Performance Study of LC-Spiral Rods Under Icing Conditions

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***Abstract*—Large pieces of ice or chunks of snow falling from overhead transmission lines can unexpectedly damage buildings, structures and cars found below. Such damage can be avoided by installing LC-Spiral Rods on the conductors as an anti-icing device. LC-Spiral Rods can generate enough heat by alternating magnetic field from conductor current, thus preventing any snow and ice from accumulating on the conductor under favorable weather and conductor current conditions. In Japan, LC-Spiral Rods have been satisfactorily used under wet snow conditions for about 20 years and are located on more than 100 spans (50 transmission lines).**

This time, the performance of LC-Spiral Rods was studied under icing conditions during the winter of 2008-2009 in Québec, Canada. A short section (20 m) of a 315 kV double-circuit transmission line located at the Mont Bélair icing test site was chosen for this performance study. Mont Bélair is equipped with several meteorological instruments to study icing, such as a remote-control camera at the top of an observation tower, an electrically-heated precipitation gauge, an Ice Rate Meter, hygroscopic/ambient temperature probes, load cells, electrically-heated anemometers, etc.

The anti-icing property of LC-Spiral Rods has been evaluated by heat balance calculations. According to the observation results, LC-Spiral Rods have been able to prevent ice accretion as per heat balance calculations. As a result, LC-Spiral Rods are effective not only under wet snow conditions but also under icing conditions (freezing rain and in-cloud icing).

I. Introduction

LARGE chunks of ice and snow falling from overhead transmission lines can unexpectedly damage buildings, structures and cars found below. Such damage can be avoided by installing LC-Spiral Rods on the conductors as an anti-icing device [1]. LC-Spiral Rods can generate enough heat by alternating magnetic field from the conductor current, thus preventing any snow and ice from accumulating on the conductor under favorable weather and conductor current conditions. In Japan, LC-Spiral Rods have been satisfactorily used under wet snow conditions, and a lot of data are available on their snow melting performance. These data are based on observations at a snow test site and actual transmission lines. However, anti-icing performance data for LC-Spiral Rods were still needed. Therefore, some observation results about anti-icing performance of LC-Spiral Rods under icing conditions are presented in this paper during the winter of 2008-2009 in Québec, Canada.

II. LC-Spiral Rods

Fig. 1 shows an example of chunks of snow falling from an overhead transmission line, which can sometimes cause damage to buildings and structures underneath the transmission lines. LC-Spiral Rods have been manufactured and installed for more than 20 years by Tokyo Electric Power Company (TEPCO) and VISCAS-Fujikura to prevent accidents caused by large chunks of snow.

Fig. 1. Chunks of snow falling from an overhead transmission line.

Fig. 2 shows a typical installation of LC-Spiral Rods on a conductor. In Japan, LC-Spiral Rods have been satisfactorily used under wet snow conditions and are installed on more than 100 spans (50 transmission lines). LC-Spiral Rods keep the conductor surface above freezing, the temperature required for ice to accumulate by generating enough heat by alternating magnetic field from the conductor current. The main characteristics of LC-Spiral Rods are as follows :

i. <u>No heat source required</u>
Heat by alternating magnetic field from the transmission line current and preventing any snow and ice from accumulating on the conductor.

ii. <u>Winter: large heating value, summer: small heating value</u>
LC-Spiral Rods have a large heating value in the winter and a small heating value in the summer as a result of

Low-Curie (LC) properties.

iii. Adjustable heating value

The heating value can be adjusted by using different wrapping lay angles.

iv. Easy installation

Bolts and nuts are not required for installation.

Fig. 2. Resulting installation of LC-Spiral Rods (single layer) on a conductor.

The heating property has been improved over the last 20 years. The optimal composition of the magnetic material was analyzed and studied together with the resulting structure and wrapping method for LC-Spiral Rods [2]. Fig. 3 shows a typical installation of double-layer LC-Spiral Rods on a conductor, resulting in about twice the calorific value of single layer LC-Spiral Rods with excellent snow melting performance.

