THE MODELING OF ICE ACCRETION ON TRANSMISSION LINE AT HUANJIALING

Wu Suliang, Jiang Chuangye, Sun Xian, Wang Qi, Fan Jianxun
Shaanxi Provincial Climate Center
Xi'an China
*Email: wusuliang@sohu.com

Abstract: According to ice accretion mechanism, an ice accretion mass model is built. It is supposed that when temperature is lower than a criterion and humidity is above another criterion, ice is increasing, the increment is proportional to water vapor density, and the wind speed vertical to conductor. When humidity is under the criterion or temperature is above its criterion ice is decreasing. The amount is proportional to air temperature difference and the wind speed vertical to conductor. The ice weight takes 0 when the sum below 0. It shows that simulated results are much significant (P<0.001) and the main icing process can be simulated properly.

1. INTRODUCTION

The phenomena that glaze, rime attached on conductor or the wet snow frozen on conductor is called wire icing [1].

The observatory is built at Huajialing, a place located in southeast of Tongwei County, Gansu Province. The icing is observed at 02, 08, 14, 20 Beijing Time each day. The contents are diameters and thickness of icing, meteorological elements. The masses are measured at 08:00 each day.

By the physical ice accretion model [2], supposing physical quantities not change with time and neglecting the dropping speed of water droplet, the icing mass P can be expressed as

$$P = \beta\, E\, \Phi\, W\, \tau\, \upsilon \sin\theta \qquad (1)$$

Where

β freeze coefficient

E freeze ratio

Φ conductor diameter

W liquid water per unit volume

υ wind speed

θ angle between wind direction and conductor

τ time.

It also can be written as

$$P = c\, \upsilon\, \tau \sin\theta \qquad (2)$$

In (2) $c = \beta\, E\, \Phi\, W$ (3)

In fact relative humidity is a restrict factor. When relative humidity is beyond a criterion, icing grows, otherwise it decreases. In addition, the icing melting should be considered too. Considering characteristic above, the adapted model and restrict conditions are

If $t < t_c$,

$$P_a = b\, V_d\, \upsilon\, \tau \sin\theta\, (u-u_c) \qquad (4)$$

If $t \geqq t_c$, ice melting

$$P_c = b\, c_e\, \upsilon\, \tau \sin\theta\ \ (t-t_c) \qquad (5)$$

Total $P = P_a + P_c \quad p > 0$ (6)

$P = 0 \quad p < 0$

Where

V_d water vapor density

τ taken 1 hour.

2. RESULTS AND DISCUSSION

Basis on the simulated model, the 11 squares of correlation coefficients of the simulated icing masses on the wires are bigger than 0.3, and all of them are significant (P<0.001). The main icing process can be simulated properly.

The icing temperature criterions differ from wire diameters, heights and direction. At the 10m height, all that are －0.1℃, and they are －4.7℃ ~ －5.0℃ at 2m height. At 5m height, thresholds of the north south wires are －0.1 ℃ and －0.2℃, and that of the east west wires are －3.25 ℃ or －4.28℃.

The simulated results are significant, but it not good enough. It will be improved by using vertical distribution of meteorological elements and drops. As the model is built only on the icing process data of Huajialing, it may not be suitable to the others.

3. CONCLUSION

On average, the east west wires icing need more humid condition to south north, and so are the thin wires. The icing temperature criterion of high wires is higher than that of lower wire.

4. REFERENCES

[1] China Meteorological Administration. Surface Meteorological Observation Specification [s]. Beijing: China Meteorologocal Press, 2003 (in Chinese)

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The modeling of ice accretion on transmission line at Huanjialing

Wu Suliang, Jiang Chuangye, Sun Xian, Wang Qi, Fan Jianxun
Shaanxi Provincial Climate Center
Xi'an China
wusuliang@sohu.com

***Abstract*—According to ice accretion mechanism, an ice accretion mass model is built. It is supposed that when temperature is lower than a criterion and humidity is above another criterion, ice is increasing, the increment is proportional to water vapor density, and the wind speed vertical to conductor. When humidity is under the criterion or temperature is above its criterion ice is decreasing. The amount is proportional to air temperature difference and the wind speed vertical to conductor. The ice weight takes 0 when the sum below 0. It shows that simulated results are much significant (P<0.001) and the main icing process can be simulated properly.**

Keywords- ice accretion; transmission line; mass; model; criterion

I. INTRODUCTION

The phenomena that glaze, rime attached on conductor or the wet snow frozen on conductor is called wire icing [1]. The wire icing may cause serious damages. From the second ten days of January 2008 to the second ten days of February, there are extreme disaster weathers with continuous low temperature, snow and sleet in large scale for long time, which caused the loss more than 150 billion RMB[2]. The studies of wire icing include observatory [3], modeling [4], icing load forecast [5] etc, and refer to icing thickness, height, conductor diameter, elevation, terrain, microclimate, the zoning of icing thickness. The measures for lightening icing damage usually are avoiding the heavy icing district, using reasonable standard and design parameters, using de-icing technology [6].

