Climate Conditions of Frost-Phenomena Adherent to the Overhead Lines

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***Abstract*—To investigate the overhead line frosting phenomena, we observed the overhead line frosting and analyzed meteorological conditions when occurred. As a result, it was ascertained that probability of the frosting outbreak was high when the following conditions occurred at the same time: air temperature was less than 0.5°C, humidity was more than 80%, wind velocity was less than 1m/s and net radiation was -120~ -70W/m^2. This was why the water vapor concentration was supersaturated in the neighborhood of the overhead line surface.**

I. Introduction

Overhead line frosting often occurs in a fine night of winter when air temperature is low and humidity is high. When a train runs such section, a contact break is occurred by frost existing between a pantograph and an overhead line, and this causes arc discharges and there are damages of pantograph, the blowouts of the overhead line, etc. As a countermeasure of the overhead line frosting, the application of freeze suppressants such as oil, the heating of the overhead line for melting the frost, and special train service in the early morning for removing the frost by pantograph or cutter are performed. It is important for effective countermeasures to forecast the outbreak of the overhead line frosting. In actuality in railway field, climatic conditions of weather, temperature, humidity, and wind velocity was recorded when the overhead line frosting occurred, and they often predict the outbreak based on those climatic conditions experientially.

In this study, we observed overhead line frosting at the site where it is often outbreak, and clarified weather characteristics when overhead line frosting occurred and the weather condition quantitatively.

II. OBSERVATION

A. Site

Observation site of the overhead line frosting was chosen at Nakatsugawa-shi (Gifu prefecture) nearby the station (figure 1) because it is easy to post the facilities such as weather surveying instruments. This site is located in the mountains, and a temperature fall by the radiational cooling is easy to occur during the winter season. In addition, there is Nakatsugawa River near the site, that is the branch of Kisogawa River, and then the humidity is easy to rise. In this way, the condition of outbreak the frosting is prepared.

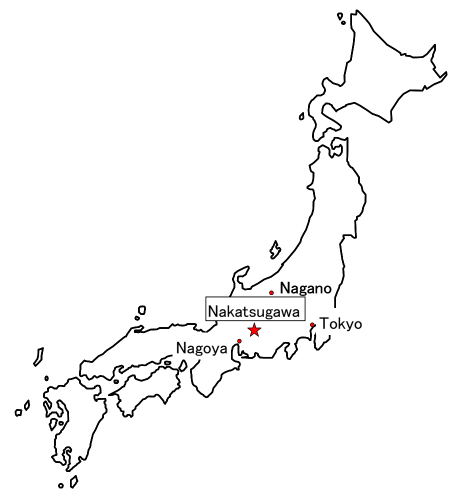

Fig. 1. Observation site

B. Instrument

It was reported that air temperature, humidity, wind velocity and weather are nominated for meteorological elements about outbreak of frost. Therefore, we observed air temperature, humidity, wind velocity and direction and precipitation. It was reported that a frost damage accident appeared in a fine early morning of winter when radiational cooling was strong. When radiational cooling occurs, the value of net radiation becomes a negative value, and then the object which there is in the vicinity of an earth surface is cooled by infrared emission. Therefore, net radiation, which is related to weather, and surface temperature of the overhead line, was measured.

The establishment situation of weather surveying instruments is shown in figure 2. Observation pillar (6m high from ground) was installed. Draft-type humidity and temperature sensor was attached to the pillar at height of 1.5m and 5.1m (almost same height of overhead lines) from ground. Short and long wave radiometer was installed at height of 5.9m from ground. Three mock overhead lines (one was new and the other were wasted ones) of 3m length were used to measure the surface temperature (figure 3). Thermo resistances were glued to the overhead lines of 3m height. Air temperature, humidity, wind direction, net radiation, and surface temperature of the overhead lines were measured at a moment of every 10 minutes, and wind velocity were measured the mean of 10 minutes. The precipitation measured multiplication value of every 10 minutes. Presence of the overhead line frosting was judged from photographs (every 10 minutes) of the Web camera, which was installed on observation pillar.

We observed two winter season and total period is 262 days; from November 10th, 2005 to March 31st, 2006 and from November 1st, 2006 to February 28th, 2007.