Fig. 3. Resulting installation of double-layer LC-Spiral Rods on a conductor.

There are two types of installation methods for LC-Spiral Rods. One is hand wrapping and the other machine wrapping. Fig. 4 shows the hand-wrapping method, which requires more manpower to install. In this case, LC-Spiral Rods are preformed for ease of installation.

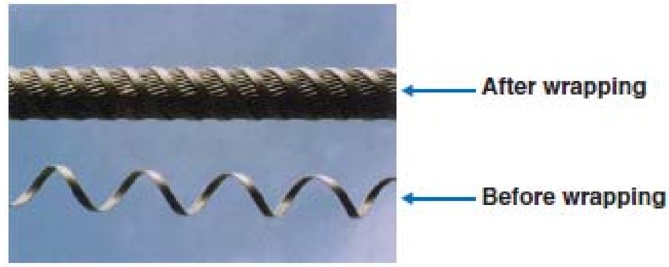


Fig. 4. LC-Spiral Rods using the hand-wrapping technique.

Machine wrapping is performed using a special wrapping machine. Fig. 5 shows the wrapping machine used for proper installation of LC-Spiral Rods. The use of end-rods is required at the LC-Spiral Rod extremities. Hand wrapping does not require any special tools and cannot provide gapless wrapping. Therefore, hand-wrapping is inferior to machine-wrapping based on anti-icing performance.

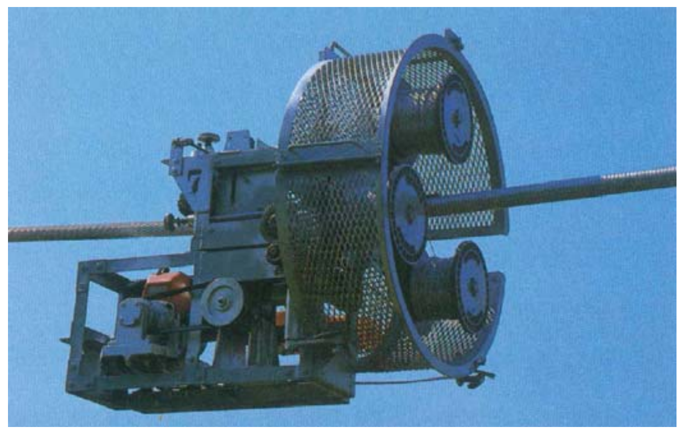


Fig. 5. Wrapping machine for the installation of LC-Spiral Rods.

Fig. 6 shows a photo from a snow test site in Japan. A normal conductor shows snow accretion, but the conductor equipped with LC-Spiral Rods does not.

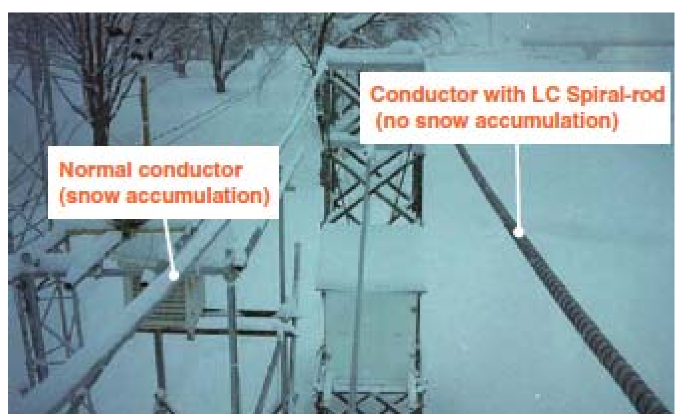


Fig. 6. Example of evaluation test results at a snow test site.

Fig. 7 shows an example of an infrared image on the actual transmission line. The red parts correspond to installed sections of LC-Spiral Rods showing that the temperature of the LC-Spiral Rods is higher than the normal bare conductor temperature.

