Development of the Snow-melting Ring (LC ring)

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***Abstract*— We developed a snow-melting ring with low curie material the produces a magnetic field which generates heat and as a result, the size of snowflakes could be reduced, thus reducing the accumulation of snow on conductors. To verify snow-melting and snowfall characteristics of the LC rings, artificial and natural snowing tests were conducted. The size of snowflakes could be reduced such that they become smaller than the interval of the installed LC rings. Additionally, the propriety of the evaluation for the possible snow fall curve based on heat balance calculation could be verified.**

I. INTRODUCTION

When the snow accumulated on the conductor consists of large snowflakes, it can damage the buildings and structures below overhead transmission lines. This is due to the large amount of energy carried by falling snow. Moreover, people whose property is damaged tend to complain to utility companies. Therefore, for power transmission line continuation, it is crucial to implement measures that prevent the accumulation of snow on transmission lines.

Presently, the Snow Resistance Ring (SR Ring) is installed in conductors to prevent the accumulation of snow. However, it is difficult to significantly reduce the accumulation of snow and to prevent it from damaging the surrounding buildings and structures. The function of the SR Rings is to reduce the quantity of accumulated snow.

On the other hand, snow-melting spiral rods (LC-Spiral Rods) made of the low curie (LC) materials also prevent the accumulation of snow. Heat is conducted via a magnetic field. However, due to an increase in the weight of the conductor created by the melting snow, the load from the Spiral Rods becomes a problem and it is difficult to use widely. Therefore, we developed a snow-melting ring made from low curie material that generates heat via a magnetic field, thus making it possible to reduce the size of the snowflakes in the accumulated snow.

II. OVERVIEW OF THE SNOW MELTING RING

To reduce the accumulation of snow and the tower load, we developed a snow-melting ring or "LC Ring". We manufactured a trial ring that is the same size and made of the same material as the LC-Spiral Rods (Table 1).

Polycarbonate was installed inside the Snow Melting Ring (Fig. 1).

TABLE 2. CABLES TESTED

Thickness	5.1[mm]
Width	10.0[kg]
Weight	56.4 [g / piece]

Fig.1. LC Ring

The installation weight of this ring when installed at an 100mm interval on an ACSR810mm^2 is 1/1.8 times larger than that of 3-LC-Spiral Rods (wire diameter φ2.0mm) wound at an 8mm interval.

This paper evaluates the magnetic characteristics and the caloric value of LC rings. In addition, snowing tests verified that the accumulation of snow on LC rings with conductors installed is reduced and falls at appropriate intervals.

III. LC RING HEATING PROPERTY

A. *The Energy Balance Calculation*

The indicator as to whether or not the snow on the LC Ring can be melted becomes the difference between the calorific value of the LC Ring and the quantity of heat dissipation from the Ring. (Fig. 2)

The calorific value of the LC Ring is as follows:

- The calorific value of the LC Ring (P_m): The calorific value of the heat generated by the magnetic field of low curie material (The function of the electric current which flows through the conductor and the weight of the ring).

The quantity of radiated heat is as follows:

- The radiated value (P_r): The heat that results from radiation of the LC Ring (The function of the temperature raise from the ambient temperature, the wind velocity near the ring, and the coefficient of solar radiation).
- The quantity of conducted heat (P_c): The quantity of heat transmitted to the electric conductor through the polycarbonate. (The function of the temperature difference between LC Ring and the conductor).
- The heat needed to melt snow (P_f): The quantity of heat that is necessary to melt the snow accumulated on the ring. (The function of the snowfall rate).

The complete melting condition is expressed by the following equation,

$$P_m \geq P_r + P_c + P_f \qquad (1)$$

T he partial melting condition is expressed by the following equation,

$$P_m \leq P_r + P_c + P_f \qquad (2)$$

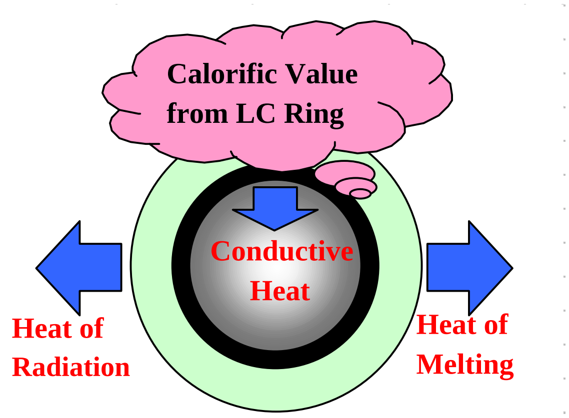


Fig.2. Heat balance model of the LC Ring

B. *LC Ring heat properties*

As shown in Fig. 3, the heat properties of the LC Ring were evaluated by installation of a circuit installed in the five rings of the electric conductor, in order to confirm that the low curie material of the ring shape was heated as designed.

