A correction method for CRREL model to estimate ice-covered value on conductors

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Abstract: It is necessary for designing on transmission lines to select an effective ice-coated model to estimate the ice properties on conductors when ice observation data is deficient. With analysis of the existing numerical icing property models and tests for the domestic icing data, CRREL model is chosen to estimate the icing value and it is advantageous and effective in drawing ice-covered distribution mapping on transmission lines. Evaluating the weather recording data, 1-hour and 6-hour wind speed records are reliable to be used to simulate ice properties. With contrast the simulating results with icing records in observatories, a correction method is obtained to modify the simulating results to conform to reality. Using the correction method and choosing appropriate correction coefficients, results obtained by simulation and observation are fairly accordant and the simulated ice-covered distribution is similar with the observations.

Key words: ice-covered property, CRREL model, correction method, conductor, transmission line

I. INTRODUCTION

Icing on overhead transmission lines and towers can cause such serious problems as line breakage, tower failure and flashover. So it affects badly the running of power grids in the world. The design values of icing thickness are very important for the transmission lines to resist the ice load. Therefore it is necessary to predict and .analyze the ice accretion characteristics accurately for transmission lines.

There are several ice models to be used at present. But the results predicted by these models can usually bring large errors for sleet icing as the same meteorological conditions. The reasons are as follow.

(1) There are differences in the detailed hypothesis for the ice physical models. For example, define the ice accretion process as dry growth or wet growth, assume the ice accretion shape as uniform or non-uniform.

(2) It is different to choose the empirical data, such as the relation between water content in air and precipitation rate, and the law of wind velocity changed with altitude.

(3) There are some differences to select necessary meteorological parameters. For example, some models need wind velocity, air humidity, precipitation rate, air temperature, but some other models need only 2-3 parameters presented above.

In this paper, an effective CRREL mode is selected by comparing these existing ice computational methods. And a correction method is obtained to modify the simulating results to conform to reality when the observation data is not enough. Finally, a practical example is presented to illustrate the applicability of the calculation method.

II. ICE THICKNESS COMPUTATIONAL MODELS

Imai's model [1] shows that ice accretion process is wet growth and ice intensity depends on heat transmission on conductor surface. But the constant to express heat transmission on ice surface is difficult to be obtained for this model and the assumption of wet growth is false when the temperature is less than -5 ℃. In addition, the icicle created by water flow on conductor is not be considered when temperature is close to 0 ℃.

Lenhard's model [2] is a simple expression to calculate ice weight. This model shows that ice value is only related with precipitation and neglects other factors such as wind velocity, temperature and humidity. But other researches show that correlation between ice accretion and precipitation amount is very lower [2-4].

Goodwin [5] model defines ice accretion as a dry growth process. But this model sometimes is false because it neglect water density [6,7].

The model deduced by Chain and Castonguay[8] is also regard the ice accretion as a dry growth process and defines the ice shape as ellipse. But the ice thickness obtained by this model depends on the special correction coefficient, and the value of correction coefficient is defined by ice thickness. So this model is false in conception.

Makkonen[9] gives a numerical method to simulate the ice accretion process. The icicle growth is considered firstly in this method.

The CRREL model established by Jones [10] is an effective and practical sleet ice computational model. This model includes two physical items. The fist is ice accretion caused by vertical rainfall. The second is ice accretion caused by horizontal wind flow. The expression is

$$R_{eq} = \frac{N}{\rho_i \pi}\left[\left(P\rho_0\right)^2 + \left(3.6VW\right)^2\right]^{1/2} \qquad (1)$$

where N is sleet time (hour), P is rain factor (mm/hour),V is wind velocity, ρ_i is ice density, W is liquid-water content, $W = 0.067P^{0.846}$.

CRREL model is obtained based on summarizing the existing other models and is a development from traditional ice models. It uses completely meteorological observation data and expresses the main physical process of ice accretion. And it is simple for calculation and solution. With the practical conditions, results by CRREL model are less than these by Chainé and Castonguay's model, because the data of wind velocity and precipitation is obtained by wind tunnel test which is much different with the actual freezing rain. And the results by CRREL model are closed with the Makkonen model. CRREL model is more effective to computer ice accretion thickness on transmission lines. And it has been used to draw ice distribution map in USA.

III. CORRECTION METHOD FOR CRREL MODEL

Although CRREL model is successful to be used in USA, the simulating results have systematic error when this model is to be used other areas and the initial meteorological observation data is not enough. For example, in China the precipitation is obtained by interpolating average based on 6 hours precipitation amount, which is difference with 1 hour extension observation. So the simulated results need to be corrected systematically in order to reduce simulating errors. The kernel of correction method is to select proper correction coefficient based on statistical analysis.