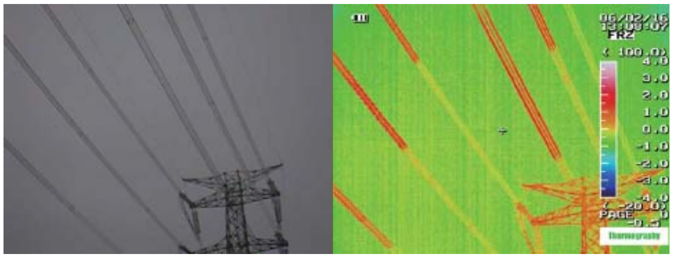


Fig. 7. Example of an infrared image (right-hand side) of the actual transmission line (left-hand side) with red parts corresponding to installed sections of LC-Spiral Rods.

III. OBSERVATION METHOD

LC-Spiral Rod performance was studied under icing conditions during the winter of 2008-2009 in Québec, Canada. A short section of a 315-kV double-circuit transmission line (bottom conductor) located at the Mont Bélair icing test site (see Fig. 8), located just a few kilometers north of the Québec City airport, was chosen for this performance study.

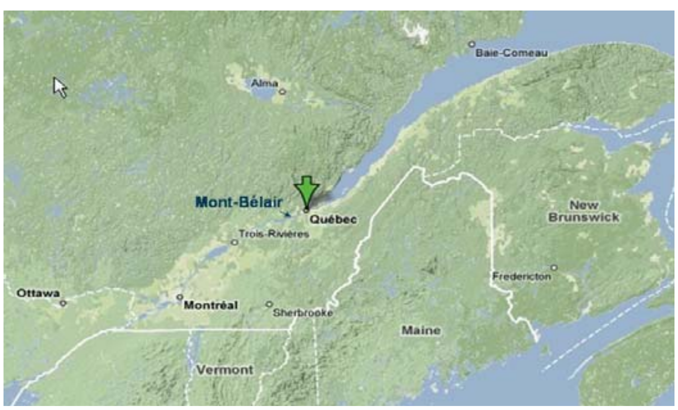


Fig. 8. Location of Mont Bélair icing test site.

Fig. 9 shows that a total of 20 m of LC-Spiral Rods (10 m of a single layer and 10 m of a double layer) was installed on the bottom phase conductor, as close as possible to the observation camera (see Fig. 10) located at Mont Bélair.

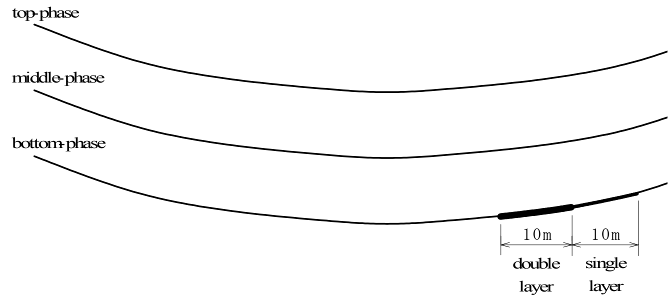


Fig. 9. Wrapping length of LC-Spiral Rods on the bottom phase conductor.

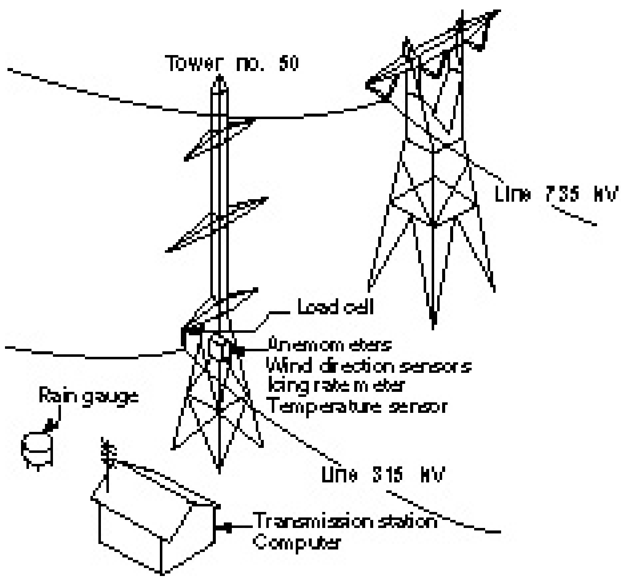
Fig. 10. Remote-control camera located at the top of an observation tower.

