/cm was 120 kV for a long-rod insulator with snow accretion, but was as much as 200 kV for a cap and pin insulator with snow accretion.

The results of the artificial wet-snow accretion test and the withstand voltage test show that cap and pin insulators are effective in preventing salty wet-snow damage.

ⅱ) Countermeasures against galloping:

a) Bundled conductor line:

It was decided to replace the spacers to bundle subconductors with loose spacers for a bundled conductor.

The loose spacer is in a structure by which a bundled conductor can freely rotate in a half of its clamps. A subconductor that is freely rotatable can rotate due to an eccentric load with snow accretion, which aerodynamically can little be formed evenly on it. As a result, a bundled conductor cannot have any particular aerodynamic characteristic, so that galloping is controlled. (Fig. 7)

To verify the effect of a loose spacer to control the oscillation of conductors, a simulation study using a non-linear analysis program for cables and three-dimensional framework structures using the finite element method, called CAFSS [1], developed by the Central Research Institute of Electric Power Industry of Japan was applied to the fault locations on the 275 kV Hokushin Trunk Line on the basis of the results of research in snow accretion samples and the meteorological data on the day of the events.

Consequently the simulation reproduced contacts of a middle phase conductor and lower phase conductor in the middle span, which is where the fault was located, when there is no countermeasure. On the other hand, when loose spacers were installed, they did swing a little, which ensured an adequate phase-to-phase distance.

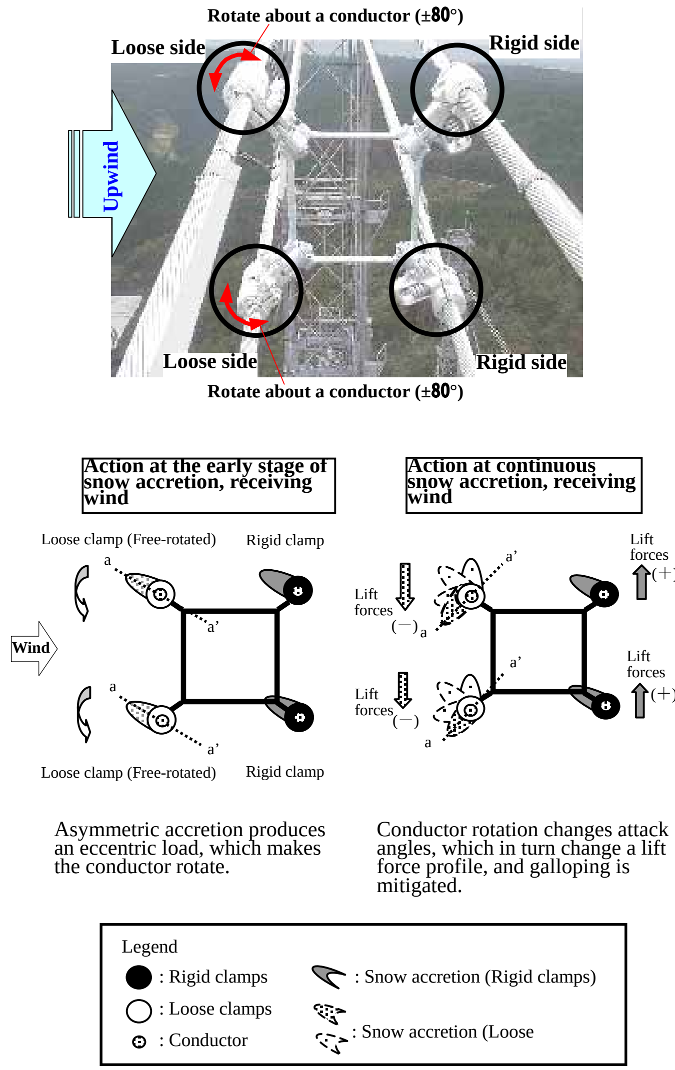


Fig. 7. Loose spacer

b) Single-conductor line:

As a countermeasure against the galloping of single-conductor lines, a phase-to-phase spacer was adopted because it had been applied for a countermeasure against snow damage in many cases and proven to be effective.

The phase-to-phase spacer converts large amplitudes of galloping to small amplitudes in a span, when it occurs there, by means of mutual interference between the spacer and the conductors. So it is expected it has a galloping-control effect regardless of the conditions for the occurrence of galloping. (Fig. 8)

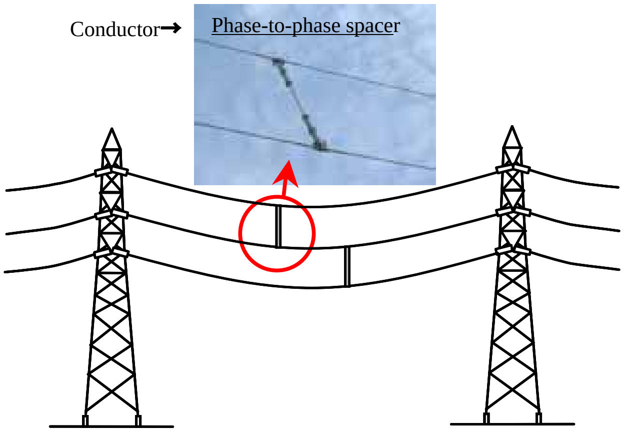


Fig. 8. Phase-to-phase spacer

B. Countermeasures in power system operation

iii) Changes in operation of transmission systems at the Kita Niigata Substation:

The demand for electricity in and around Niigata City had been met mainly via three transmission routes starting from the Niigata Substation. In order to deal with future increases in the electricity demand and ensure a stable power supply, we planned to supply power in two ways from the Niigata Substation and Kita Niigata Substation, and the transformers in the Kita Niigata Substation were reinforced. In view of the salty wet-snow-damage events that have occurred, the plan was implemented in full scale about two months earlier than scheduled.

ii) Operation with lower voltage based on meteorological information and observation data:

Our company has implemented operation with lower voltage on the basis of AMeDAS data at 12 points on the Sea of Japan side in Niigata Prefecture, salt-content observation data at the Substations, and field information. It has been decided that the lower voltage operation will be on the basis of additional conditions such as a snow storm alarm issued from the Meteorological Agency, in addition to the above-mentioned data and information, to ensure that salty snow damage can be more securely prevented.

V. CONCLUSION

The snow damage on the power facilities that occurred in the Niigata Kaetsu area on December 22, 2005 caused unprecedented snow-damage events due to salty wet-snow simultaneously on multiple power lines, combined with short-circuit faults due to galloping, in rare and severe weather conditions to power facilities, which resulted in power outage in a wide area for a long time.

Tohoku Electric Power will use the above-mentioned measures on its power transmission facilities to ensure a more stable supply of power.

In view of the fact that snow damage events have also occurred in the service area of other electric power companies, and their effect on the society, three events of snow damage (salty snow damage, galloping and heavy snow accretion) will be studied, and observation data on snow damage will be collected, led by the Central Research Institute of Electric Power Industry.

VI. REFERENCES

[1] M. Shimizu and J. Sato "Galloping observation and simulation of a 4-conductor bundle transmission line," Journal of Structural Engineering, Vol. 47A, pp.479-488, 2001.(in Japanese)