Analyze on the Ice-covering Recurrence Interval of Power Grid based on PSO optimization

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***Abstract*—Hunan has suffered great loss in the ice disaster of 2008, thousands of Transmission tower has been damaged in that winter. In the reconstruction period, it's important to improve the anti-ice ability of these transmission lines and towers. Calculation of ice-covering recurrence interval for power grid is of great significance for anti-ice design of the transmission line. As a common probability distribution curve，the P-III distribution can be used to analyze the Recurrence Interval of power grid. In concern of that the P-III distribution has the disadvantages of uncertain distribution parameters, which is easy to be disturbed by manual factors, the curve fitting method based on particle swarm optimization (PSO) is proposed in this paper. PSO is an effective algorithm that can accomplish parameters calibration rapidly, and find out the global optimal solution of parameters accurately. Besides, this improved method is easy to be realized with convenient calculation process and it has also been taken to analyze the power grid recurrence interval. Through calculating and analyzing ice-covering recurrence period based on the 57 years observation data of icing days of 97 weather stations distributed all over Hunan area, Ice-covering days for recurrence period of 15 years, 30 years, 50 years and 100 years of these stations are calculated, Icing days distributing maps of Hunan province are painted The result shows that the number of icing day recurrence period of 50 years for Chenzhou and Hengyang regions is more than twenty days, these two regions are severe icing area in Hunan province. This new method has mature calculation methodology and has greatly intensified the exact property of estimation of parameter means and decreased the human effects, thus can obtain more stable calculation result, which is definitely more accurate. Therefore, it can offer much useful guidance for the analysis of ice-covering law and early warning of icing disaster.**

Key words— P-III type distribution； optimal curve fitting method based on PSO； Ice-covering recurrence interval

I. INTRODUCTION

Hunan has suffered great loss in the icing disaster of 2008, thousands of Transmission tower has been damaged in that winter. In the reconstruction period after disaster[1], the designers begin to consider taking reasonable anti-icing designing standard to make design for the transmission lines[2]. It's of great meaning to improve the icing-prevention ability of these transmission lines and towers accordingly[3]. To achieve designing appropriate anti-icing thickness for different areas, it's important to make acquaint for the recurrence interval of the crucial areas.

To calculation of ice-covering recurrence interval for power grid is of great significance for anti-ice design of the transmission line. As a common probability distribution curve，the P-III distribution can be used to analyze the Recurrence Interval of power grid[4]. In concern of that the P-III distribution has the disadvantages of uncertain distribution parameters[5], which is easy to be disturbed by manual factors, the curve fitting method based on particle swarm optimization (PSO) is proposed in this paper. PSO is an effective algorithm that can accomplish parameters calibration rapidly, and find out the global optimal solution of parameters accurately.

The ice-covering recurrence interval is the frequency that the disaster outbreaks. In this paper, we take the

average icing day number for the basis data to calculate the ice-covering recurrence interval. And in the field of hydrology, the experts always take the Person-III distribution to draw the frequency distribution curve，in which the statistic parameter can firstly be established through moments method and then be confirmed by curve-fitting method. In this way, we can obtain the recurrence interval of the disasters.

When taking the P-III distribution to confirm the frequency distribution model, the crucial step is to establish the parameter of the model concisely and reasonably. However, the fitting result using moments method always has large difference with the actual curve , and meanwhile the curve fitting method doesn't have a certain fitting optical standard, and in the fitting process, it's often with great blindness and uncertainty, which has been greatly affected by the personal experience, and can't achieve the purpose of optimization.

Therefore, the optimal curve-fitting method has been proposed, which is to search for the statistic parameters that can best fit the calculation curve with the actual one under the certain criteria (i.e. line objective function),. In this method, the mechanism has the certain fitting rule, in order to avoid the arbitrariness of the traditional estimation method and better satisfy the requirements of frequency analysis.

The particle swarm optimization (PSO) algorithm has been proposed by Kennedy and Eberhart in 1995. As a new global stochastic optimization algorithm, PSO has been widely used in engineering optimization field for the algorithm has many advantages such as with the unique searching mechanism, superior convergence and simple computer implementation [7].

