Priority Subjects — **Establishment of Optimal Risk Management**

Establishment of Protective Measure Technologies against Wind and Snow Damage of Overhead Transmission and Distribution Facilities

Background and Objective

In December of 2005, severe snowstorms on the coast of the Sea of Japan caused damage to overhead transmission facilities including the partial collapse of transmission towers due to the weight of heavily accreted snow, short circuiting of transmission lines caused by galloping*1, and the failure of electrical insulators, (flashover) due to heavily accreted snow containing sea salt. After the occurrence of snow-related damage, CRIEPI started a ten-year research project from FY2007 to FY2016 on damage to overhead transmission facilities caused by severe snowstorms. This project is conducted in cooperation with electric power companies.

In the first phase (from FY2007 to 2011) of this project, field observations were mainly conducted in order to elucidate the physical processes of snow-related damage and to examine current measures against it. The second phase of the project commenced in FY2012 to propose effective countermeasures against snow-related damage using practical analysis and prediction methods. Applicability of the research results to distribution facilities is also investigated.

Main results

1 Continuous operation of field observation and consolidated data management systems

Field observation data related to meteorological conditions of snow-related damage and effectiveness of countermeasures have been obtained in seven sites across Japan. Data management systems for storing practical examples of snow-related damage and their meteorological conditions have been continuously operated and 223 new practical examples*2 have been added to the database. These data are used for to elucidate the meteorological conditions of snow-related damage, examine its prediction methods, and evaluate effectiveness of countermeasures.

2 Evaluation of a thermodynamic model for snow accretion on electric wires

CRIEPI has recently developed a dynamic snow accretion simulation code for overhead transmission lines, named SNOVAL-dyn. Further improvement of the SNOVAL-dyn has been made by incorporating a thermodynamic model with heat exchange between the air and snow sleeve, solar radiation, Joule heating of the conductor, etc., which makes it possible to calculate the liquid water content of the snow sleeve as well as cohesive and adhesive forces (Figures 1, 2). This simulation enables us not only to evaluate the snow accretion process including snow melting and snow shedding, but also to improve the accuracy in predictions on accreted snow mass by a known simple snow model.

3 Detailed elucidation of the flashover mechanism of snow-accreted insulators

In order to evaluate the effect of time-variation in snowstorm and snow conductivity on flashover, high-voltage tests were performed under artificial snowstorm conditions in a climatic laboratory. The process of partial discharge propagation until flashover was observed for an energized 33 kV long-rod insulator under snowstorm conditions. As a result, it was found that the higher the snow conductivity, the greater the discharges on the snow-accreted insulator were. However, too much discharge activity prevented snow accretion on the insulator. This led to snow melting or snow shedding. To conduct further study, new facilities to conduct similar high voltage tests were prepared in the Yokosuka Area. Also, as shown in Figure 3, the generation of fine ice particles with well-defined conductivity in the form of artificial snow was possible. We will continue to observe the flashover phenomena of snow-accreted insulators in detail and develop a high-voltage test method.

4 Construction of a new full-scale test facility for snow-storm damage to overhead transmission lines (abbreviated to "Kushiro test line")

For field observation of galloping and wet-snow accretion on conductors and insulators, full-scale test facilities for snow-storm damage to overhead transmission lines has been newly constructed in Kushiro city, Hokkaido, and operation commenced (Figure 4). The test facility consists of two phases of four-bundled conductor, five phases of single conductor, insulators for observation of snow accretion, and various meteorological instruments. Using these facilities, field observation data related to meteorological conditions of snow accretion and galloping are acquired. Effects of loose spacers on galloping and of snow resistant rings and counterweights against snow accretion are also examined.

*1 Self-excited oscillation of conductors due to wind and accreted snow or ice. If the amplitude becomes large or the oscillation continues, the phenomenon causes short circuiting or facility failure through fatigue.
*2 Practical examples of short circuit accidents, and damage to electric facility such as supports and conductors due to icing

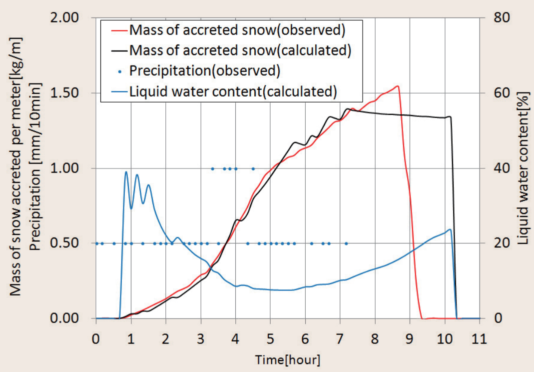

Fig. 1: Time change of mass for accreted snow and liquid water content calculated by SNOVAL-dyn

Using the meteorological data of a wet snow event, the mass of accreted snow calculated by SNOVAL-dyn is compared with that observed on a short conductor sample supported by wire ropes. The SNOVAL-dyn incorporating a thermodynamic model enables us to calculate the liquid water content of snow sleeve, as well as to determine the start time of snow accretion and the snow shedding time.