In this paper we define the correction formula as follow

$$R_v = \alpha R_m + S \quad (R_m \geqslant 10\text{mm}) \tag{2}$$

where R_v is the standard ice thickness obtained by correction model, R_m is the standard ice thickness obtained by non-corrected model, α is correction coefficient, S is model system deviation correction coefficient.

The range of model correction value should be greater than or equal to 10mm, which can avoid new error by model correction when simulated data is less than discrete range.

IV. ANALYSIS EXAMPLE

HuNan province is one of the most severe ice areas for transmission lines in China. So as an example, select the major ice observation data in HuNan province as simulating objects to validate the method proposed in this paper. Firstly, choose the effective data which include 1 hour wind velocity\direction and 6 hours precipitation. Secondly, calculate the standard ice thickness on January and February in 2008 in Hunan province using the CRREL model. Fig.1 gives the contrast on observed standard ice thickness and simulated standard ice thickness by CRREL model. The results show that general trend from simulating model is fit well with the observation, but simulating values are larger than observation. The reason is that observation data precision is not enough, for example the precipitation is obtained by 6 hours interpolation, not by 1 hour interpolation. So the correction method is used to calculate more accurate ice thickness.

Fig.2 gives contrast on observed standard ice thickness and simulated standard ice thickness by correction model with different correction coefficients 0.90, 0.85, 0.80, 0.75, 0.70, 0.65, 0.60. Table 1 gives the characteristics of simulation results with different correction coefficients. Firstly, the fitting curve slope is approximate 1 which proves that correction results reproduce the observation data. And the correction result is most accurate when the correction coefficient is equal to 0.85.

Secondly, standard deviations present the dispersions of correction results and the dispersions are lower when correction coefficients choose 0.9, 0.85, 0.80 and 0.75.

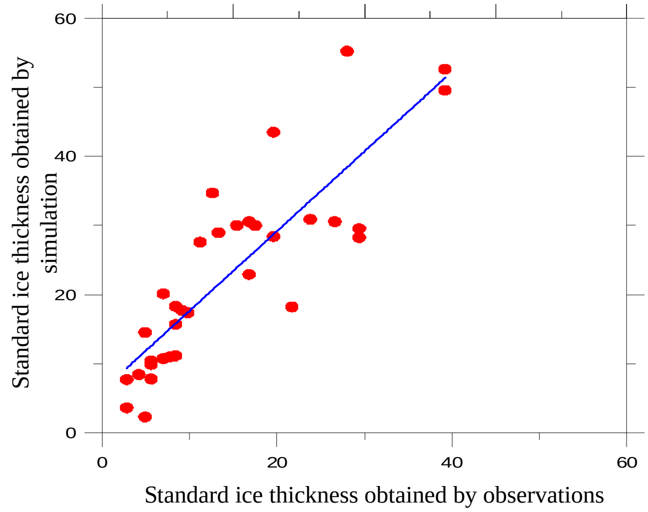
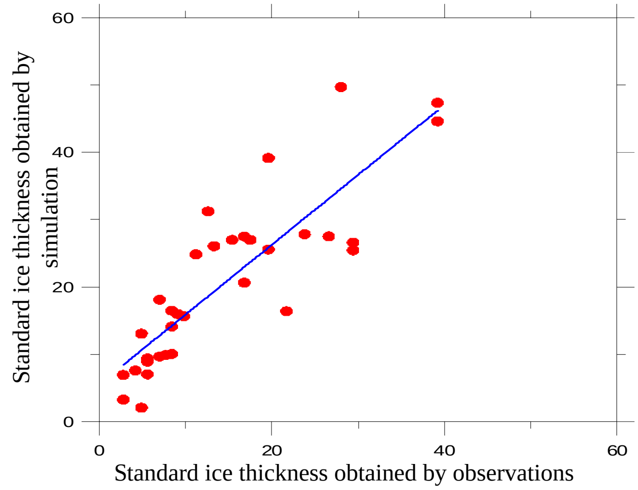
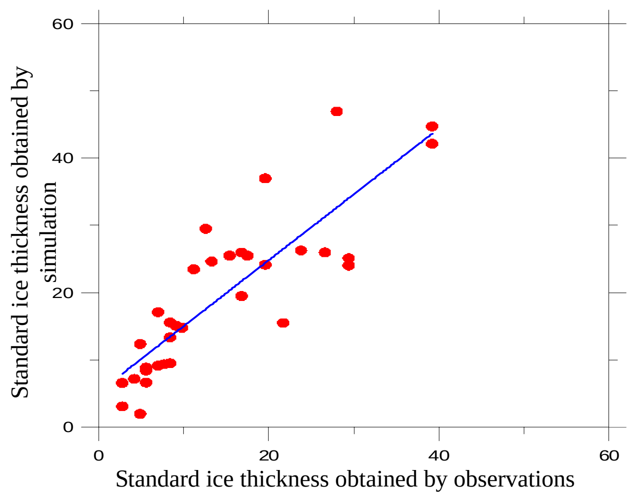


