Research on Standard Cost Prediction of Intelligent Overhaul Based on Multiparticle Optimization

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Abstract. In order to effectively control the cost consumption in the process of intelligent overhaul of power grids, so as to maximize the saving of power supply cost, a standard cost forecast model based on multi-particle optimization algorithm is proposed. Starting from the global mode and local mode, the concrete calculation results of optimization operator are determined, and the cost statistics of power network based on multi-particle optimization algorithm is realized. On this basis, the cloud application concept of maintenance cost is defined, and the actual value of standard gray number is determined according to the numerical calculation law of cost characteristics. Experimental results show that MPSO can save the consumption of overhaul cost and meet the practical need of effectively controlling the supply cost of electricity under the same power supply.

Keywords: Multi-particle optimization algorithm · Power grid maintenance · Cost forecast · Global model · Local model · Predicted grey number

1 Introduction

Each algorithm is to solve some practical problems or better to solve these problems, particle swarm optimization algorithm is no more than the production of such. Multi-particle optimization algorithm is a stochastic optimization algorithm based on iteration. Many scholars have studied a lot of classical optimization algorithms before they are produced. For example, the classical simplex method, steepest descent method, Newton method, quasi-Newton method, conjugate gradient method and trust region method are suitable for solving unconstrained optimization problems, but less effective for more complex problems. In order to solve more and more complex practical problems, with the continuous development and growth of applications based on bionics, a series of optimization algorithms inspired by biological or biological group behavior characteristics and some natural phenomena have emerged through continuous research on artificial life, such as genetic algorithms, quasi-annealing algorithms, tabu search and artificial neural networks, which were proposed successively after the 1940s according to the actual

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needs. These algorithms are derived from the actual laws of nature and the experience of practical problems [1].

Power grid plays a fundamental role in China's economic development, mainly in the transmission and distribution of electric power and electric power trading functions of these two aspects. The construction of power grids is facing new challenges and opportunities, and the construction of a well-off society in an all-round way puts forward new requirements for the breadth of the coverage of power grid construction; the promotion of the development of energy bases in the northwest puts forward new requirements for the regional density of power grid construction; and the demand for network access of multiple renewable energies puts forward new requirements for the intelligent regulation of power grids. In order to meet the needs of national economic development and strategic adjustment, power grids need to be constructed vigorously in the future. Prior to the upgrading of the power grid, it is faced with the problems of inadequate capacity for the allocation of power grid resources and inadequate security, reliability and economy [2]. In order to solve the above problems, the State Grid carried out the backbone grid construction and grid upgrading projects during the 11th Five-year Plan period, with a cumulative investment of 1.2 trillion yuan to increase transmission lines and transformer capacity, with growth rates of 8.0% and 14.5% respectively. Compared with the "Tenth Five-year Plan", the length of new transmission lines increased by 1.20 times and the capacity increased by 1.93 times. After ten years of transformation and upgrading of power lines and substations, the above-mentioned problems have been greatly improved, and the economic stability of the power grid continues to improve.

2 Power Grid Cost Statistics Based on Multi Particle Optimization Algorithm

2.1 Global Mode

The original particle swarm optimization algorithm is a global optimization algorithm, which searches for the best position in all the allowed search space until finding the global best position. In the optimization theory, we define the particle as the possible solution of the optimization problem. The optimization process can be seen as follows: first, a group of particles is determined randomly in the solution space, then each particle in the swarm is evaluated by the objective function, and then the optimal solution is found through continuous evolution by following the optimal position of its own understanding. The global mode flow chart of multi particle optimization algorithm is shown in Fig. 1:

