

NEW RESULTS ON THE ANTI-ICING PERFORMANCE OF LC-SPIRAL RODS

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Abstract: Snow and ice falling from overhead transmission lines may unexpectedly damage buildings, structures and cars just beneath. Such damages can be avoided by installing LC-Spiral Rods on the conductors as an anti-icing device.

1. INTRODUCTION

In Japan, LC-Spiral Rods have been satisfactorily used under wet snow conditions for more than 20 years and are located on more than 100 spans (50 transmission lines). Fig. 1 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.

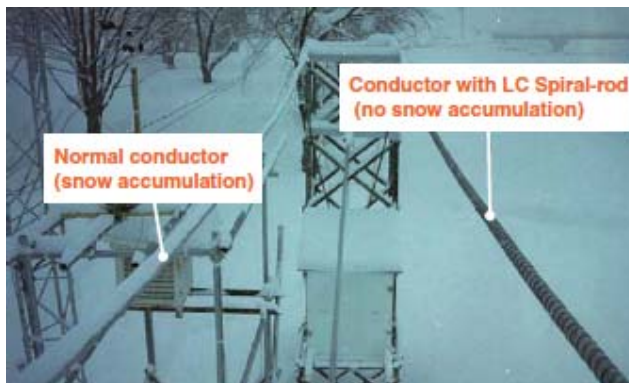


Figure 1: Example of evaluation test results at a snow test site.

2. RESULTS AND DISCUSSION

Hydro-Québec TransÉnergie (Canada), TEPCO (Japan) and VISCAS Corporation (Japan) studied LC-Spiral Rods performance under icing conditions during the 2008-2009 [1] and 2009-2010 winter seasons at Mont Bélair in Quebec, Canada. For this performance study, a total of twelve icing events were analyzed during the observation period, such as freezing rain, in-cloud icing and wet snow events. Fig. 2 shows a photo that was taken from the remote-control camera of Mont Bélair during an icing event that occurred on January 15-17, 2010. This figure clearly shows that there was no ice accretion on LC-Spiral Rods, while ice accretion was present on the rest of the conductor.

Anti-icing performance of LC-Spiral Rods was also evaluated by heat balance calculations. According to the observation results from Mont Bélair, LC-Spiral Rods could prevent ice accretion in accordance with heat balance calculations.



Figure 2: Photo taken from the remote-control camera showing the right-hand extremity of LC-Spiral Rods (no ice).

Anti-icing performance of LC-Spiral Rods has also been evaluated by carrying out artificial icing tests (glaze ice) in a wind tunnel at Kitami Institute of Technology. The anti-icing properties of LC-Spiral Rods were evaluated using heat balance calculations. Calculation includes the complete melting condition and the partial melting condition. These equations include the heating value generated by LC-Spiral Rods, the heating value from conductor Joule effect, the heating value radiated from the conductor and heating value needed to melt snow and/or ice. Comparative figures from experimental and calculated results suggest that melting performance from the calculated results are almost similar to the experimental results.

3. CONCLUSION

Anti-icing performance of LC-Spiral Rods have been evaluated using heat balance calculations. According to the observation results from Mont Bélair and from Kitami Institute of Technology, LC-Spiral Rods were able to prevent ice accretion as per heat balance calculations. LC-Spiral Rods are effective under natural and artificial icing conditions occurring under favorable weather and conductor current conditions.

4. REFERENCES

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Abstract— Snow and ice falling from overhead transmission lines may unexpectedly damage buildings, structures and cars just beneath. Such damages can be avoided by installing LC-Spiral Rods on the conductors as an anti-icing device. LC-Spiral Rods can produce enough heat by alternating magnetic field from the conductor current, thus preventing any snow and ice accretion on the conductor under suitable weather and conductor current conditions.

Hydro-Québec TransÉnergie (Canada), TEPCO (Japan) and VISCAS Corporation (Japan) studied LC-Spiral Rods performance under icing conditions during the 2008-2009 and 2009-2010 winter seasons at Mont Bélair in Quebec, Canada. Also, in collaboration with Kitami Institute of Technology, TEPCO has studied the anti-icing performance of LC-Spiral Rods and validity of heat balance calculations by carrying out artificial icing tests in a wind tunnel. According to the results, LC-Spiral Rods could prevent ice accretion in accordance with heat balance calculations.

In consideration of these results, Hydro-Québec installed LC-Spiral Rods on the conductors of two major road crossings of a 735 kV quad bundle transmission line in November 2010, in Quebec city.

Keywords: *LC-Spiral Rods, anti-icing, heat balance calculation, conductors, OPGW.*

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 2008-2009 and 2009-2010 winter seasons in Quebec, 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. 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.



Figure 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 located 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 :

A. No Heat Source Required

Heat by alternating magnetic field from the transmission line current and preventing any snow and ice from accumulating on the conductor.

B. Season-Dependent Heating Value

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.

C. Adjustable Heating Value

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

D. Easy Installation

Bolts and nuts are not required for installation.



Figure 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.



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

Fig. 4 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. 5 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.

