Research On Ice-Covering Alarming Model For Transmission-Line Based On The Multivariate Regression Of Meteorological Factors

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***Abstract*—The ice-covering degree has a close relationship with the meteorological factors, which mainly include temperature that is cold enough to frozen, high humidity and adaptive wind velocity. Considering that the current growing formulas of transmission line's ice-covering are mostly conducted by theoretical way and it is difficult to measure those various complex physical factors, the transmission line's icing experiments were carried out in the artificial climate laboratory. Through simulating the certain environment, the transmission line's actual icing data for different diameters are acquired under various meteorological conditions. The growing characteristic of transmission line's ice-covering thickness under the influence of environmental parameters such as ambient temperature and rain fall as well as wind speed were analyzed, and we found them obviously non-linear related. Furthermore, the transmission line's actual ice-covering growing model for precaution system based on the method of multivariate regression was set up by using the Hunan power grid's ice-covering data in 2008 and the experimental results. The results indicated that the model has advantages of convenient computation, measuring the input physical parameter easily and working out appropriate predicted value. Therefore it can improve the precautionary ability of the transmission line's ice-covering monitoring system.**

***Key word*：ice-covering growing experiment；meteorological factors；actual ice-covering growing model；Multivariate Regression**

I. INTRODUCTION

The ice-covering degree has a close relationship with the meteorological factors[1], which mainly include temperature that is cold enough to frozen, high humidity and adaptive wind velocity[2]. At present, some foreign experts and scholars made a variety of growing formula of ice coating, such as the glaze growth empirical formula by C. Kuoiwa; the conductor icing intensity empirical formula by H. H. Cohmathha; the ice density empirical formula by Macklin; the ice coating growth mode [3] by Imai, Lenhard, Goodwin, Makkonen and so on. These formulas were generally deduced from theoretical points in order to get facilitate solution, so they often overlook the role of some factors, especially the situation of the wire was electrified, and the calculated results are quite different from the actual results.

II. ICE GROWTH TESTING

A. Test content

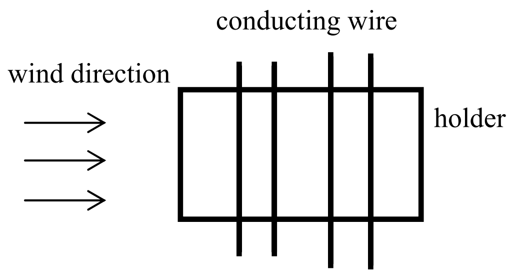

Figure 1: Layout of the wire

Experiments were carried out in the artificial climate laboratory, the experimental conditions can be found in the literature. Two wires (LGJ-300 and LGJ-400) were placed as shown in figure 1 during the experiment:

During the experiments, we changed the rainfall and temperatures respectively (with wind speed increase, wind become asymmetry, so we took the wind speed about 1m/s)

B. test data analysis

The results shown in figure 2 by scatter diagram, in which different colors distinguished different ice thickness level.

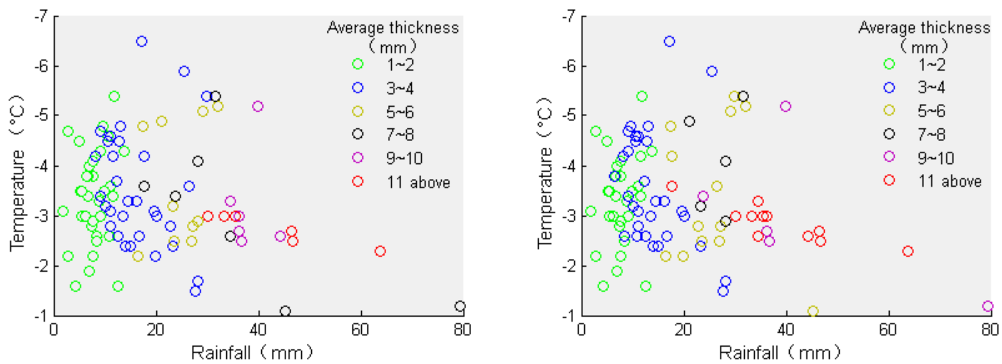

Figure 2: Relationship between temperature and rainfall at different ice thickness degree(LGJ-300，400)

The average thickness of ice of LGJ-400 was greater than LGJ-300. It increases with the rainfall, but no significant relationship with the temperature. As the test cannot maintain a constant temperature, the temperature of the test data range is divided into five segments: -1 ℃ to -2 ℃, -2 ℃ to -3 ℃, -3 ℃ to -4 ℃, -4 ℃ to -5 ℃, -5 ℃ to -6 ℃. Fitting curves were shown in figure 4 with the MATLAB curve fitting tool.