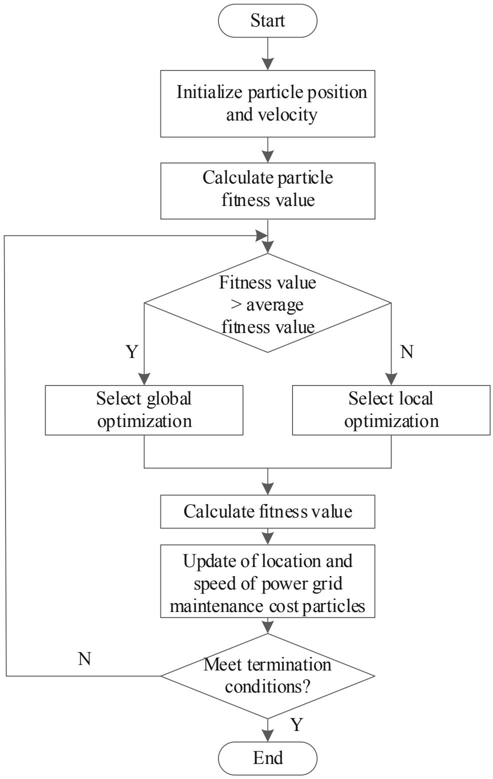

Fig. 1. Global mode flow chart of multi Particle Optimization Algorithm

N problem of a is set, and a power grid maintenance cost particle swarm with size M is set. The position of the i particle is $X_i = (x_{i1}, x_{i2}, \cdots x_{iN})$ and the speed is $V_i = (v_{i1}, v_{i2}, \cdots, v_{iN})$. The speed determines the distance and direction of each movement of the power grid maintenance cost particle. The current fitness value of the particle is calculated according to the objective function describing the problem to measure the quality of the particle. Let $pb_i = (p_{i1}, p_{i2}, \cdots p_{iD})$ be the best position experienced by the particle of power grid maintenance cost moving in the search space so far, and $pb_i = (p_{i1}, p_{i2}, \cdots p_{iD})$ be the best position found by all particles so far.

The location and speed of power grid maintenance cost particles are updated generation by generation according to the following formula:

$$\begin{cases} V_{in}(k+1) = V_{in}(k) + c_1 r_1 (pb_{in} - x_{in}(k)) \\ x_{in}(k+1) = x_{in}(k) + v_{in}(k+1) \end{cases} \tag{1}$$

In the formula, k represents the algebra of the current power grid maintenance cost particles, $i = 1, 2, \cdots, M$ represents the dimension of the problem, $n = 1, 2, \cdots, N$ represents the number of each particle in the group, N is the set power grid maintenance cost particle swarm size, and in the update formula of c_1 and c_2 speed, it affects the power of particles moving towards their own experience and group experience, so it is often vividly called learning factor or acceleration factor. If these two factors are properly adjusted, we will find that they do not have a great impact on the convergence, but they can make the particles not close to the local minimum as far as possible, so as to improve the convergence speed. The parameters r_1 and r_2 are two random numbers between (0, 1). Their function is to maintain the diversity of particles, so as to reduce the algorithm falling into local optimization.

The second item of the first formula, which is related to all the experience of the particles in the process of optimization, is usually called the "cognition" part of the particles, which represents the self-learning ability of the particles. The third item of the formula is called the part of the particles' recognition in the "society", and these two parts also reflect the direct experience and indirect experience of the particles, which reflects the obvious advantage of the cooperation between the particles based on the multi-particle optimization algorithm.

2.2 Local Mode

In the global version of standard multi-particle optimization algorithm, particle swarm optimization algorithm, the cost of power network maintenance is to find the global optimal solution by tracking the optimal value and population. This method can quickly converge to find the optimal solution, but it is easy to fall into the local optimum (or local extremum) because the search is not careful enough, and the optimal solution in the specified solution space cannot be found accurately [3]. To solve this problem, in order to find the global optimal solution accurately, a local version of the optimization algorithm is produced. It stipulates that the position and velocity of particles are updated by referring to the optimal value in the "memory" of particles and the optimal value in the nearest particles. By comparing these two values, the position and velocity of particles are constantly adjusted to achieve full search and finally find the global optimal. Compared with the global version, this model can find the global optimum more effectively, but it also has the disadvantage of slow convergence speed.

The basic steps for the global and local versions are the same, except that the reference points for evaluating the particles are different, in short, the ways in which the particles move.