During an icing event, the observation camera was automatically triggered to acquire images of the LC-Spiral Rods and ice build-up on the bottom-phase conductor. All the data were recorded and sent to Hydro-Québec TransÉnergie offices in Montréal.

Mont Bélair is equipped with several meteorological instruments for studying icing, such as a tipping bucket rain gauge (heated), Ice Rate Meter (IRM), hygroscopic/ambient temperature probes, load cells, electrically-heated anemometers, etc., as shown in Figs. 11a and 11b [3]. The IRM, developed for rime detection and accretion rate measurement, consists of a vertical, 25.4-mm long cylindrical probe, found at the top of the instrument (see Fig. 12). When ice accumulates on the probe, the 40-kHz frequency, at which the probe is naturally excited, decreases at rate of about 2 Hz for each mg of accreted mass. After an accretion of 60-65 mg, an electronic controller heats up and de-ices the probe, and thus completes a cycle recorded by a cumulative counter. The hourly number of cycles, or IRM signals, can be used as warning alarms, but also as an ice detector to provide a rough estimate of the ice accretion rate during icing events [4].

In Québec, a program for studying atmospheric icing and its impact on power networks has been under way since 1994. The SYGIVRE system, Hydro-Québec's real-time ice monitoring system, has been used to send warning messages and meteorological data from measurement stations. Most of these stations are instrumented with modern measuring equipment that provides real-time meteorological information available to users via satellite. At some sites located in mountainous areas which are particularly prone to in-cloud icing, Hydro-Québec TransÉnergie installed telemonitoring stations that directly measure climatic loads [5].

One of the best-equipped measurement stations in the SYGIVRE network is the Mont Bélair icing test site. On average, 15 to 20 icing events occur at Mont Bélair during a typical winter season, such as freezing rain, in-cloud icing and wet snow events.



a)

b)

Fig. 11. a) Sketch of the Mont Bélair icing test site and measuring equipment; b) Photo of meteorological instruments at Mont Bélair.

Fig. 12. Ice Rate Meter.

IV. Observation Results

A first in-cloud icing event occurred at Mont Bélair in late October 2008. Figs. 13 to 16 show some photos that were taken from the remote-control camera at the top of the observation tower during this icing event. They clearly show that there was no ice accretion on LC-Spiral Rods (single layer + double layer) while rime ice was clearly present on the rest of the conductor.

Fig. 13. Overall view of LC-Spiral Rods on the bottom phase conductor.

Fig. 14. Right-hand extremity of LC-Spiral Rods with end rods and vibration damper.

Fig. 15. Junction of single-layer and double-layer LC-Spiral Rods.

Fig. 16. Left-hand extremity of LC-Spiral Rods + end rods.

The ambient temperature was not so cold and varied between -2.1 and -1.5°C during this icing event, as shown in Fig. 17. The perpendicular wind velocity with respect to the line was between 1 and 19 km/h, as shown in Fig. 18. The relative humidity was 98% on average (see Fig. 19). The maximum ice load at the end of this icing event was determined to be 1610 g/m by the IRM (see Fig. 20). During this icing event, the conductor current varied between 97 and 489 A (see Fig. 21).

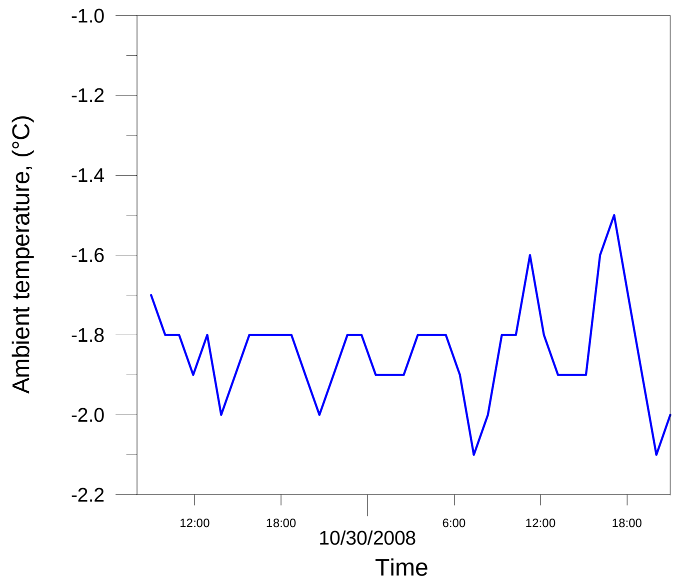


Fig. 17. Ambient temperature as a function of time.