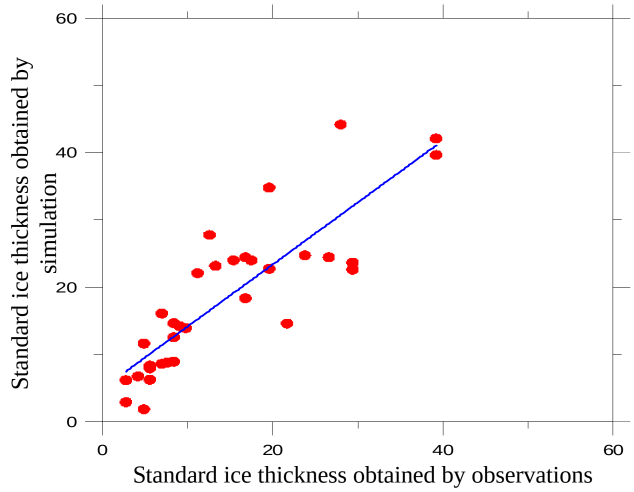
Fig.1 Contrast on observed standard ice thickness and simulated standard ice thickness by CRREL model



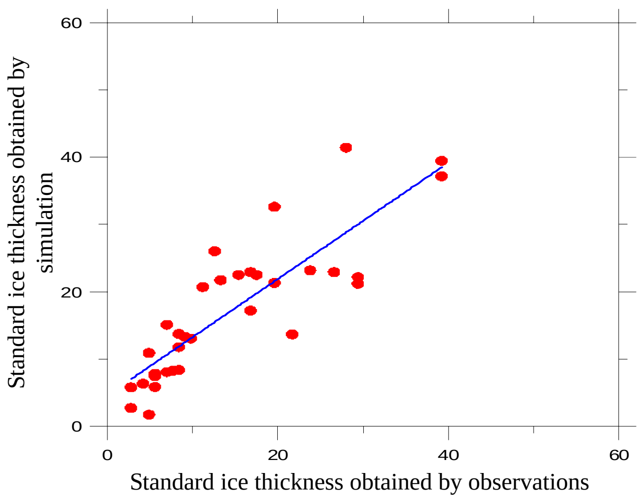
(a) Correction coefficient is 0.90



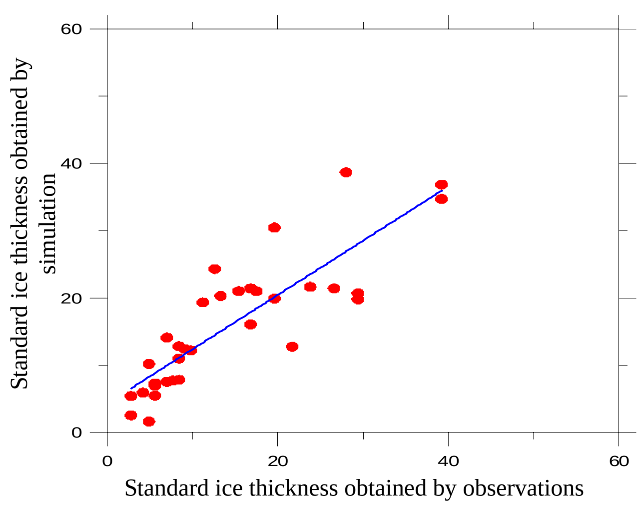
(b) Correction coefficient is 0.85



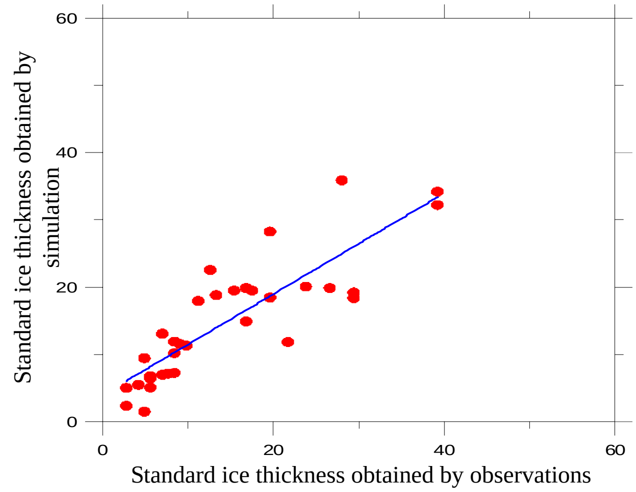
(c) Correction coefficient is 0.80



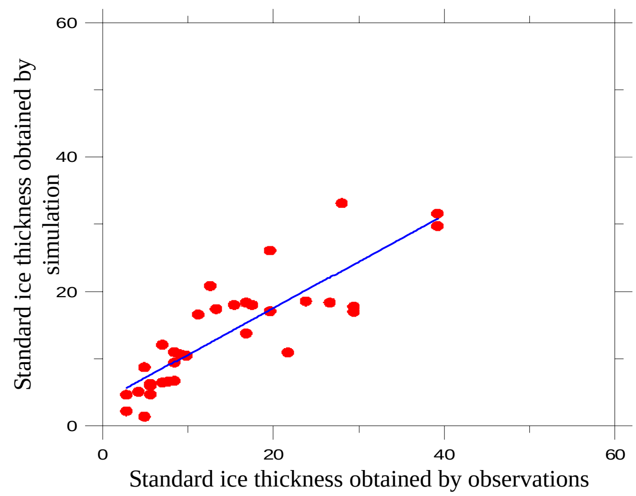
(d) Correction coefficient is 0.75



(e) Correction coefficient is 0.70



(f) Correction coefficient is 0.65



(g) Correction coefficient is 0.60

Fig.2 Contrast on observed standard ice thickness and simulated standard ice thickness by correction model

Table1 Results characteristics by correction method

Correction coefficient	Fitting curve slope	Standard deviation of correction results（mm）	Variance standard deviation of correction results（mm）
0. 90	1. 03	12. 41	6. 46
0. 85	0. 98	11. 72	6. 09
0. 80	0. 92	11. 03	5. 78
0. 75	0. 86	10. 34	5. 55
0. 70	0. 81	20. 82	5. 39
0. 65	0. 75	19. 51	5. 31
0. 60	0. 69	18. 20	5. 33

Thirdly, variance standard deviations present systematic dispersions between correction results and differential of observation results. The results show that variance standard deviations have the approximate results with different correction coefficients and the systematic deviation can be choose as 6mm and correction value is -6mm.

Finally, with summary analysis 0.85 is the most optimal correction coefficient. The results show that simulating results obtained by correction model are more closed with the observation values. The observation average result is 14.62mm and the average result obtained by correction model is 14.80mm. The standard deviation for observation data is 10.22mm and the standard deviation for results calculated by correction is 10.43mm. The observation maximum value is 39.20mm and the maximum value obtained by correction model is 40.92mm.

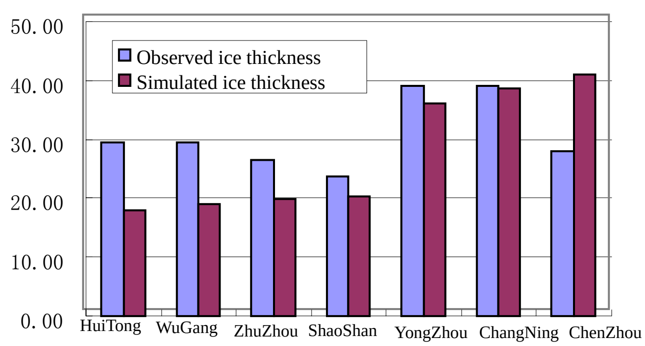


Fig.3 Contrast on observed standard ice thickness and simulated standard ice thickness at representative stations