Based on the analysis of the curve-fitting method, we use the PSO algorithm to make optimization for the parameters of the Person type III for the frequency calculation taken the average ice-covering day of Hunan province as the computation objects in order to improve the speed and quality of parameter optimization. Through calculation, we obtain the average ice-covering recurrence interval and also draw the ice-covering distribution figure based on ice-covering recurrence interval of each area, which has offer greatly guidance for the anti-icing work.

II. PERSON TYPE III DISTRIBUTIOIN

Supposed X1，X2，…Xn are the ice-covering day for each year. Here, the maximum icing day is x, the least one is 0. These time series can be seen to be presented as the Person type-III[6], the distribution function is as followed:

$$F(\chi_p) = P(x < \chi_p) = \frac{\beta^a}{\Gamma(\alpha)} \int_{-\infty}^{\chi_p} x^{\alpha-1} e^{-\beta x} dx \qquad (1)$$

Here, $\Gamma(\alpha)$ is gamma function，χ_p is the designed value, and the designed frequency will satisfy the condition:

$$P = P(x \geq \chi_p) = 1 - F(\chi_p) \qquad (2)$$

$$\alpha = 4/C_s^2, \quad \beta = 2/\bar{x} C_v C_s \qquad (3)$$

C_v is the deviation coefficient，C_s is the coefficient of skewness. Therefore, when $\bar{x}$，C_v，C_s have been confirmed through data samples, the P-III distribution has been completely confirmed. The crucial step to calculate the icing recurrence interval is to confirm C_v and. C_s.

III. CRITERIA FOR CURVE-FITTING

In the optimization process, we take the criteria for the curve-fitting is to make the following objective function F to be the minimum in order to search the optimal parameter, and the formula is as followed:

$$\min F = \sum_{i=1}^{n} \left| \chi_i - \chi_p \right|^k \qquad (1)$$

In the formula, n is the sample length, χ_i is the actual value in the sample, χ_p is the value on the curve which has the same frequency with χ_i，k is the index of the exponential function，when k = 2, it's the least-square method, which is also an usual parameter optimization method with good fitting performance.

IV. PSO OPTIMIZATION ALGORITHM

Particle swarm optimization algorithm is an evolutionary intelligence computation technology based on the swarm which is put forward with the simulation of the birds to find foods. It begin search from randomly creating the initial values, then evaluate the quality of the solution through the fitness, and find the optimal solutions through iteration. To be different with the Genetic algorithm, the PSO takes each particle corresponding to one solution, and each particle has its own position and velocity, to determine its optimization direction and distance. Meanwhile, it also has a fitness decided by the optimal function to measure each particle's pros and cons.

V is the optimal solution that the population has now found, called global extreme value point. The update formula is as followed[7]:

$$V_{i,d}(t+1) = w * V_{i,d}(t) + r_1 * (P_{i,d} - X_{i,d}(t)) + r_2 * (P_{g,d} - X_{i,d}(t)) \quad (2)$$

$$X_{i,d}(t+1) = X_{i,d}(t) + a * V_{i,d}(t+1) \quad (3)$$

Here, D dimension searching space, and the population has m particles, the position for particle i is $X_i = (X_{i,1}, X_{i,2}, \cdots, X_{i,D})$,the velocity is $V_i = (V_{i,1}, V_{i,2}, \cdots, V_{i,D})$, and the individual extreme value point is $P_i = (P_{i,1}, P_{i,2}, \cdots, P_{i,D})$, the global extreme value point is $P_g = (P_{g,1}, P_{g,2}, \cdots, P_{g,D})$, $i = 1,2, \cdots, m; d = 1,2, \cdots, D$; t is the evolution generation; w is inertial factor, r_1 and r_2 are the random values distributed evenly between[0,1]. $V_i \in [-V_{i\max}, V_{i\max}]$; $V_{i,\max}$ is the maximum velocity for each dimension, a is the constraint factors to control velocity weight.

In general, the iteration of algorithm suspend on the condition that the maximum iterating times or the optimum position found by the particle swarm so far has satisfied the adaptive threshold value.

V. APPLICATION

In the application, the PSO algorithm has been used to optimal the parameters of the P-III distribution when calculating the ice-covering recurrence period of Hunan Province，which is based on 57 years observation data of the average ice-covering day of Hunan province.