Set χ to represent the local optimization coefficient of the power grid maintenance cost particle swarm, c and a to represent the execution step value of two different optimization instructions, f to represent the local mode eigenvalue of the power grid maintenance cost particle, ΔD to represent the local mode change of the power grid maintenance cost particle per unit time, and the simultaneous formula (1) to represent the local mode of the power grid maintenance cost particle swarm based on the multi-particle optimization algorithm as follows:

$$S = \sqrt{\frac{1}{\chi}\sum_{c=1}^{a}\left(\frac{V_{in}(k+1)^2 - x_{in}(k+1)^2}{f \cdot \Delta D}\right)} \quad (2)$$

Since the local version was proposed, multi-particle optimization algorithms based on different topological structures have been proposed successively, including random ring, wheel and random wheel. These topological structures put forward a new direction for the improvement of traditional particle swarm optimization algorithm.

Based on the trend of tax law and market price, the paper analyzes the relationship between project cost and income, that is, the payback period and the ability to repay the loan, and gives the benefit conclusion. In financial evaluation, the selection of price is the key of evaluation and analysis. Whether the price of each product can be selected accurately or not directly affects the accuracy of the final conclusion. But the product price is a dynamic attribute, which is changing with the market supply and demand [4]. Only by managing the price of key materials in the west market and fully analyzing the price sensitivity, can the conclusion be used to provide the basis for the decision-maker to make an accurate decision. But the project cost in view of this aspect correlation research and the application is quite lag.

2.3 Operator Design

Different from function optimization, the object of MPO is discrete, each discrete state corresponds to a set of discrete values, and each discrete state corresponds to a value of objective function.

In the global mode and local mode formulae given above, the maximum value of particle distribution determines the ability of particle to find the global optimal solution. If the particle movement step is too large, it is easy to skip the most position and can not find the global optimal solution. That is, the larger particle distribution condition can make the particle search faster and more sufficient, and improve the particle excavation ability, while the smaller particle distribution condition can make the particle search more careful, and improve the particle excavation ability.

The key of a successful optimization algorithm lies in a good balance between global search and local search, but the whole search process of particle swarm is a nonlinear search process from global to local, and the search from global to local can not be accurately grasped by linear decreasing inertia weight [5]. For different optimization problems, this improved particle swarm optimization algorithm may not be able to achieve good results. Especially for the dynamic optimization problem, the simple linear decreasing inertia weight strategy can not meet the requirements of problem solving.

For the simple optimization problem, the particle swarm can get the optimal solution quickly, but for the complex optimization problem, the particle swarm is easier to fall into the local optimum. Therefore, it is not enough to rely on group experience, but also rely on their own experience.

Let $\overline{L}$ represent the optimization mean value of power grid maintenance cost particles, f represent the particle swarm integration coefficient, ϕ represent the established optimization index parameters, and β represent the definition conditions of power grid maintenance cost. The operator design result based on multi particle optimization algorithm can be expressed as:

$$\mu = \frac{f \cdot \overline{L}}{\left|2 - \phi - \sqrt{S^2 - 4\beta}\right|} \tag{3}$$

Through the simulation of the multi-particle optimization algorithm, we can be familiar with the basic process of the particles of the maintenance cost of the power grid [6].

It can be seen from the above that compared with the standard multi particle optimization algorithm, the application effect of local optimization algorithm is better, which can effectively solve the problem of falling into local optimization because the search of traditional algorithm is not careful enough. Through the optimization mean value of power grid maintenance cost particles, particle swarm integration coefficient, established optimization index parameters and definition conditions of power grid maintenance cost, the operator in particle algorithm is designed to solve the problems such as insufficient particle convergence behavior.

3 Standard Cost Prediction Method of Power Grid Intelligent Maintenance

3.1 Maintenance Cost Cloud Definition

When making investment decisions for power grid infrastructure projects, the analysis of the various stages of the future life cycle is obtained through the available historical data or the forecast of development prospects. This forecast often uses a fixed forecast value to indicate an uncertain factor in the future. The accuracy of this expression is not high. Often, the cost of the various stages of the life cycle of the power grid infrastructure projects is an interval number. The accuracy of this expression is far greater than the accuracy of a forecast value [7]. Therefore, we can reduce the loss of information to the greatest extent by describing the uncertainties in each phase of the life cycle of the power grid infrastructure project as a cloud model. The cost cloud is defined as follows.