Calorific value W was calculated by using Equation (3) based on the current flow through the conductor and the voltage applied to the LC ring. (Fig. 4)

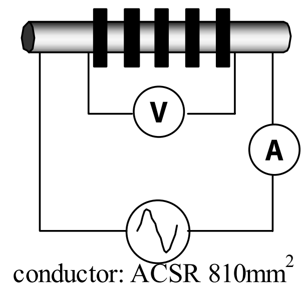


Fig.3. Measurement of heating property

$$W = \int V(t) \times I(t) dt / 5 \qquad (3)$$

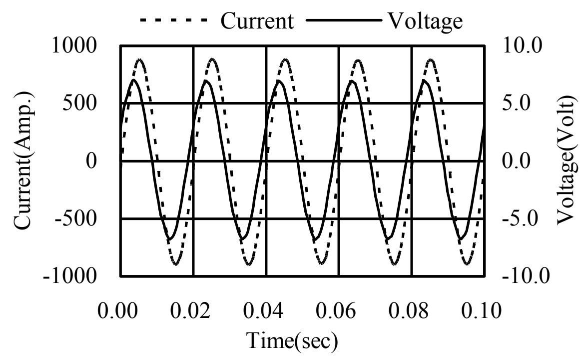


Fig.4. Electric current and voltage wave pattern

The relationship between the current flowing through the conductor and the calorific value of the LC rings is shown in Fig. 5. The electric field produced by the current confirmed that the LC Ring made from low curie material was energized to heat as expected by the calculated value.

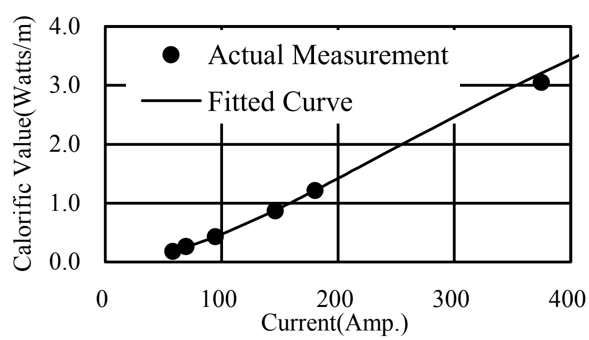


Fig.5. Heat properties of LC Ring

IV. LC RING TEST

To verify snow-melting and falling snow characteristics of the conductor installed in the LC rings, an artificial and a natural snowing test were conducted.

A. *Artificial arrival snow test*

After 1 hour of continuous snowfall, the snow-melting characteristics of the electric conductor installed in the LC rings were estimated according to the following test conditions (Fig. 6). To compare to the characteristics of the rings, SR rings were also installed.

Testing conditions:

- Conductor: ACSR810mm2
- Installation interval of the rings: 100 mm
- Wind velocity: 6m/sec
- Current flowing though the conductor: 100 Amp.
- Parameters: ambient temperature [ºC], snowfall rate [mm/hour]

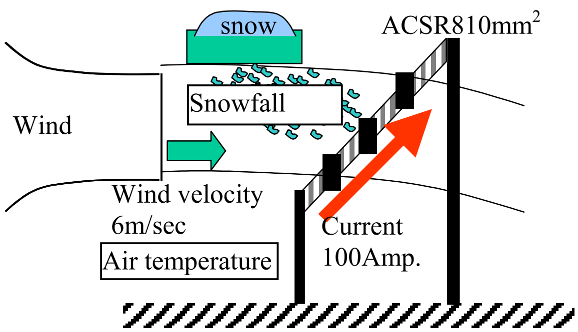


Fig. 6. Artificial snowing test condition

The possible snow melting curve is shown in Fig. 7. The curve was calculated based on the energy balance calculations shown in §3.1 of the testing conditions (wind velocity: 6 m/s, current value: 100Amp.). If the snowfall conditions fall below the possible snow melting curve ("Possible melted snow condition area"), it means that theoretically the snow on the LC Rings can melt under such conditions.

For this artificial snowing test, LC Ring snow-melting characteristics for each snowfall condition per hour are shown in Fig. 7. Accumulation of snow on the ring is denoted by an "X"; if there was no accumulation of snow on the ring, it is represented by a "○".