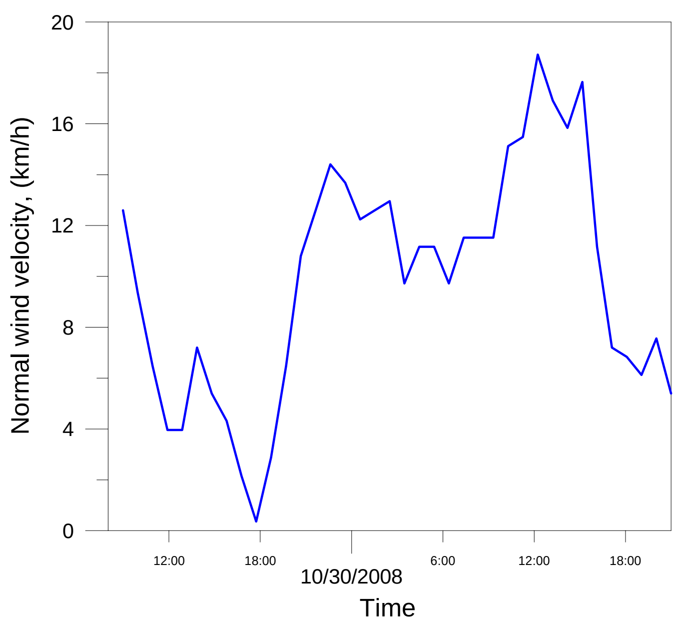


Fig. 18. Normal wind velocity as a function of time.

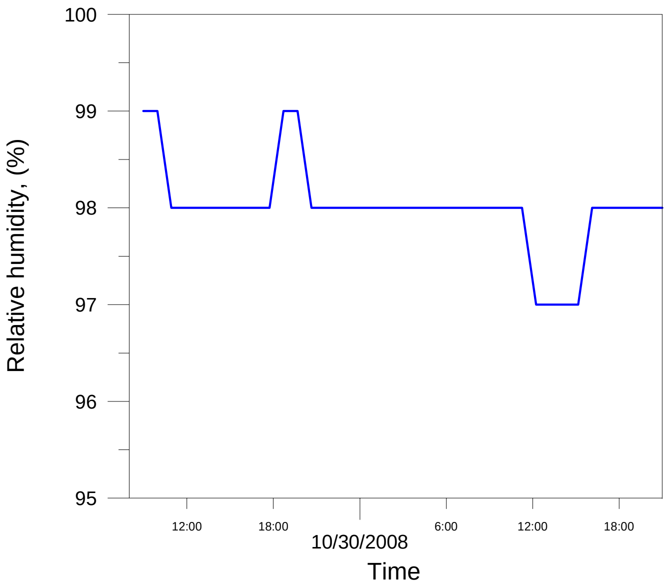


Fig. 19. Relative humidity as a function of time.