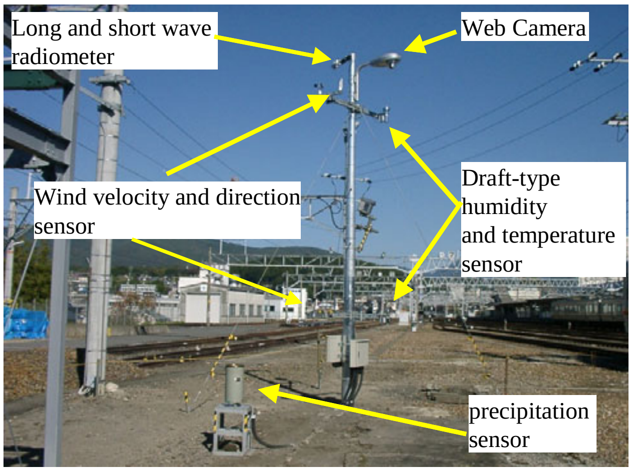

Fig. 2. Establishment situation of weather surveying instruments

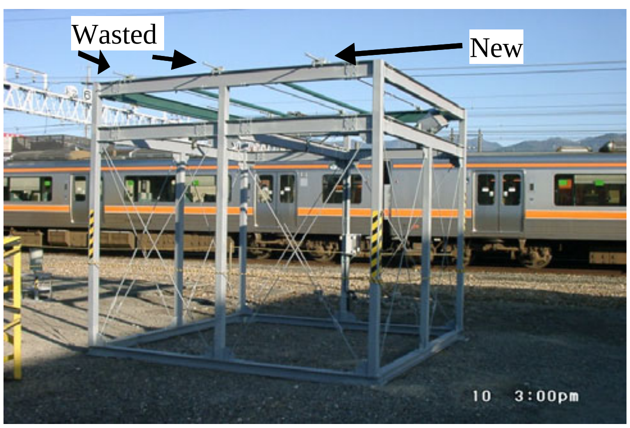

Fig. 3. Establishment situation of mock overhead lines

III. Observation Results

A. *Characters of outbreak day of overhead line frosting*

We could not measure the data only 13 days owing to the failure of power supply. Overhead line frosting occurred 72 days during all 249 days. The frost outbreak frequency of January was high, in 2005 and 2006 season.

As an example of a typical weather condition of the overhead line frosting outbreak day, the change of air temperature, humidity, wind velocity, net radiation and the surface temperature of overhead lines were shown in figure 4 from January 28th at 8:00 to 29th at 16:00, 2006. Overhead line frosting observed from 2:00 to 7:00; (time between dashed lines). The value of air temperature and humidity by the difference of the height of the sensor were hardly accepted.

Air temperature decreased from 2.8°C at 17:00 on 28th to -6.8°C at 5:00 on 29th, and humidity increased from 49% to 92% during this period. The surface temperature also decreased like air temperature after sunset, which was 1-3°C lower than temperature, and reached to -9.1°C at 5:00 on 29th. Wind velocity was less than 1m/s from 18:00 on 28th to 8:00 on 29th. It was a fine night and net radiation decreased less than -100W/m^2 after sunset and kept between -120 and -100 W/m^2 until 5:00 on 29th. This was the cause that the overhead line surface temperature was about 1-3°C lower than air temperature. Similar weather conditions at the overhead frosting outbreak day were observed. Therefore, the probability of overhead line frosting is high when the following conditions occurred at the same time; (a)air temperature largely decreased, (b)humidity was high, (c)wind velocity was small, (d)there is a strong radiational cooling, and (e)overhead line surface temperature was lower than air temperature.