The content of wire icing observatory include the diameter, thickness, mass, wire direction, the starting and ending time, meteorological elements, droplet spectrum etc. Basis on the ice accretion model [7], a model of icing mass is built, in which temperature and relative humid are taken as criterion. The ice accretion mass can be calculated by temperature, wind direction, wind speed, relative humidity and water vapor. It can be taken as reference model to estimate ice accretion for others.

II. DATA

A. The observation

The observatory is built at Huajialing, a place located in southeast of Tongwei County, Gansu Province (figure 1).

Figure 1. The observation tower and the field of Huajialing Weather Station

It is at 105°east and 35.37°. It situates in hilly-gully region of Loess Plateau, and belongs to the transition region of warm temperature zone and semi-arid zone. The highest elevation in it is 2450m.

A 10m icing observation tower is built in Huajialing Weather Station. The tower consists of 2 shelves: one is north south (NS), another is east west (EW). The 2 shelves are connected together. At the height of 10m, 5m, 2m, conductors with a diameter of 27mm and 19mm are installed in 2 directions. The data from January 2007 to March 2009 are gotten.

The icing is observed at 02, 08, 14, 20 Beijing Time each day. The contents are diameters and thickness of icing, meteorological elements. The masses are measured at 08:00 each day. In each icing period, the maximum icing mass and its diameter, thickness, accompanied meteorological element must be recorded by synoptic situation.

The meteorological data are temperature, wind direction, wind speed, relative humid, water vapor and precipitation.

Huajialing Weather Station has been found for decades, and its field and instruments are set up by "Surface Meteorological Observation Specification". The tower is located to northwest of the field in the station. There are a small house 10m away from the west and another house 8m away from the east of the tower. To the southeast of tower, several pines are 5m to 8m high.

B. Data

The times of the observation of icing sizes are 383, and that of the icing mass not included maximum are 257.

During the observation, the meteorological elements are showed in figure 2.

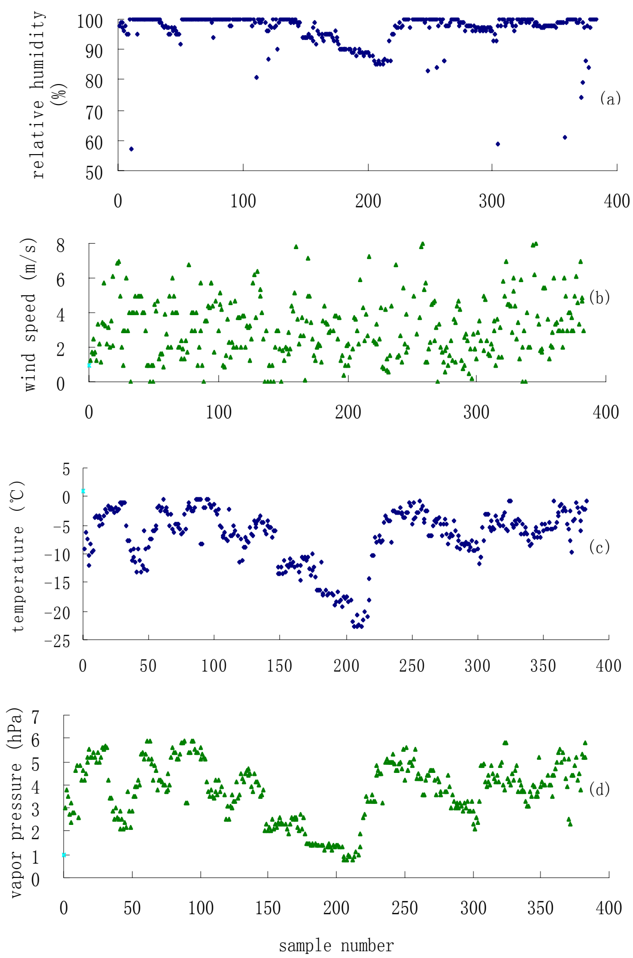

Figure 2. The meteorological elements in icing period

The relative humidity ranges from 57% to 100%, and has average of 97%. The wind speeds are from 0 to 12.9 m/s, and the mean is 3.3m/s. The temperatures vary from —0.4℃ to —22.8℃, and the average temperature is —6.9℃. The water vapors are from 0.8 hPa to 5.9hPa, and the average is 3.8 hPa. The change of water vapor is similar of that of temperature.

III. THE ASIMULATION OF ICE ACCRETION ON WIRE

A. Simulation methods

By the physical ice accretion model [7], supposing physical quantities not change with time and neglecting the dropping speed of water droplet, the icing mass P can be expressed as

$$P = \beta E \Phi W \tau \upsilon \sin\theta \tag{1}$$

Where

β freeze coefficient

E freeze ratio

Φ conductor diameter

W liquid water per unit volume

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It also can be written as

$$P = c \upsilon \tau \sin\theta \tag{2}$$

In (2)

$$c = \beta E \Phi W \tag{3}$$

In fact relative humidity is a restrict factor. When relative humidity is beyond a criterion, icing grows, otherwise it decreases. In addition, the icing melting should be considered too. Considering characteristic above, the adapted model and restrict conditions are

If $t < t_c$,

$$P_a = b V_d \upsilon \tau \sin\theta (u - u_c) \tag{4}$$

If $t \geqq t_c$, ice melting

$$P_c = b c_e \upsilon \tau \sin\theta \quad (t - t_c) \tag{5}$$

Total $P = P_a + P_c \quad p > 0$ (6)

$P = 0 \quad p < 0$

Where

V_d water vapor density

τ taken 1 hour.