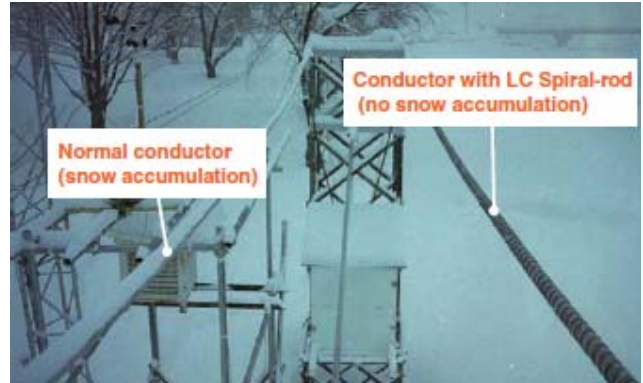


Figure 4. Example of evaluation test results at a snow test site.



Figure 5. 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. NEW TEST RESULTS

Hydro-Québec TransÉnergie (Canada), TEPCO (Japan) and VISCAS Corporation (Japan) have studied LC-Spiral Rods performance under icing conditions at Mont Bélair in Quebec, Canada. Also, in collaboration with Kitami Institute of Technology, TEPCO has studied the anti-icing performance of LC-Spiral Rods and validity of heat balance calculations by carrying out artificial icing tests in a wind tunnel. The following sections present test results both from Mont Bélair and from Kitami Institute of Technology.

A. Results from Mont Bélair Icing Test Site

Hydro-Québec TransÉnergie (Canada), TEPCO (Japan) and VISCAS Corporation (Japan) studied LC-Spiral Rods performance under icing conditions during the 2008-2009 [4] and 2009-2010 winter seasons in Quebec, Canada. A short section of a 315 kV double-circuit transmission line located at the Mont Bélair icing test site was chosen for this performance study. A total of twelve icing events occurred at Mont Bélair during the observation period, such as freezing rain, in-cloud icing and wet snow events. Mont Bélair is equipped with several meteorological instruments for studying icing [3]. A total of 20 m of LC-Spiral Rods (10 m single layer and 10 m double layer) was installed on a conductor of the 315 kV double-circuit transmission line, as close as possible to the observation camera located at Mont Bélair [4].

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. Fig. 6 shows such a photo that was taken during the icing event

that occurred on January 15-17, 2010. This figure shows that there was no ice accretion on LC-Spiral Rods, while ice accretion was present on the rest of the conductor.



Figure 6. Photo taken from the remote-control camera showing the right-hand extremity of LC-Spiral Rods with end rods and vibration damper.

For this performance study of LC-Spiral Rods at Mont Bélair, a total of twelve icing events were analyzed during the observation period, such as freezing rain, in-cloud icing and wet snow events. An overview of these icing events is presented in Table I.

TABLE I. OVERVIEW OF RELEVANT ICING EVENTS DURING THE 2008-2009 AND 2009-2010 WINTER SEASONS.

Date	Type of Icing	Total Accretion (g/m)	Ambient Temperature (°C)	Anti-Icing Efficiency*	
				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	■	■
December 25-30, 2009	Mixture of glaze + rime	2407	-21.4 to -0.3	■	■
January 15-17, 2010	Rime	416	-14.6 to -1.8	■	■
January 26-31, 2010	Rime	915	-24.1 to 0.0	■	■

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

B. Icing Test Results from Kitami Institute of Technology

Artificial icing tests on LC-Spiral-Rods have been carried out in a wind tunnel at Kitami Institute of Technology. Anti-icing and de-icing performances of LC-Spiral Rods have been studied under the following icing conditions : temperature of -3°C and -5°C; wind speed of 2 m/s, precipitation rate of 2 mm/h, icing duration time of 3 hours. The conductor sample was an ACSR 810 mm². Two winding methods of LC-Spiral Rods have been used : single-layer and double-layer LC-Spiral Rods. Conductor current values were 80, 100, 150 and 200 A. Temperature on the upper and bottom surface of the conductor was measured from the icing process to ice shedding.

Icing test section of the wind tunnel was 1.6 m x 1.6 m square as shown in Fig. 7. Maximum wind speed and minimum temperature in this icing wind tunnel were 6 m/s and -30°C respectively.

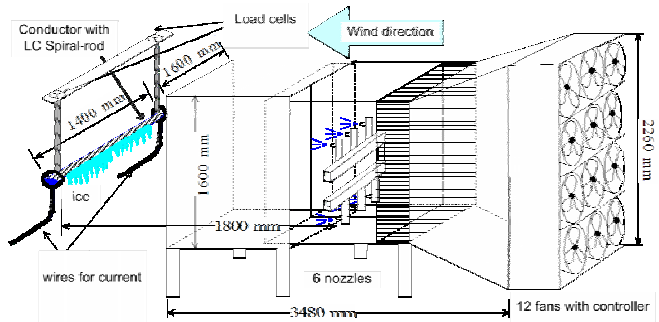


Figure 7. Icing wind tunnel for conductor equipped with LC-Spiral Rods.