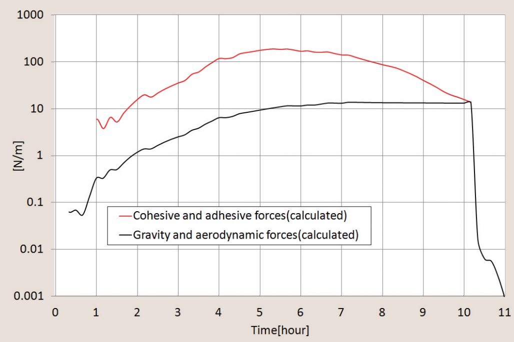

Fig. 2: Time change of cohesive and adhesive forces, and gravity and aerodynamic forces

The cohesive force between the snowflakes as well as the adhesive force between the surface of electric wire and the snowflakes are a mathematical function of the liquid water content of snow sleeve. The snow shedding time in Figure 1 is determined from the point where gravity and aerodynamic forces exceed the cohesive and adhesive forces, which is the intersection between the red and black curves.

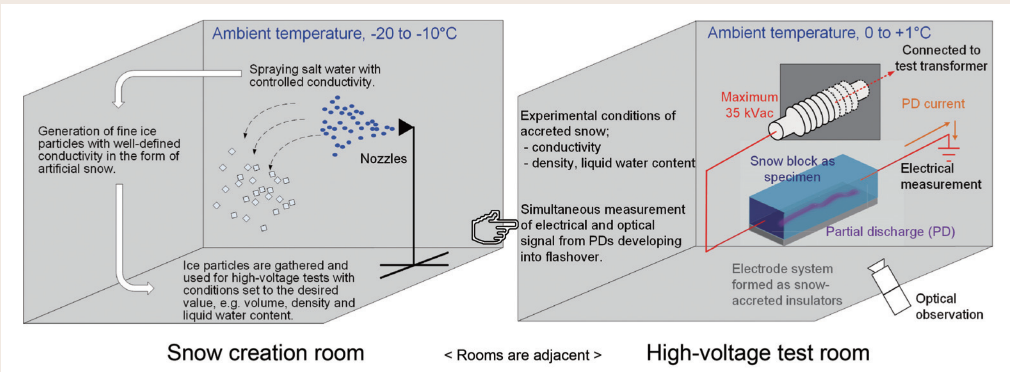

Fig. 3: Overview of snow generation and high-voltage test using the new facilities

New test facilities to conduct further experiments were prepared in the Yokosuka area. These facilities consist of two adjacent rooms used for snow generation and high-voltage tests on snow-accreted specimen. Simultaneous measurement of electrical and optical signal from PD provides important information to clarify flashover mechanisms on snow-accreted insulators.

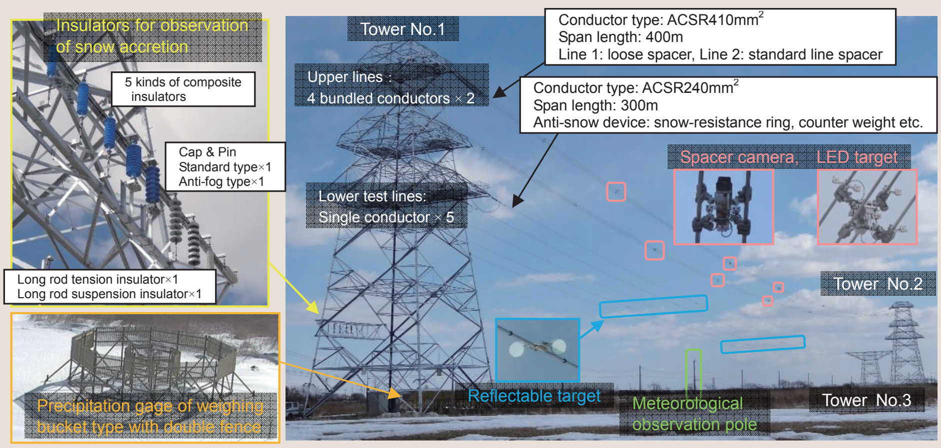

Fig. 4: Full-scale test facilities for snow-storm damage to overhead transmission lines

Meteorological data are acquired by using various kinds of instruments installed in towers and poles. The dynamic behavior of overhead wires is observed by using a tension meter and angle meter, with targets installed in conductors, infrared ray projector, network cameras, spacer cameras. Moreover, insulator specimens were also installed to compare their snow accretion property as well as a precipitation gage, which can measure precipitation with high accuracy under strong wind conditions.