B. Determination of the parameters

The ranges of the parameters are confined below after several times' test calculations. They are

Temperature: t_c: —5.0℃~0℃

Relative humidity u_c: 60%~100%

Ratio of accreting and melting c_e: 0~200.

C. Disposal of data

The lacked mass data can be gotten by diameter and thickness of the icing, and the density near it. As the time when maximum mass appeared is not recorded, it is not taken into account. The maximum mass is usually close to one of mass data in a day.

D. Estimation of parameters

In the modeling, the mass at one time is taken as Y, the total mass modeled 6 hour ago and the increment between the 6 hours are taken as X, so the parameters can be estimated in its equation. Using iterative and searching calculating, that having the least residual will be the parameters of the model. The steps are

First, 3000 values are interpolated at equal interval in the range of the first parameter, while the mean values of two others are used. By comparing, the one with least residual will be taken as initial best parameter of first factor.

Next, second initial best parameter can be gotten by using the first initial best parameter and the mean value of third parameter.

Then, the third initial best parameter can be gotten with first and second initial best parameters.

Repeating the steps above, the parameters of the model will be gained after the result tended stable. The icing mass can be estimated by the model.

E. Simulation results

The parameters calculated by the method are showed in table 1.

TABLE I. CRITERIONS AND PARAMETERS CALCULATED IN THE MODEL

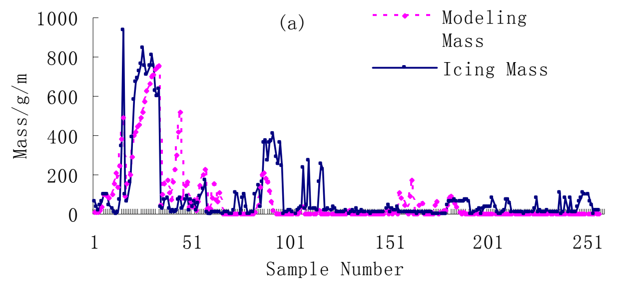
Height (m)	Diameter (mm)	Wire direction	t_c	u_c	c_e	b	R2
10	27	NS	-0.1	70.6	8900	0.000267	0.6677
10	27	EW	-0.1	60.02	7880	0.000234	0.6840
5	27	NS	-0.2	67.26	5005	7.62E-05	0.3840
5	27	EW	-3.25	95.4	15000	0.001402	0.5206
2	27	NS	-5.0	60.02	5005	2.69E-05	0.4520
2	27	EW	-4.7	85.42	5675	9.4E-05	0.3356
10	19	NS	-0.1	81.9	5005	0.000375	0.5539
10	19	EW	-0.1	95.36	12040	0.002627	0.7797
5	19	NS	-0.1	66.82	5005	6.71E-05	0.3399
5	19	EW	-4.28	95.14	7555	0.001336	0.086
2	19	NS	-5.0	60.02	5005	1.95E-05	0.3873
2	19	EW	-4.7	88.44	5005	0.000102	0.3026

IV. CONCLUSION

Basis on the classical icing the theory, the 11 squares of correlation coefficients of the simulated icing masses on the wires are bigger than 0.3, and all of them are much significant ($P<0.001$). The main icing process can be simulated properly. The first one simulated are showed in figure 3.

The icing temperature thresholds differ from wire diameters, heights and direction. At the 10m height, all that are −0.1℃, and they are −4.7℃ ~ −5.0℃ at 2m height. At 5m height, thresholds of the north south wires are −0.1℃ and −0.2℃, and that of the east west wires are −3.25℃ or −4.28℃. It means that, high wires need higher temperature but the lower need colds. At 5m, that the east west wires need more cold condition may be caused by solar radiation though it is overcast.

On average, the east west wires icing need more humid condition to south north, and so are the thin wires.



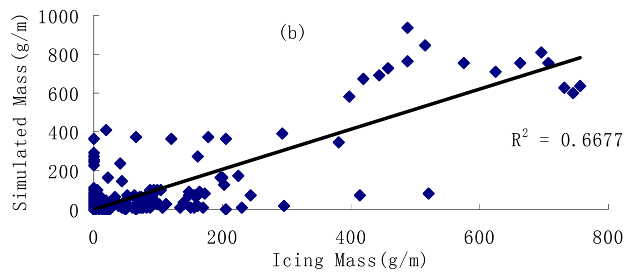


Figure 3. The simulated ice accretion masses and relative coefficient

The simulated results are significant, but it not good enough. It will be improved by using vertical distribution of meteorological elements and drops.

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