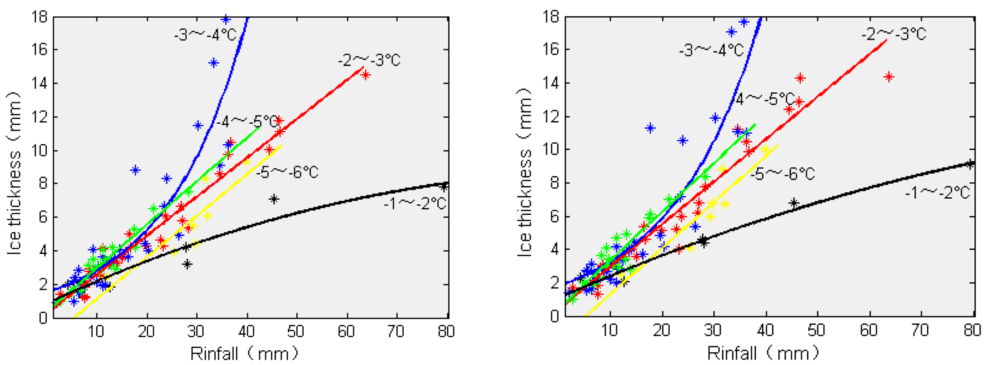

Figure 3: Ice thickness vs. rainfall at different temperature segments(LGJ-300，400)

In the chart, the thickness of ice and rainfall have linear relationship at - 2~-3°C, - 4~-5°C, - 5~-6°C, but they have the obvious nonlinear relationship at -1~-2°C, -3~-4°C. The figure shows the slope of the fitting curve increase as the temperature decreases, and reached the maximum at -3 ~ -4 ° C, then the slope decreases as the temperature increase.

III. The transmission line's actual ice-covering growing model for precaution system

A. The method of ice-covering growing model

According to the experimental data, there is no significant correlation between ice-thickness and single environmental factor around the wire. The method of ice-covering growing model based on the method of multivariate regression[4], because of its simple and great interpretational ability.

The multivariate linear regression model is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \mu \quad (1)$$

In the formula: $\beta_0, \beta_1, \beta_2, \ldots, \beta_k$ are the regression coefficients, μ is the random error.

Took the historical data into this equation, we got:

$$\begin{cases} Y_1 = \beta_0 + \beta_1 X_{11} + \beta_2 X_{21} + \cdots + \beta_k X_{k1} + \mu_1 \\ Y_2 = \beta_0 + \beta_1 X_{12} + \beta_2 X_{22} + \cdots + \beta_k X_{k2} + \mu_2 \\ \cdots\cdots \\ Y_n = \beta_0 + \beta_1 X_{1n} + \beta_2 X_{2n} + \cdots + \beta_k X_{kn} + \mu_n \end{cases} \quad (2)$$

Used the least square method to get the estimator of unknown parameters $\beta_0, \beta_1, \beta_2, \ldots, \beta_k$, then took them into equation (2), we got:

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 X_{1i} + \hat{\beta}_2 X_{2i} + \cdots + \hat{\beta}_k X_{kn} \quad (3)$$

Table 1 ice monitoring data of sample selection

Number	Station	Day 0：00～24：00	Wind speed m/s	Rainfall (mm)	Temperature (℃)	Ice thickness Δr(mm)
1	Gangai307	12～13	4	6. 3	-5	8
2	Wumin37	16	2	5. 1	-7	6. 8
3	Pingyang189	22	2	1. 8	-8	4. 6
4	Fuwai122	26	1	49. 4	-3. 7	5. 7
5	Fuwai122	27	1	14. 6	-7. 8	5. 7
6	Tianshang175	25	2	0. 7	-4. 9	6. 4
7	Tianshang175	19	2	14. 2	-1. 2	7
8	Pingyang277	22	4	0. 7	-3. 3	4. 6
9	Yanwan II	23	4	0. 2	-6. 1	6. 4

In this paper, we put wind speed as X1 rainfall as X2 temperature as X3 and Ice thickness as Y (Table 2) into formula 2), then we got:

y＝1.2412*X1+0.0815*X2-0.3950*X3 (4)

The maximum error of this formula is 2. 9mm by Tianshang line 175#.