Fig.3 presents the contrast between observed standard ice thickness and simulating standard ice thickness at representative stations in which the observation results are all greater than 20mm in Hunan province. The results show that the simulating ice thickness from ShaoShan, YongZhou, ChangNing and Zhuzhou areas is very closed to the observation standard ice thickness. The simulation value for ChenZhou is 40.92mm which is larger than observations, because the observation stations are usually installed lower altitude areas, but ice accretion on mountains is more severe than on plain. Actually, it has already observed more acute ice greater than 40mm on transmission lines in mountains in ChenZhou. So this simulation value is valuable.

V. CONCLUSIONS

The study described here is to obtain a correction method for CRREL model to estimate ice-covered value on transmission lines. And the method is used to simulate ice accretion thickness on transmission lines in HuNan province in China. The main concluding remarks are given as follow:

(1)Analyze the existing ice thickness computional models which include Imai model, Lenhard model, Goodwin model, Chainé and Castonguay model, Makkonen model and CRREL model. CRREL model is more effective and accurate as simulation methods by comparing their characteristics and physical mechanism.

(2) Enough meteorological data is the base to analyze ice accretion characteristics. When choose 1 hour wind velocity and 6 hour rainfall data which are the more reliable recently, the simulation results have error by the CRREL model. So a correction method is presented by introducing a correction coefficient. The correction coefficient is defined by specific observation data.

（3）The results obtained by correction model is fit well with the observation when it is used to calculate ice value in HuNan as an example. And the most optimal correction coefficient 0.85 is obtained.

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