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Research on Optimization of Planned Interruption Non-Effect for Distribution Network Planning Based on Improved Particle Swarm Optimization Algorithm

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Abstract. This paper proposes a distribution grid network planning model based on improved particle swarm optimization algorithm with planned interruption non-effect load fluctuation uncertainty, and studies the distribution network reconstruction and distribution network fault isolation recovery. Through simulation, it is found that the improved particle swarm optimization algorithm enhances particle diversity, accelerates convergence, and has good global search ability. It is feasible and effective, and has positive significance for promoting the application of PSO in power systems.

1. Introduction

Planned interruption non-effect through scientific prediction, reasonable arrangements for annual power outage plans, and comprehensive consideration of overhaul, technical transformation, urban integration construction tasks, and unified coordination of distribution network grid planning. In accordance with the principle of “line maintenance with substation main equipment, branch line maintenance along with the main line”, the power outage is suspended from the substation maintenance, and the number of power outages is reduced and the power outage range is reduced. At the same time, it will strengthen the comprehensive inspection, maintenance and temperature measurement of the transmission, transformation and distribution equipment, and find out the problems in time to ensure the reliable operation of the equipment. The entire search update process is the process of following the current optimal solution. In most cases, all particles may converge to the optimal solution faster. In this paper, the improved particle swarm optimization algorithm is applied to the optimization planning of distribution network grid. Finally, the effectiveness of the method is illustrated by an example.

2. Planned interruption non-effect distribution network grid planning mathematical model

2.1. Objective function

In this paper, the grid optimization model uses the planned interruption non-effect as the objective function. The expression is as follows:

$$\min f(x) = \sum_{i=1}^n (C_{li} T_i x_i + C_{2i} \tau_{\max i} \Delta P_i) \quad (1)$$

In the formula, $f(x)$ is the optimal investment cost of the grid under the planned power outage condition, that is, the objective function; x is the dimensional decision vector, that is, the solution of the problem, and $x=(1,2,3,...,n)$ is the optional line in the planning problem; the first part of the right side of the equation is zero. Planned power outage impact factor, where $C_{li} = \gamma_i + \alpha_i$, γ_i is the investment recovery rate, α_i is the equipment depreciation maintenance expense rate, T_i is the investment cost of the new line, x_i is the element of vector x , when the candidate line i is selected $x_i=1$, otherwise $x_i=0$; The latter part is the network loss cost, where C_{2i} is the unit price, $\tau_{\max i}$ is the maximum load utilization hours, and ΔP_i is the active loss of the line [1-2].

2.2. Constraints

2.2.1. Current constraints

$$AP=D \quad (2)$$

Where A is the node-associated arc matrix; P is the network power flow; D is the load demand.

2.2.2. Capacity constraints

$$P_i \leq P_{\max} \quad (3)$$

Where P_i the branch is flow; P_{\max} is the maximum allowable capacity of the branch.

2.2.3. Radial network structure constraints. Among them, the power flow constraint can be realized by the power flow calculation based on the forward push back method [3], and it is not added to the objective function as the fitness function of the PSO; both the capacity constraint and the radial constraint are realized by constructing the penalty function. Thus, the mathematical model after considering the constraints is:

$$\min f(x) = \begin{cases} \sum_{i=1}^n (C_{li}T_i x_i + C_{2i}\tau_{\max i}\Delta P_i) + U_1 L & \text{Radiation network} \\ U_2 & \text{Non-radiative network} \end{cases} \quad (4)$$

Where U_1 is the overload penalty factor; L is the portion of the network that is overloaded (exceeds the maximum allowable load on the line), and its value can be obtained from the load flow of the network; U_2 is the non-radiative network penalty value, and U_2 should be set very well. Great to prioritize the elimination of infeasible solutions.

2.3. Improved particle swarm optimization

2.3.1. Original Particle Swarm Optimization. In a PSO system, each particle represents a solution to the problem. The particle has three properties: position vector x_i , velocity vector v_i , and fitness value. The position vector of the particle is the solution vector of the problem; the velocity vector determines the flight direction and distance of the particle, which determines the position vector under the particle; the fitness value is a function of the position, which determines the pros and cons of the current position of the particle. The purpose of all particle flight is to find the location where the fitness value is optimal.