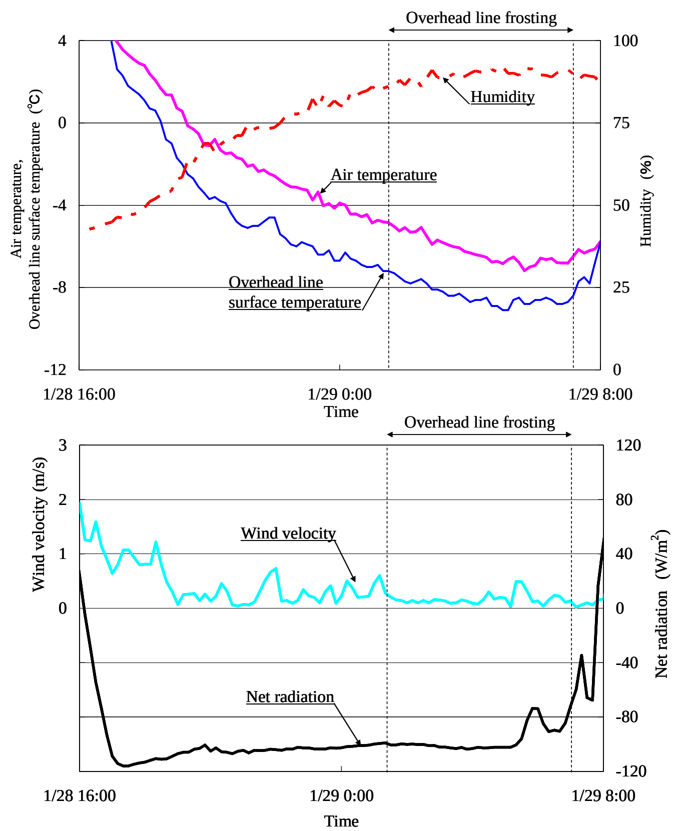

Fig. 4. Typical weather condition of overhead line frosting outbreak day

B. *Meteorological conditions of the overhead line frosting*

We mentioned characters of outbreak day of the overhead line frosting. Next, we analyzed each meteorological conditions of the overhead line frosting quantitatively. All data were used and we distinguished the conditions when the overhead line frosting occurred or not and plot both data in the following figures.

(1) Air temperature and humidity (Figure 5): It was clarified that air temperature was less than 0.5°C when the overhead line frosting occurred. Humidity was more than 90% when temperature was 0°C, however temperature decreased to around -5°C, the humidity of outbreak the frosting was from 85 to 90%. It was clarified that the humidity that the frosting occurred tended to decrease with decreasing temperature.

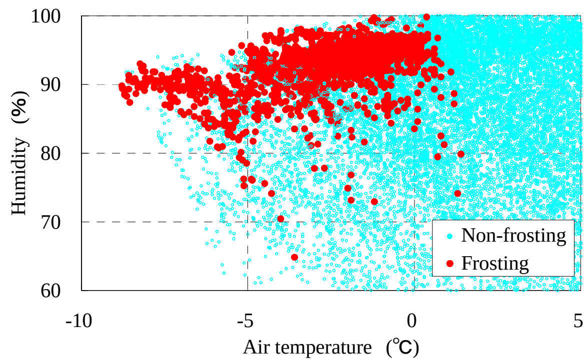

Fig. 5. Relationship between air temperature and humidity

(2) Air temperature and wind velocity (Figure 6): It was clarified that wind velocity was less than 1m/s when the frosting occurred.

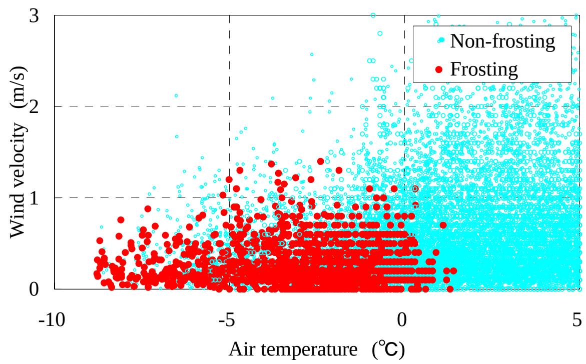

Fig. 6. Relationship between air temperature and wind velocity

(3) Air temperature and net radiation (Figure 7): It was clarified that net radiation at the time of the frosting outbreak was less than -70W/m^2. From the value of this net radiation, it was fine day as for the night weather at the time of the frost outbreak and seemed that a typical radiational cooling was occurred.

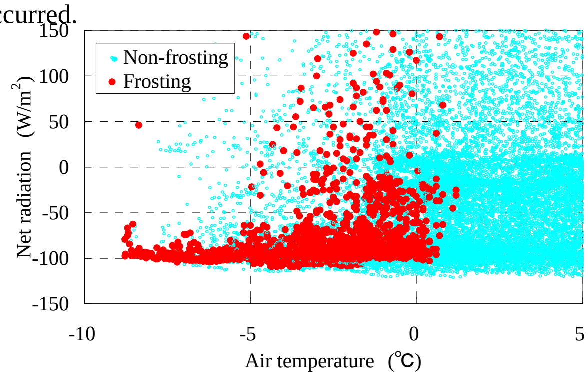

Fig. 7. Relationship between air temperature and net radiation

(4) Air temperature and the overhead line surface temperature (Figure 8): Overhead line surface temperature was less than 0°C and about 1-3°C lower than air temperature at the time of the frosting outbreak. Such temperature difference between air temperature and the surface temperature was mainly affected by the net radiation because wind velocity is small.