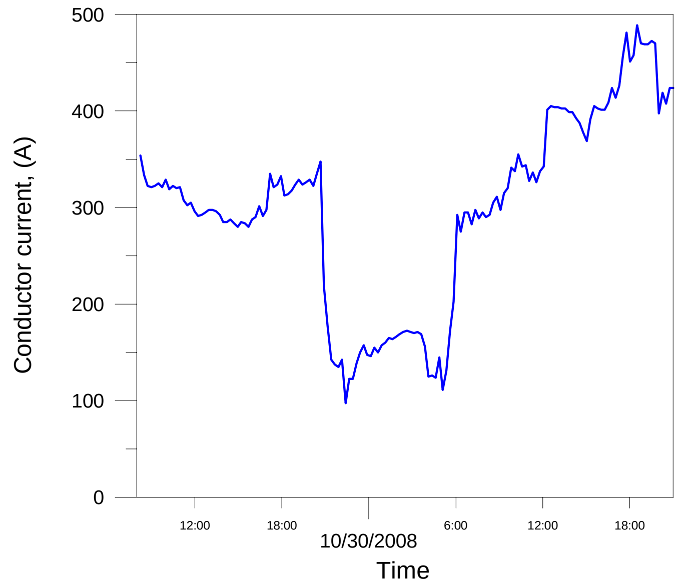


Fig. 21. Conductor current as a function of time.

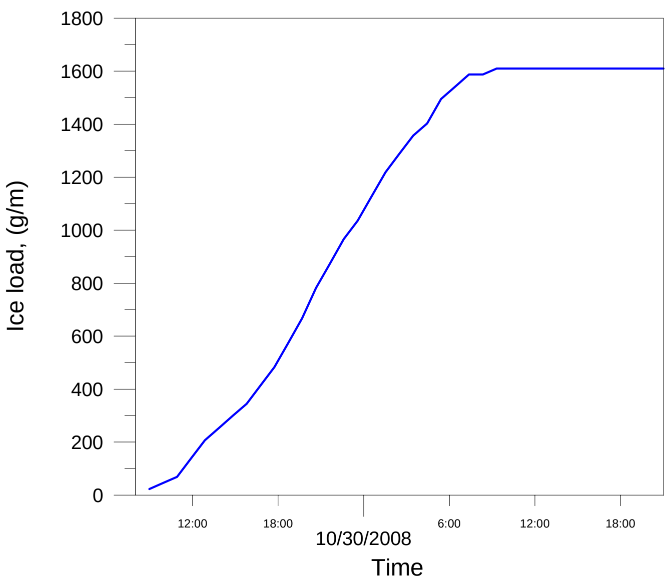


Fig. 20. Ice load evaluated by the Ice Rate Meter as a function of time.

For this performance study of LC-Spiral Rods, a total of 9 relevant icing events occurred during the winter of 2008-2009 at Mont Bélair. An overview of these icing events is presented in Table I, which clearly shows that LC-Spiral Rods are effective not only under wet snow conditions but also under natural icing conditions (freezing rain and in-cloud icing) under favorable weather and conductor current conditions.

TABLE I
OVERVIEW OF RELEVANT ICING EVENTS DURING THE WINTER OF 2008-2009 AT MONT BÉLAIR.

				Anti-Icing Efficiency*	
Date	Type of Icing	Total Accretion (g/m)	Ambient Temperature (°C)	Single Layer	Double Layer
October 29-30, 2008	Rime	1610	-2.1 to -1.5	■	■
November 13-14, 2008	Wet snow	161	-1.2 to +1.9	■	■
November 16-17, 2008	Rime	414	-5.1 to -0.5	■	■
November 26, 2008	Freezing drizzle	207	-0.6 to +0.3	■	■
November 27-29, 2008	Wet snow	193	-4.3 to -1.4	■	■
December 01-02, 2008	Rime	279	-4.0 to +0.1	■	■
December 04-05, 2008	Mixture of rime + wet snow	713	-13.4 to -0.1	■	■
December 17-18, 2008	Rime	9	-12.1 to -11.6	□	■
February 07-08, 2009	Mixture of glaze + rime	736	-15.4 to -0.5	■	■

*Anti-icing efficiency is indicated by "■" for total and "□" for partial.

V. Evaluation of Anti-Icing Properties

The anti-icing properties of LC-Spiral Rods were evaluated using heat balance calculations.

The complete melting condition is expressed by :

$$P_m + P_j > P_r + P_f \quad (1)$$

where P_m is the heating value generated by LC-Spiral Rods (W/m), P_j the heating value from conductor Joule effect (W/m), P_r the heating value radiated from the conductor (W/m) and P_f the heating value needed to melt snow and/or ice (W/m).