B. the rule of precaution model

According to the scene-ice-covering situation, the rules of precaution model are as follows:

Table 2 rules of precaution

Ice thickness	Forecast temperature	Forecast rainfall	Forecast ice accretion	Propose measures
R<threshold**	T>0	Yes	Natural ice-melting	Natural ice-melting and attention to melting flashover
R< threshold	T>0	No	Natural ice-melting	Natural ice-melting and attention to melting flashover

R< threshold	T<0	Yes	growth thickness is less than the design	Strengthen the monitoring and de-icing preparations
R< threshold	T<0	No	No growth	Strengthen the monitoring
R> threshold	T>0	Yes	Natural ice-melting	Natural ice-melting and attention to melting flashover
R> threshold	T>0	No	Natural ice-melting	Natural ice-melting and attention to melting flashover
R> threshold	T<0	Yes	Growth	Melting ice immediately
R> threshold	T<0	No	No growth	Artificial removing ice

** Threshold is determined by the line type, such as LGJ-300 is10mm，LGJ-400 is 12mm.

IV. CONCLUSIONS

This paper analyzed the growth characteristics of transmission lines icing under the influence of climatic factors such as Temperature, rainfall and wind speed, and found non-linear relationship among them. Then we combined the results of experiments, worked out the model of the thickness of ice-growing. The results indicated that the model has advantages of convenient computation, measuring the input physical parameter easily and working out appropriate predicted value. Therefore, it can provide a theoretical basis for the prediction of transmission line's ice-covering [5].

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RESEARCH ON ICE-COVERING ALARMING MODEL FOR TRANSMISSION-LINE BASED ON THE MULTIVARIATE REGRESSION OF METEOROLOGICAL FACTORS

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The average thickness of ice of LGJ-400 was greater than LGJ-300. It increases with the rainfall, but no significant relationship with the temperature. As the test cannot maintain a constant temperature, the temperature of the test data range is divided into five segments: -1 ℃ to -2 ℃, -2 ℃ to -3 ℃, -3 ℃ to -4 ℃, -4 ℃ to -5 ℃, -5 ℃ to -6 ℃. Fitting curves were shown in figure 4 with the MATLAB curve fitting tool.

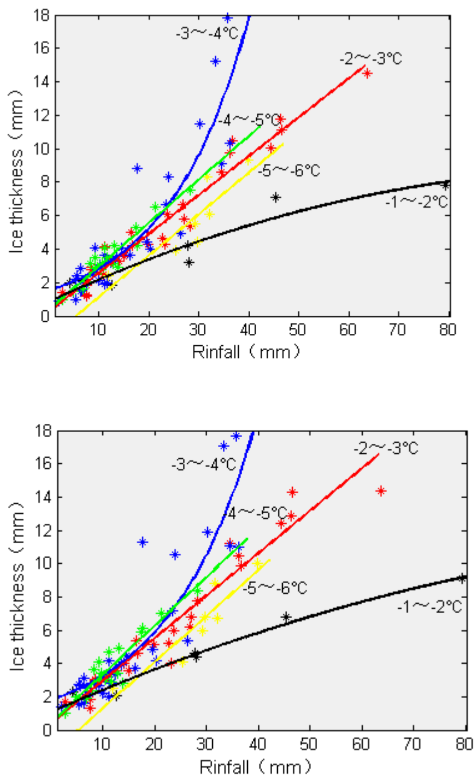

Figure 1 Ice thickness vs. rainfall at different temperature segments(LGJ-300，400)

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$$y = 1.2412*X1 + 0.0815*X2 - 0.3950*X3$$

3. CONCLUSION

The results indicated that the model has advantages of convenient computation, measuring the input physical parameter easily and working out appropriate predicted value.