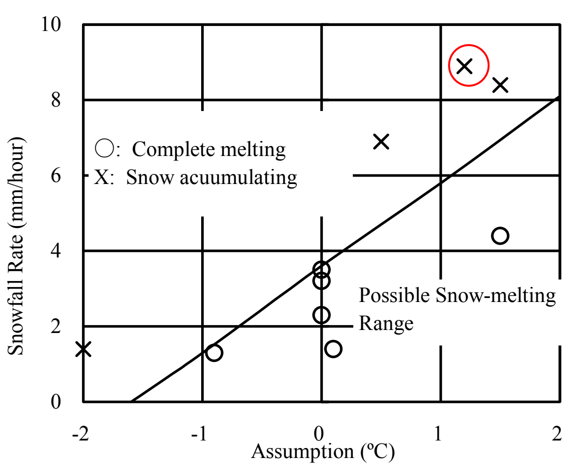


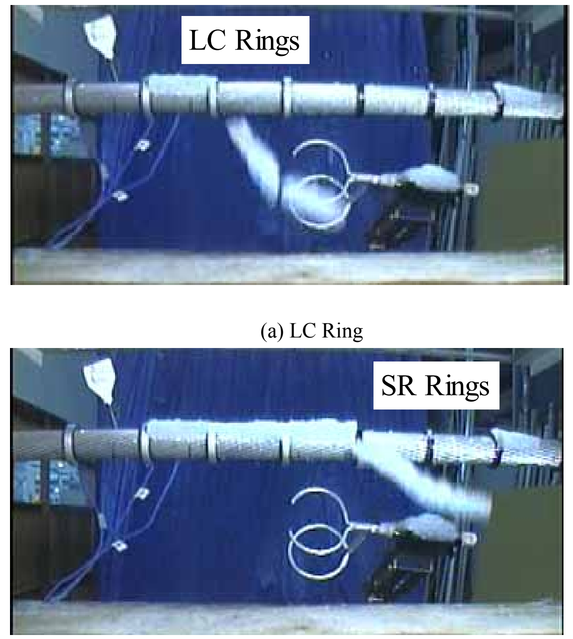
Fig.7.Snow-melting properties

Due to the snowfall conditions in the "possible snow melting condition area", the accumulation of snow on the LC rings was not observed.

Therefore, it became clear that falling snow from the electric conductor could be made smaller than the installed interval of the rings. In addition, the propriety of the evaluation method for the possible snow melting curve based on the heat balance calculation was verified.

Next, the conditions under which the accumulation of snow were observed (the snowfall strength: 8.9 [mm/hour], the ambient temperature 1.2 [ºC]) verified the falling characteristics of the snow accumulated on the rings 1 hour after snowfall and ventilation had stopped.

The result was shown in Fig. 8



(a) LC Ring

(b) SR Ring

Fig.8. Arterial Snowing test results

Snow accumulated where all LC rings were installed fell. However, snow accumulated on SR ring installations did not.

Therefore, despite hard snowfall conditions and the increased accumulation of snowfall, the possibility that snow accumulated on the rings can be melted was confirmed. In addition, it was confirmed that the snowflakes fell at a length below the installed interval after the snow had softened.

B. The natural snowing test

Observation results from January 2007 of a snow accumulation test line in Ishiuchi City in Niigata Prefecture are shown below (Fig. 9).

Test conditions are as follows:

- Conductor: ACSR810mm2
- Installation interval of the rings: 100 mm
- Wind velocity: 6m/sec
- Current: 100 Amp.
- The installed rings:
  - LC Rings (installation interval is 100 [mm], 200 [mm], 300 [mm]
  - SR Rings (installation interval is 300 [mm])

Fig. 9 Observation equipment outline

The height of snow accumulation on the surface of the LC Ring and the SR Ring and between the respective rings was compared (Figure 10). The results are shown in Figure 11. The height of snow accumulation became smaller on the surface of the LC Rings, thus confirming the possibility that the size of snowflakes falling from the electric conductor could be reduced.

Fig.10. Observation conditions of accumulated snow on the test line

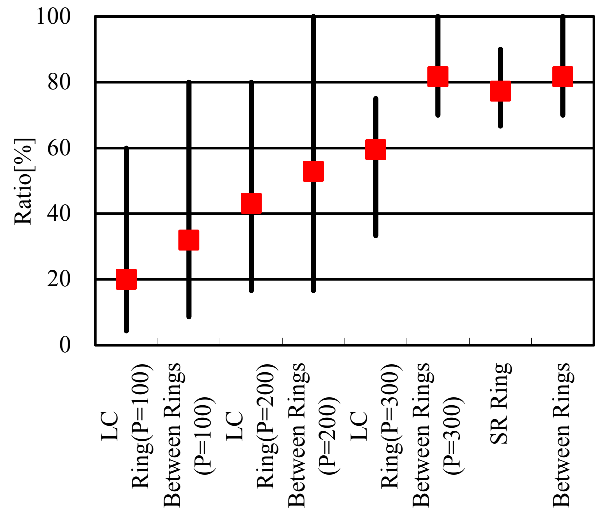


Fig.11. Comparison of snow accumulation height

V. Conclusion

The following was demonstrated in this paper:

The ring was made of low curie material (LC material). It was verified that LC Rings could generate heat when the electric current and the magnetic field are small. To verify snow melting and snow fall characteristics from the conductor installed in the LC rings, an artificial and natural snowing test were conducted. Based on the results of these tests, it was verified that the size of the snowflake falling from the conductor installed LC rings could be reduced to a size that is smaller than the installed interval of the rings. Additionally, the propriety of the evaluation method for the possible snow melting curve based on heat balance calculation was verified.

In addition, it was confirmed that the load added by the installation of LC rings to steel towers is smaller than existing snow-melting spiral rods (LC-Spiral Rods).

In the future, characteristic tests will be conducted where actual application of the rings is planned. Testing on the application of LC rings to transmission lines will continue.

VI. References

[1] H.Nakamura, D.Takagi, T.Kitamura, S.Katayama, Y.Asano, and T.Saitoh, "Development of snow-melting magnetic material wire for low current transmission" IEEE/PES 2002 Asia Pacific.