Cost cloud is the stage cost domain that can be expressed by accurate values within the research scope of life-cycle cost of power grid infrastructure projects, and T is the qualitative estimate associated with l. The elements in l are random numbers with stable membership, and the distribution of membership ξ in universe l is cost cloud. The specific definition conditions are as follows:

$$\varpi = \frac{\sum_{c=1}^{b} l \times T}{\mu \xi^2} \tag{4}$$

Among them, c and b represent two different definition coefficients of intelligent overhaul cost c.

The basic construction projects of power grids have the characteristics of long life cycle, complicated factors to be considered, numerous indicators and so on. By analyzing the closeness between the to-be-estimated project and the historical project, the historical project most similar to the to-be-estimated project is selected by using the principle of maximum closeness, and the final full-life cycle cost of the to-be-estimated project is estimated by using the data of the historical project, thus ensuring the accuracy and rationality of the estimation [8]. But it also has some disadvantages, such as the calculation is too detailed and comprehensive, the inevitable calculation of complex, the cost of human and material huge, which itself involves a cost issue. Moreover, there is a great uncertainty in the whole life cycle of the power grid construction project. Using historical data analysis can not fully reflect the uncertainty of the cost in the whole life cycle of the project to be estimated, and can not provide comprehensive cost information for the final decision.

3.2 Cost Characteristic Value

There are many uncertainties in the life cycle cost of power grid construction projects. How to express and transform these uncertainties into scientific theories is the key to solve these problems. The cloud model can well describe the uncertainty of the whole life cycle of the power grid construction project. Using the multi-particle optimization algorithm, the experts can estimate the cost of each phase of the construction project. Then the cost cloud can be transformed into the gray number of three parameter interval. Therefore, the cloud model can retain the uncertain information to the maximum extent and is more advantageous to the final cost accounting.

The concept of cost management in the management of infrastructure projects in our power grid is more lacking, mainly in three areas. Firstly, because of the limitation of cost management scope, the scope of cost management of power grid capital construction projects is only limited to the construction period, while the management of operation expenses, maintenance expenses and overhaul expenses after construction is largely ignored. The cost of power grid capital construction projects is characterized by one-time investment (construction cost) accounting for only about 40% of the life cycle cost of power grid capital construction projects, so the scope of cost management at present is limited [9]. Secondly, because of the ambiguity of cost management, the cost management of power grid enterprises is generally limited to how to reduce the cost, but not how much benefit it can bring to the enterprise. Third, the method of cost management is backward, power grid enterprises use traditional means to manage costs, and advanced theories such as lifecycle theory are not timely applied in power grid enterprises.

Set j_1 and j_2 to represent two different coefficients of power grid construction cost, $\dot{e}$ to the intelligent definition index of power grid maintenance cost, θ to the predicted scalar value of power grid maintenance cost, and the simultaneous formula (4). The standard cost eigenvalue of power grid intelligent maintenance based on multi-particle optimization algorithm may be represented as follows:

$$M = \frac{\sum_{j_1}^{j_2} \varpi (1 + \dot{e})^{j_2 - j_1}}{\theta^2} \tag{5}$$

In the implementation of power grid maintenance projects, due to the time and region differences, will directly affect the cost of each link, and ultimately affect the entire construction phase of capital investment. Then the time and region adjustment coefficients can be introduced to correct the change of input caused by time and region by comparing the price of the key process of the estimated project with that of the key process of the historical similar project.

3.3 Standard Prediction Grey Number

The characteristics of power grid infrastructure projects determine that the life-cycle cost theory is of great value in cost management. However, the application of multi-particle optimization theory in power grid infrastructure projects is superficial and has great theoretical value. From the perspective of power grid enterprises, the cost of the whole life cycle of power grid infrastructure projects is analyzed and studied in detail, and the cost structure and estimation model of each link in the life cycle are determined by consulting historical data and using modern statistical methods. Through the analysis of the internal relations between the costs of each link, the cost improvement approach is found, and the cost optimization is finally realized. Through the application of life-cycle theory, the cost control of power grid construction project can achieve the harmony of the cost of each stage and the life-cycle cost [10, 11]. When the life-cycle cost is used to control the cost of power grid construction project, the cost of operation, maintenance, overhaul and scrapping should be minimized besides the reduction of one-time investment.