To achieve this, each particle updates its velocity and position based on two extreme values: the individual extreme value p_i and the global extreme value g . The individual extremum is the optimal position found by a single particle in the past k iterations, and the global extremum is the optimal position found by all particles in the past k iterations. The update process is expressed by a formula, namely:

$$v_i = K \left[v_i + c_1 r_1 (p_i - x_i) + c_2 r_2 (g - x_i) \right] \quad (5)$$

$$x_i = x_i + v_i \quad (6)$$

Where i represents the first particle; x_i, v_i, p_i, g is the n dimensional vector of the n dimensional solution space; K is the convergence factor, $K = 2 / \sqrt{2 - \varphi - \sqrt{\varphi^2 - 4\varphi}}$, $\varphi = c_1 + c_2$, $\varphi > 4$; c_1, c_2 is a non-negative constant, called the learning factor; r_1, r_2 is between [0,1] A random number between. This is the basic PSO. If the current neighborhood extremum defined by each particle is used instead of the current global extremum g of the particle swarm, this method is called PSO with neighborhood operation [4].

2.3.2. Improved hybrid particle swarm optimization algorithm. From the intermediate results of the particle swarm algorithm, it can be found that when the PSO falls into local extremum or premature convergence, the particle's motion speed is very small, basically equal to zero. In addition, the experiment also found that in many optimization problems, different dimensions usually do not affect each other. The speed in a certain dimension of the algorithm is always close to 0 at a certain time, but other dimensions still maintain high speed. Movement speed. In the population-based search process, in the early stages of the search, it is desirable to search on a larger scale so that the population can maintain sufficient diversity to converge to the global optimal solution. As the search progresses, it is desirable to reduce the size of the search and find an accurate optimal solution. To this end, this paper presents a more direct improvement to the original PSO, introducing an adaptive scale factor $\left(K - (t/T_{\max})^p\right)v_{\max}$ into the PSO algorithm. By adding this coefficient, as the evolutionary algebra gradually increases, it follows the algebra of evolution. The decline, which controls the scale of the search, is called the speed adaptive particle swarm algorithm, and its purpose is to improve its convergence efficiency. The improved algorithm is described as follows:

$$v_{id}(t+1) = v_{di}(t) + c_1 r_1 (p_{id} - x_{id}(t)) + c_2 r_2 (p_{gd} - x_{id}(t)) \quad (7)$$

$$v_{id} = \begin{cases} \left(K - (t/T_{\max})^p\right)v_{\max} & , \text{ if } v_{id} > \left(K - (t/T_{\max})^p\right)v_{\max} \\ v_{id} = -\left(K - (t/T_{\max})^p\right)v_{\max} & , \text{ if } v_{id} < -\left(K - (t/T_{\max})^p\right)v_{\max} \end{cases}$$

Where: $K - (t/T_{\max})^p$ is the scale factor; t, T_{\max} are the current iteration step and the maximum number of iteration steps; p, K is the normal number that controls the size of the scale factor.

3. Optimization of grid planning for Planned interruption non-effect distribution network based on improved particle swarm optimization

3.1. Algorithm steps

(1) The breadth-first search method is used to generate the position of the initial population, and the velocity of the initial population is randomly generated. Divide the population into S initial populations. Set each particle swarm size m and algorithm parameters, inertia coefficient, learning factor, speed limit, etc.; determine the dimension D of the particle (the sum of the network candidate lines); set the maximum number of iterations [5].

(2) Perform power flow calculation on the generated network, and calculate the fitness value of each particle by using equation (4) according to the result of the power flow calculation.

(3) Evaluate the fitness value of the particles to which each initial subgroup belongs, set the individual extremum of the particles to which each initial subgroup belongs to the current position, and set the global extremum to the optimal particle position in the initial subgroup. The individual extremum P_i and the global extremum P_g of each population are obtained separately. Compare these S global extremums P_g , find the global optimal particles, replace the worst particles in each subgroup with this global optimal particle, but keep each subgroup's own global extremum unchanged.