Besides, the least-square method is taken as the object function, which is the criteria of the minimization of the squared residuals sum. Meanwhile, the value for the parameter of algorithm is set as follows: the particle population scale is 50, the iteration time is 100, c_1 and c_2 are both set as 2.05，a is set at 0.9, w is 0.95.

To make compartment, we obtain the deviation coefficient and the skewness coefficient of the frequency curve, the sum of residuals and the sum of squared residuals using the moment method, probability weighting moment method and PSO optimization curve-fitting method.

Table.1 Parameter Results

Method	*Deviation Coefficient*	*Skewness Coefficient*	*Sum of Residuals*	*Squared residuals sum*
moment method	0.89	1.78	23.582	30.382
probability weighting	0.95	2.85	14.760	17.308
PSO	1.020	3.180	9.673	16.874

The frequency curves obtained based on the above method is shown in the following fig 1~3:

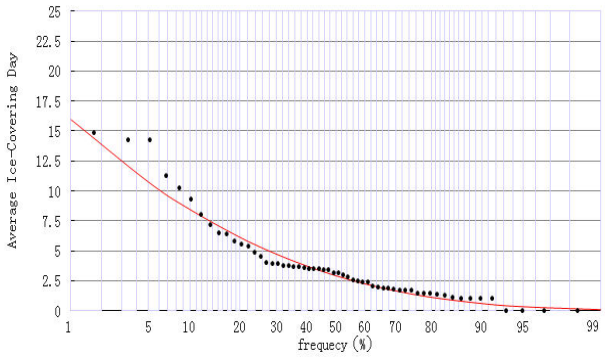

Fig.1 The frequency curve based on the moment method

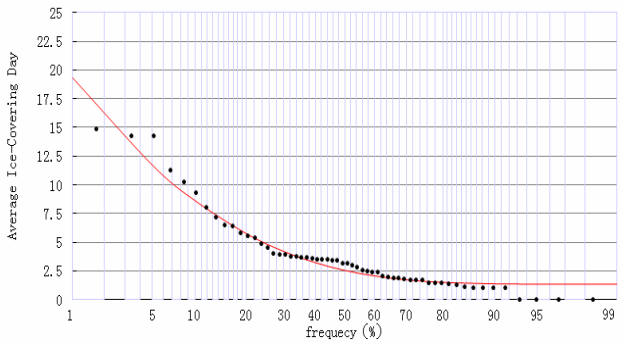

Fig.2 The frequency curve based on the probability weighting moment method

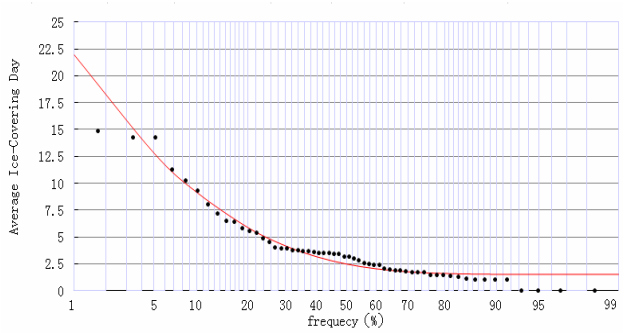

Fig.3 The frequency curve based on the PSO

Through Fig2~4, we can find that no matter from the sum of residuals, the sum of squared residuals or from the effect of the curve-fitting, the result of PSO optimization method are obviously better than moment method and probability weighting moment method.

VI. THE ICE-COVERING RECURRENCE PERIOD DISTRIBUTION MAP

Through calculating and analyzing ice-covering recurrence period based on the 57 years observation data of icing days of 97 weather stations distributed all over Hunan area using the proposed method, ice-covering days for recurrence period of 15 years, 30 years, 50 years and 100 years of these stations are calculated, Icing days distributing maps of Hunan province are painted. The following shows the distribution map with recurrence period of 15 year.The result shows that the number of icing day recurrence period of 15 years for Chenzhou and Hengyang regions is more than ten days, these two regions are severe icing area in Hunan province.