The development of network intelligent overhaul cost forecast can be regarded as the development of cost management research of construction enterprises. Through carding the development context of engineering cost, we can understand the exploration of cost control of construction enterprises. First of all, the definition of project cost, the main body of project cost is different, its meaning is not the same, the main body has a complete project, a single project, water and heating projects or installation projects. Its main body is different its project cost content also along with it changes.

Set up $g_{\min}$ to indicate the minimum overhaul cost forecast condition, $g_{\max}$ to indicate the maximum overhaul cost forecast condition, ψ to indicate the processing authority characteristic value of the grey number forecast, $\hat{h}$ to indicate the characteristic index of the power network overhaul cost optimization under the specific situation. With the support of the above physical quantities [12], the standard predictive grey value can be represented by the simultaneous formula (5):

$$I = \frac{\psi \cdot M}{\sum_{g_{\min}}^{g_{\max}} \hat{h}^{g_{\max}-g_{\min}} \Big/ \Delta U^2} \tag{6}$$

In the above formula, ΔU represents the power grid maintenance cost consumption per unit time.

The grey number of standard forecast is an index that can determine the trend of maintenance cost of power network. The cost accounting ability directly determines its bidding, construction and acceptance. Therefore, the study of the work cost has great practical significance, and the research results must have the characteristics of universality, convenience and accuracy, otherwise the project cost is of no practical significance.

Bidding for power grid infrastructure projects refers to the process whereby the bid inviter, after releasing the bidding information of power grid infrastructure projects, drafts bidding documents and puts forward specific construction measures for the relevant projects based on the bidding information, and selects the entities with the highest bidding price within a reasonable scope and with the relevant qualifications required by the State and the highest personnel level according to the bidding documents of all bidding entities. In the evaluation process of a bidding document, it is not only necessary to analyze the bidding documents of the current project, but also to make a comprehensive analysis in combination with the bidding documents of the same kind or of the same bidder so as to comprehensively analyze the internal economy, management, qualification and other aspects of the bidding enterprise and provide the basis for decision-making. In order to select the enterprises with high capacity and high level, it is necessary to compare the quoted price of each stage with the internal quota, analyze the reasons, reflect the real project cost level on the premise of guaranteeing the construction quality, and finally get a project cost quota with basis, competitiveness and management level.

4 Case Analysis

In order to verify the practical value of the standard cost prediction model of power grid Intelligent Maintenance Based on multi particle optimization algorithm, the following comparative experiments are designed. The periodic estimation model and multi particle optimization algorithm are used to control the cost of power grid intelligent maintenance, in which the former is used as the control group and the latter as the experimental group.

Table 1 records the specific numerical changes of power grid work during the given experimental time.

Table 1. Work done by power grid

Project	Experimental time/(h)	Power grid work/(KWh)
1	2	104
2	4	205
3	6	311
4	8	420
5	10	532
6	12	608
7	14	703
8	16	826
9	18	904
10	20	997

Analysis of Table 1 shows that the experiment takes 2h as a unit duration, and the power value keeps increasing during the whole experiment process, and the increase rate is higher than the experiment.

The cost consumption of power grid overhaul can describe the implementation of power grid project. The smaller the cost consumption value is, the stronger the application ability of power grid project in saving supply cost is, otherwise the weaker it is. In this experiment, the cost prediction method of substation maintenance and operation based on Improved BP neural network proposed in reference [1] and the cost prediction method of power grid project based on whole life cycle proposed in reference [2] are selected as the experimental control group, and compared with the experimental test results of the proposed method, The specific numerical changes of power grid maintenance cost consumption of different methods are shown in Fig. 2.