The partial melting condition is expressed by :

$$P_r + P_f > P_m + P_j > P_r \quad (2)$$

According to the observation results at Mont Bélair, LC-Spiral Rods were able to prevent ice accretion in accordance with heat balance calculations.

For each icing event occurring at Mont Bélair, several parameters were measured such as ambient temperature, wind velocity and directions, relative humidity, rainfall rate, the ice load evaluated by the IRM, and conductor current. All these measuring data were gathered by Hydro-Québec TransÉnergie in order to produce an observation report that was sent to VISCAS Corporation for analysis and heat balance calculations.

Fig. 22 shows the heat balance calculation results for single-layer LC-Spiral Rods, while Fig. 23 shows the results for double-layer LC-Spiral Rods during this icing event. These figures clearly show that since the meltable icing rate is always higher than the actual icing rate, LC Spiral-Rods have sufficient ice melting performance, as confirmed visually by the photos in Figs. 13 to 16. It can also be determined that the shape of the meltable icing rate curve in Figs. 22 and 23 is very similar to the conductor current curve shown in Fig. 21. As a result, the anti-icing properties of LC-Spiral Rods depend mainly on favorable conductor current and weather conditions.

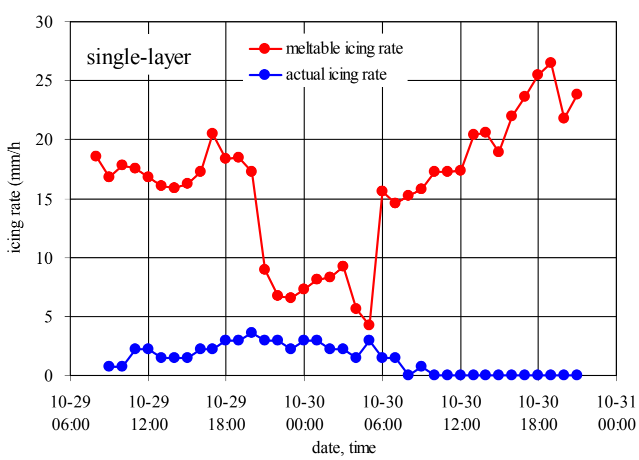


Fig. 22. Heat balance calculation results of single-layer LC-Spiral Rods

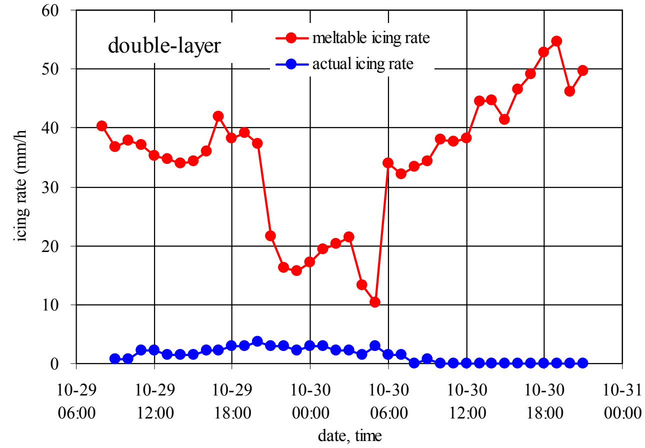


Fig. 23. Heat balance calculation results of double-layer LC-Spiral Rods

VI. Conclusion

The anti-icing properties of LC-Spiral Rods were evaluated using heat balance calculations. According to the observation results from Mont Bélair, LC-Spiral Rods were able to prevent ice accretion as per heat balance calculations. As a result, LC-Spiral Rods are effective not only under wet snow conditions but also under natural icing conditions (freezing rain and in-cloud icing) under favorable weather and conductor current conditions.

VII. References

[1] M. Yasui, K. Maekawa, Y. Naganuma, K. Suzuki, Y. Kojima, H. Ando, “Removal of Icy Snow Accumulation on the Transmission Line by Applying LC-Spiral Rod” *Fujikura Technical Review,* No.16, 1987.

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