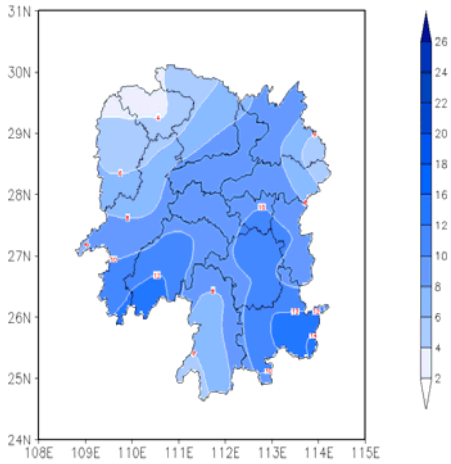

Fig.4 Hunan distribution map of ice-covering days for recurrence period of 15 years

VII. CONCLUSION

This paper has taken the P-III distribution can to analyze the recurrence interval of power grid, and considering the P-III distribution is easy to be disturbed by manual factors, the curve fitting method based on particle swarm optimization (PSO) is proposed in this paper. This comparison has shown that PSO has mature calculation methodology and has greatly intensified the exact property of estimation of parameter means and decreased the human effects, thus can obtain more stable calculation result, which is definitely more accurate, and make PSO a useful analysis tool for frequency calculation.

Through calculating and analyzing ice-covering recurrence period based on the 57 years observation data of icing days of 97 weather stations distributed all over Hunan area, ice-covering day for recurrence period of 15 years, 30 years, 50 years, 100 years are calculated and the icing days distributing maps of Hunan province are painted, which can give an obvious presentation of the crucial place for icing, and from the result, there are two severe icing areas in Hunan province, that is, Chenzhou and Hengyang regions. It can be offered as much useful guidance for the analysis of ice-covering law and early warning of icing disaster and the design of the anti-icing standard.

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Abstract: Calculation of ice-covering recurrence interval for power grid is of great significance for anti-ice design of the transmission line. As a common probability distribution curve，the P-III distribution can be used to analyse the recurrence interval of power grid. To avoid the disadvantages of the P-III distribution, the curve fitting method based on particle swarm optimization (PSO) is proposed in this paper. Hunan distribution map of ice-covering days for recurrence period of 15 years is also presented.

1. INSTRUCTION

In concern of that the P-III distribution has the disadvantages of uncertain distribution parameters, which is easy to be disturbed by manual factors, the curve fitting method based on particle swarm optimization (PSO) is proposed in this paper. PSO is an effective algorithm that can accomplish parameters calibration rapidly, and find out the global optimal solution of parameters accurately.

2. CALCULATION AND DISCUSSIOIN

We use the PSO algorithm to make optimization for the parameters of the Person type III for the frequency calculation taken the average ice-covering day of Hunan province as the computation objects in order to improve the speed and quality of parameter optimization[1].

We take the criteria for the curve-fitting is to make the following objective function F to be the minimum in order to search the optimal parameter, and the formula is as followed:

$$\min \quad F = \sum_{i=1}^{n} \left| \chi_i - \chi_p \right|^k \qquad (1)$$

To make comparison, we obtain the deviation coefficient and the skewness coefficient of the frequency curve, the sum of residuals and the sum of squared residuals using the moment method, probability weighting moment method and PSO optimization curve-fitting method.

Table.1 Parameter Results

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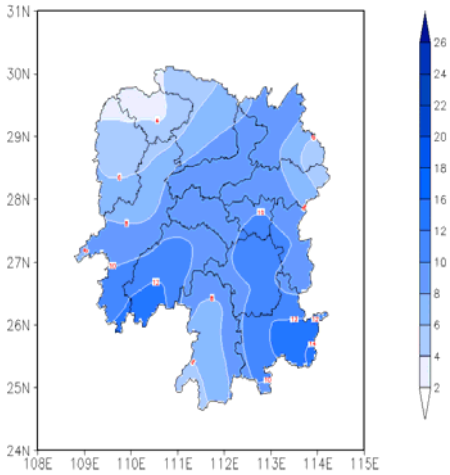

Fig.4 Hunan Distribution Map of ice-covering days for recurrence period of 15 years

3. CONCLUSION

This comparison has shown that the proposed P-III curve fitting method based on PSO can obtain more stable calculation result, and thus is a useful analysis tool for frequency calculation

4. REFERENCES

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