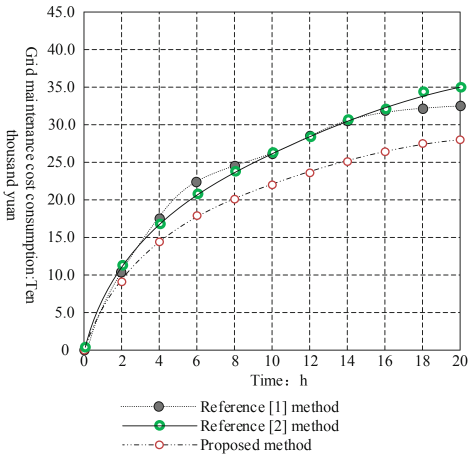

Fig. 2. Power grid maintenance cost consumption

Analysis of Fig. 2, with the extension of the experimental time, the experimental group, the control group of power grid maintenance cost consumption has shown a rising trend of numerical change. For the experimental group, the global maximum value is only 278,000 yuan, while for the control group, the global maximum value is 350,000 yuan.

Table 2 records the increment amplitude of the power grid maintenance cost consumption of the experimental group and the control group in unit time, and its numerical comparison with the actual power grid work.

Table 2 shows that the unit increment of power grid maintenance cost consumption in control group is always larger than that in test group in 0–8 h and 12–16 h, and is always smaller than that in test group in 10th and 18–20 h. During the whole experiment, the maximum value of the rising amplitude of the experimental group and the control group was 92,000 yuan and 102,000 yuan, respectively. The time of the rising amplitude was 2h.

Compare the cost prediction accuracy of the proposed method, the substation maintenance and operation cost prediction method based on Improved BP neural network proposed in reference [1] and the power grid project cost prediction method based on life cycle proposed in reference [2]. The experimental results are shown in Fig. 3.

Table 2. Unit rising amplitude of power grid maintenance cost consumption

Experimental time/(h)	Power grid work/(KWh)	Rising amplitude of experimental group/(Ten thousand yuan)	Rising amplitude of reference [1] method/(Ten thousand yuan)	Rising amplitude of reference [2] method/(Ten thousand yuan)
2	104	9.2	10.2	10.1
4	205	5.4	7.3	7.4
6	311	3.3	4.8	4.7
8	420	2.4	2.5	2.3
10	532	1.9	1.2	1.8
12	608	1.7	1.9	1.9
14	703	1.2	2.5	2.5
16	826	1.6	1.9	1.9
18	904	0.9	0.3	0.3
20	997	0.4	0.2	0.6

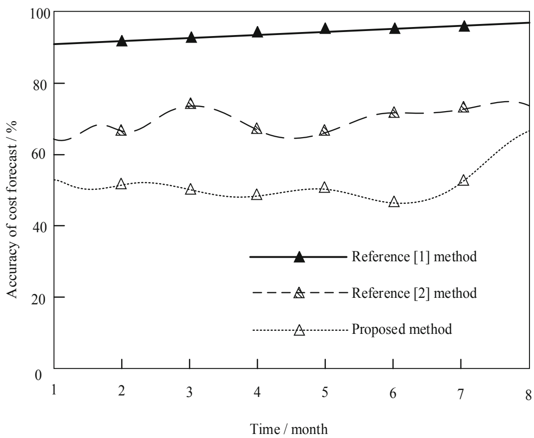

Fig. 3. Comparison of cost prediction accuracy

According to the comparative experimental results of cost prediction performance of various methods in Fig. 2, the cost budget accuracy of the proposed method is higher than that of reference [1] method and reference [2]. Therefore, with the application of multi particle optimization algorithm, the consumption value of power grid maintenance cost has been effectively controlled, and the cost prediction has higher accuracy, This has indeed played a promoting role in saving the cost of power supply.

5 Conclusion

Compared with the periodic estimation model, the standard cost prediction model based on multi-particle optimization algorithm can accurately calculate the parameters of the optimization operator, and the cost eigenvalue can directly affect the actual calculation result of the grey value of the standard prediction. The experimental results show that the increase amplitude of power grid maintenance cost under the proposed method is always relatively small, and the global maximum can only reach 278000 yuan; In contrast, the global maximum of power grid maintenance cost of the other two reference methods has reached 350000 yuan. The proposed method also has lower maintenance cost and consumption. The cost budget accuracy of the proposed method is always higher than 90%, which is always higher than that of reference [1] and reference [2]. From the point of view of practicality, the cost of maintenance and repair of power network has been effectively controlled, and the increase in the cost of consumption per unit time has also shown a trend of reduction, which can achieve the maximum savings in the cost of electricity supply.

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