Another icing wind tunnel with precipitation type droplets under low wind speed was also available. Icing length of conductor sample in the icing tunnel was about 1.2 m of whole length, 2.3 m.

The snow and ice melting properties of LC-Spiral Rods were evaluated using heat balance calculations. The complete ice melting condition is expressed by the following equation :

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

while the partial ice melting condition is expressed by :

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

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).

Experimental and calculated results are summarized in Figs. 8 and 9. Those figures suggest that anti-icing performance from the calculated results are almost similar to the experimental results. According to the results, LC-Spiral Rods could prevent ice accretion in accordance with heat balance calculations.

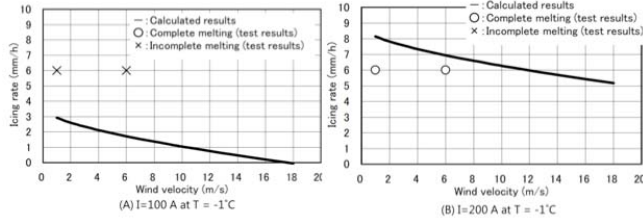


Figure 8. Test and calculated results of single-layer LC-Spiral Rods.

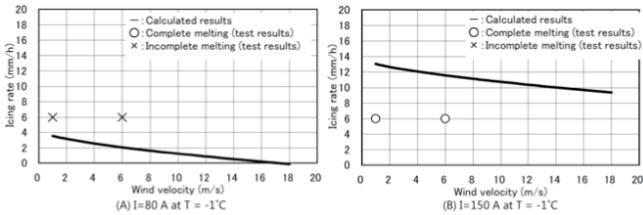


Figure 9. Test and calculated results of double-layer LC-Spiral Rods.

IV. ANTI-ICING PERFORMANCE AND HEAT BALANCE CALCULATION

The anti-icing performance of LC-Spiral Rods has been evaluated using heat balance calculations. For each icing event occurring at Mont Bélair [4], several parameters were measured such as ambient temperature, wind velocity and directions, relative humidity, rainfall rate, the ice load evaluated by the Ice Rate Meter, and conductor current. All these measuring data were then gathered by Hydro-Québec TransÉnergie in order to produce an observation report that was sent to VISCAS Corporation for further analysis and heat balance calculations.

According to the observation results from Mont Bélair and from Kitami Institute of Technology, LC-Spiral Rods were able to prevent ice accretion in accordance with heat balance calculations.

V. ROAD CROSSING INSTALLATION IN QUEBEC CITY

In Quebec city, whenever the Lévis substation DC converter will be used to de-ice overhead line quad-bundled conductors using Joule effect, ice shedding will occur. Specifically on road crossings, this may unexpectedly damage cars found below.

In order to start securing its major road crossings against ice shedding during de-icing procedures, Hydro-Quebec TransÉnergie and VISCAS Corporation installed LC-Spiral Rods on quad-bundled ACSR conductors of two important road crossings of a 735-kV transmission line in November 2010, in Quebec city (see Fig. 10). LC-Spiral Rods were installed not only on the conductors but also on OPGW, which had previously been electrically insulated from the towers as part of the Lévis substation DC de-icing project [5]. In this case, anti-icing performance of LC-Spiral Rods installed on the OPGW simply makes use of the induced current in the OPGW. Double-layer LC-Spiral Rods were installed on the OPGW in order to have a better calorific

value, while single-layer LC-Spiral Rods were installed on quad-bundled ACSR conductors.

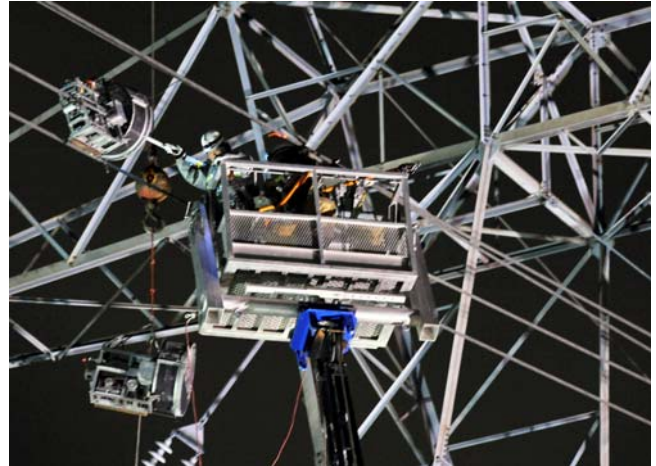


Figure 10. Installation of wrapping machines and LC-Spiral Rods on the conductors of a road crossing in Quebec city in November 2010.

VI. CONCLUSION

The anti-icing performance of LC-Spiral Rods has been evaluated using heat balance calculations. According to the observation results from Mont Bélair and from Kitami Institute of Technology, 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.

In consideration of these results, Hydro-Québec TransÉnergie and VISCAS Corporation installed LC-Spiral Rods on the quad-bundled conductors and OPGW of two important road crossings of a 735-kV transmission line in November 2010, in Quebec city.

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