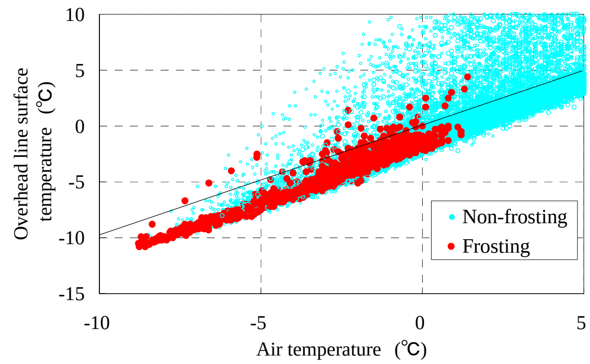

Fig. 8. Relationship between air temperature and overhead line surface temperature. Solid line shows that air temperature is equal to the overhead line surface temperature.

In addition, we can see scattered data in figure 5-8. We observed the frosting after sunrise when air temperature, the surface temperature, and net radiation increased and humidity decreased, and it seems that these data cause the scattering.

As these results, it was clarified meteorological conditions of the overhead line frosting; (a)air temperature is less than 0.5°C, (b)humidity is more than 80%, (c)wind velocity is less than 1m/s, (d)net radiation is between -120~ -70W/m^2, (e)overhead line surface temperature is less than 0°C and 1-3°C lower than air temperature.

IV. Discussion

When we consider the mechanism of the frost outbreak, it is important that movement of water vapor in atmosphere. IT seems that the surface temperature of overhead line reaches the frost point under the influence of the radiational cooling, and water vapor condenses onto the overhead line surface. Therefore, we calculated the water vapor condensation and frost point temperature from temperature and humidity using following expressions [1].

$$e = e_{SAT} \times RH \div 100 \qquad (1)$$

$$a = 2.167 \frac{e}{T + 273} \qquad (2)$$

Here, e (Pa) is water vapor pressure at a certain temperature T (K), e_{SAT} (Pa) is saturated water vapor pressure at a certain temperature T (K), as for saturation steam pressure at the age of the temperature, RH (%) is humidity, and a (g/m^3) is water vapor condensation.

For an example as 28-29th January 2006 (same as figure 4), time changes of overhead line surface temperature, frost point temperature, humidity and water vapor condensation were shown in figure 9. We can see that the time when overhead line frosting observed (time between dashed lines) agrees with a time period when the overhead line surface temperature was less than frost point temperature (red parts). This shows that super-saturated water vapor is included in air in the neighborhood of overhead line surface and then it was condensed on the overhead line surface. This tendency was similar at other overhead line frosting outbreak day.

One more characteristic thing on the frost outbreak day is that calculated water vapor condensation is almost same value through a night when the frosting outbreak day.

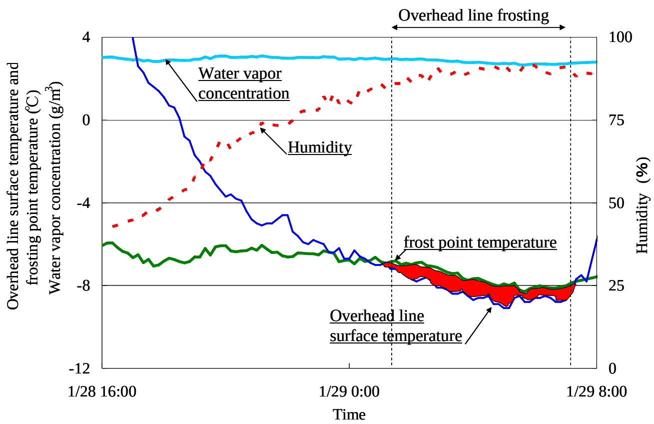

Fig. 9. Time change of overhead line surface temperature, frost point temperature, humidity, water vapor concentration. Frost point temperature and water vapor concentration are touched up on fig. 4.

V. Conclusion

We observed overhead line frosting and analyzed meteorological elements when occurred. As a result, it was ascertained that probability of the frosting outbreak was high when the following conditions occurred at the same time: air temperature was less than 0.5°C, humidity was more than 80%, wind velocity was less than 1m/s and net radiation was -120~ -70W/m^2. This was why the water vapor concentration was supersaturated in the neighborhood of the overhead line surface.

VI. References

[1] J. Kondo, *Atmospheric Science near the Ground Surface* , vol. I. University of Tokyo Press: 2000, p. 3.