(4) Update the particle velocity in each subgroup according to formula (7). If $v_{idk+1} > V_{max}$, then $v_{idk+1} = V_{max}$; if $v_{idk+1} < V_{min}$, then $v_{idk+1} = V_{min}$. Update the position of the particles in each subgroup according to equation (7).

(5) Detect whether the network composed of the evolved particles satisfies the conditions of the radiation network. If it is not satisfied, its fitness is set to U_2 , U_2 is a large value; if it is satisfied, the power flow calculation is performed, and the fitness value of each particle is calculated, and the individual extreme value and the global extreme value are updated.

(6) Whether the number of iterations is reached. If the maximum number of iterations is reached, the operation stops; if not, go to (4).

3.2. Example analysis

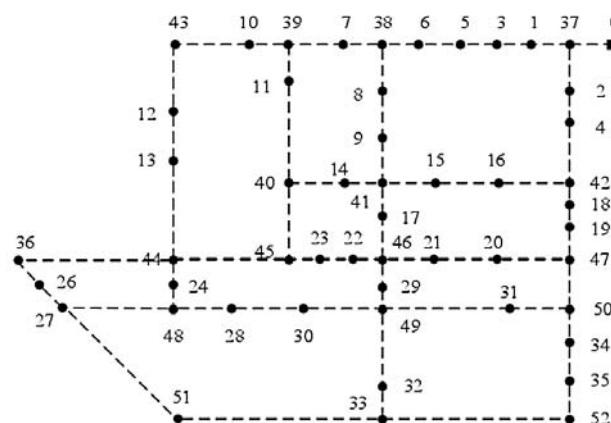


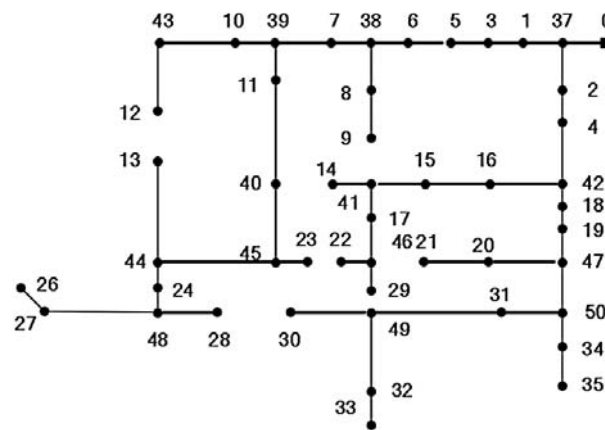
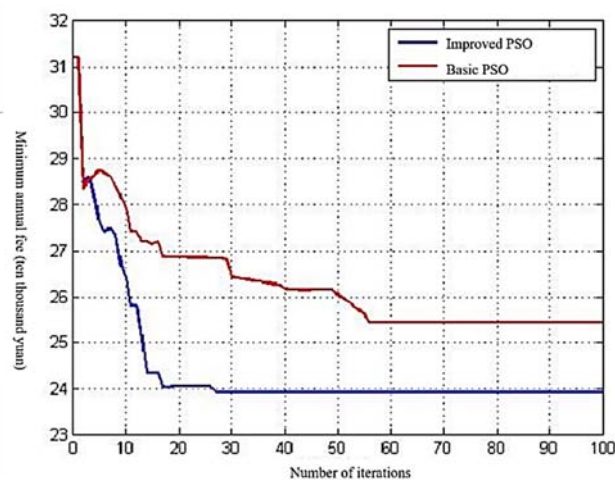
Figure 1. Possible paths in the planning area

The following figure shows a single power point in a city with a 53-node distribution network planning area. The planned area is rated at 10kV. The feasible path for the planning area is shown below.

Table 1. Node load situation

Load capacity ((kVA)	Node number
200	13, 23, 29
315	2, 7, 8, 12, 14, 22, 25, 30, 33, 34
400	3, 10, 11, 19, 27, 31, 32
500	1, 4, 6, 9, 17, 18, 20, 21, 24, 26, 28, 35
800	16
1000	5, 15

Using the improved particle swarm optimization algorithm proposed in this paper, the improved particle swarm optimization method is used to optimize the grid. In the calculation process, the parameters are set as follows: the particle swarm size is $n=40$, $c_1=c_2=2$, and the maximum number of iterations is $T=1000$. The optimization planning result is shown in Fig. 2. The minimum annual cost of the program is 239,100 yuan, and the basic particle swarm algorithm is used for calculation. The annual minimum cost of the planning result is 254,100 yuan [6-7].

**Figure 2.** Distribution network grid optimization results**Figure 3.** Comparison of the fitness curve after the improved algorithm

(1) Improved particle swarm optimization algorithm, which improves the diversity of particles and improves the convergence speed of the algorithm through immune improvement. Its fitness curve is

better than the basic particle swarm algorithm, and the overall search efficiency is significantly improved. (2) By using the function flatness information to improve the counterpart, the improved particle swarm optimization algorithm makes full use of the information of the objective function, which makes the heuristic of the search direction stronger, and the convergence speed is faster, and it is not easy to fall into the local extreme point [8-9]. The dynamic load model and the static load model are optimized by the improved particle swarm optimization algorithm. It can be seen from the above figure that after introducing the dynamic load distribution grid optimization model, the annual minimum cost is smaller and the grid optimization result is more economical.

4. Conclusion

This paper proposes an improved hybrid particle swarm optimization algorithm to introduce cross-operation between dynamic neighborhoods in basic PSO. In addition, a method of "satisfying the radial constraints" is proposed, which effectively solves the contradiction between the processing of discrete variables and the judgment of the radiation network, and makes the improved particle swarm optimization algorithm suitable for distribution network planning. The case study shows that the algorithm has fast convergence speed and good global search ability, which is feasible and effective. It has positive significance for promoting the application of PSO in power system.

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References

- [1] Yi Zhongwei. Research on distribution network planning based on improved particle swarm optimization algorithm. Vol. 2 (2015) No.37, p. 57-59.
- [2] Zhang Xian. Research on GIS-based grid planning for distribution network. North China Electric Power University (Hebei), Vol.5 (2006) No.25, p. 17-21.
- [3] Ni Ruijun. Research on Transmission Network Expansion Planning Based on Improved Particle Swarm Optimization Algorithm. Zhejiang University, Vol. 3 (2013) No.25, p.98-101.
- [4] LI Lin, LI Yan-Qing, WEN Xiufeng. Multi-particle Swarm Optimization Algorithm for Distribution Network Frame Planning. Power System Protection and Control. Vol. 3(2007) No.18, p. 415-418.
- [5] Cheng Xiaorong, Zhang Qiuliang, Wang Zhihui, et al. Optimal Planning of Distribution Network Based on Artificial Fish Swarm Algorithm. Power System Protection and Control, Vol. 21 (2007) No.35, p. 34-38.
- [6] Zhang Tao, Shi Suyi, Xu Xueqin. Reconstruction of distributed power distribution network based on binary quantum particle swarm optimization. Power System Protection and Control, Vol. 4 (2016) No.44, p. 22-28.
- [7] Ma Prairie, Sun Zhazhan, Yin Zhichao, et al. Distribution Network Reconfiguration Based on Double Hybrid Particle Swarm Optimization Algorithm. Transactions of China Electrotechnical Society, Vol. 11 (2016) No.31, p. 120-128.
- [8] Pan Chao, Jiao Weiyu, Meng Tao, et al. Optimal Configuration of Generalized Power Active Distribution Network Based on Hybrid Intelligent Particle Swarm Optimization Algorithm. Power System Protection and Control, Vol. 7 (2016) No.44, p. 69-75.
- [9] CHEN Ping, MAO Wei, TONG Wei, et al. Multi-objective Optimization Reconstruction of Distribution Network Based on Multi-objective Particle Swarm Optimization Algorithm. Electric Power System and Automation, Vol. 7 (2016) No.28, p. 68-72.