Research on Reactive Power Optimization for Distribution Network Based on Dual Population Improved Ant Colony Algorithm

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Abstract: Ant Colony Algorithm is a heuristic search algorithm based on probability selection. It fits for solving the reactive power optimization problem of distribution network, but at the same time, easily falling into the problems of local optimal solution. So Dual Population Improved Ant Colony Algorithm is used to study Reactive Power Optimization Solution. Finally, with an actual example calculation and analysis, and node voltage comparison with and without compensation, the results are proved to be satisfactory. It verified the effectiveness and feasibility of the algorithm and the results show that the algorithm has better effect on optimization.

Keyword: Dual Population Improved Ant Colony Algorithm; Distribution Network; Reactive Power Optimization

1 Introduction

In recent years, with people's attention to the construction of the distribution network and the development of the reactive power compensation technology, the reactive power compensation is gradually popularized in the distribution system, and has accumulated rich experience in practice. Great progress has been made in the research of reactive power optimization theory, optimization algorithm and its application in the field of distribution network. However, due to the complexity of optimization objectives and many constraints in the problem of reactive power optimization, it is difficult to find the global optimal solution, but it is easy for local optimal solution to appear. Therefore, it is of great significance to find an effective method for optimal control of reactive power and voltage both in theory and in practice.

The reactive power optimization of the distribution network includes reactive power planning optimization and reactive power operation optimization. Reactive power planning optimization is used to calculate the optimal installation location and capacity of reactive power compensation equipment, which can achieve the purpose of saving investment costs. Reactive power operation optimization refers to how to adjust the existing reactive power control devices in various operation ways (such as the number of switching groups of compensation capacitors, the tap position of adjustable transformer, etc.) so as to achieve the operation objectives of the highest qualified rate of grid voltage and the minimum network loss of the system.

The ant colony algorithm has the advantages of strong robustness, essential parallelism and the ability to find optimal solutions. It is first applied to the solution of TSP with good results obtained. But at the same time, it is found that the convergence speed of the algorithm is slow and easy to stagnate. Therefore, many scholars try to improve the basic ant colony algorithm. The improved dual-population ant-colony algorithm occurs in this environment, which is applied to the reactive power optimization of the distribution network.

2 Mathematical model of reactive power optimization under multi-load condition

For the reactive power optimization under multi-load conditions, it is necessary to compensate reactive power supplies with different capacities under different load conditions, so as to achieve the best comprehensive economic benefits. Then, the electricity loss expenses are calculated in various states respectively. The objective function is the formula of the minimum comprehensive investment expenses in the system. It is unreasonable for the existing model to regard the investment of reactive power supplies as the expenses in the planning period. In this paper, the discount rate and the service life of the capacitor are considered in the model, and the minimum value of the sum of the operation expenses of the system and the depreciation costs of the newly-added reactive power supplies is taken as the objective:

1.1 Objective function

$$\min C = \min \sum_{t=1}^{N}[K_P \sum_{K=1}^{S} t_{ik} P_{Lik}(Q_{ck}^i, Q_{RK}^i, T_k^i) + \sum_{j\in H}(N-i+1)M_j I_j^i]$$

$$+\min[\sum_{i=1}^{N}\sum_{j\in H}I_j^i F_j^i + \sum_{i=1}^{N}\sum_{j\in H}I_j^i \frac{(1+r)^{(N-i+1)}-1}{(1+r)^m-1}(1+r)^{(m-N+i-1)}K_{ci}Q_{cj}^i$$

$$+\sum_{i=1}^{N}\sum_{j\in H}I_j^i F_j^i + \sum_{i=1}^{N}\sum_{j\in H}I_j^i \frac{(1+r)^{(N-i+1)}-1}{(1+r)^m-1}(1+r)^{(m-N+i-1)}K_{Ri}Q_{Rj}^i]$$

Constraint equations for constraint equation1.2:

$$P_i = U_i \sum_{j\in i}U_j(G_{ij}\cos\theta_{ij} + B_{ij}\sin\theta_{ij})$$

$$Q_i = U_i \sum_{j\in i}U_j(G_{ij}\sin\theta_{ij} + B_{ij}\cos\theta_{ij})$$

Constraint formulas for inequality 1.3:

$U_{\min} \le U_i \le U_{\max}$ (Node voltage constraint)

$0 \le Q_{ci} \le Q_{c\max}$ (Capacity constraint of capacitive reactive power supply)

$0 \le Q_R \le Q_{R\max}$ (Capacity constraint of inductive reactive power supply)

$T_{\min} \le T \le T_{\max}$ (Transformer ratio)

3 Overview of improved dual-population ant-colony algorithm

The basic idea of improved dual-population ant-colony algorithm [33] is: the ants in the basic ant colony algorithm are isolated into two populations with these two independently searched, and the excellent solutions and information are exchanged regularly, which can ensure the diversity of solutions in the algorithm. There are two basic problems to be solved in the implementation of dual-population ant colony algorithm: one is the content and form of information exchange; the other is how to determine the conditions of information exchange.

The basic flow of improved dual-population ant-colony algorithm is as follows:

a. Initialize parameters to generate two populations of m1 and m2;

b. for n=1 to 5// In the process of optimization, the number of pheromone exchanges is set to 5 times, and the optimization starts.

1) for i=1 to m1//Dealing with the first population;

The ant j is placed somewhere and the taboo list is initialized;

for j=1 to line_n-1

The next path is chosen by probability P(i,j)K; the pheromone distribution is recalculated;

2) for j=1 to m2//Dealing with the second population;

The ant j is placed somewhere and the taboo list is initialized;

for j=1 to line_n-1

The next path is chosen by probability P(i,j)K; the pheromone distribution is recalculated;

3) If the exchange conditions are met, information exchange will be carried out; otherwise, this step will be skipped;

c. If the terminating condition is satisfied, the algorithm is terminated, otherwise, turn to b;

Through the above analysis, it can be found that the time complexity of improved dual-population ant-colony algorithm is the same as that of basic ant colony algorithm, but its search performance is greatly improved.

4 Reactive power optimization flow chart based on improved dual-population ant-colony algorithm
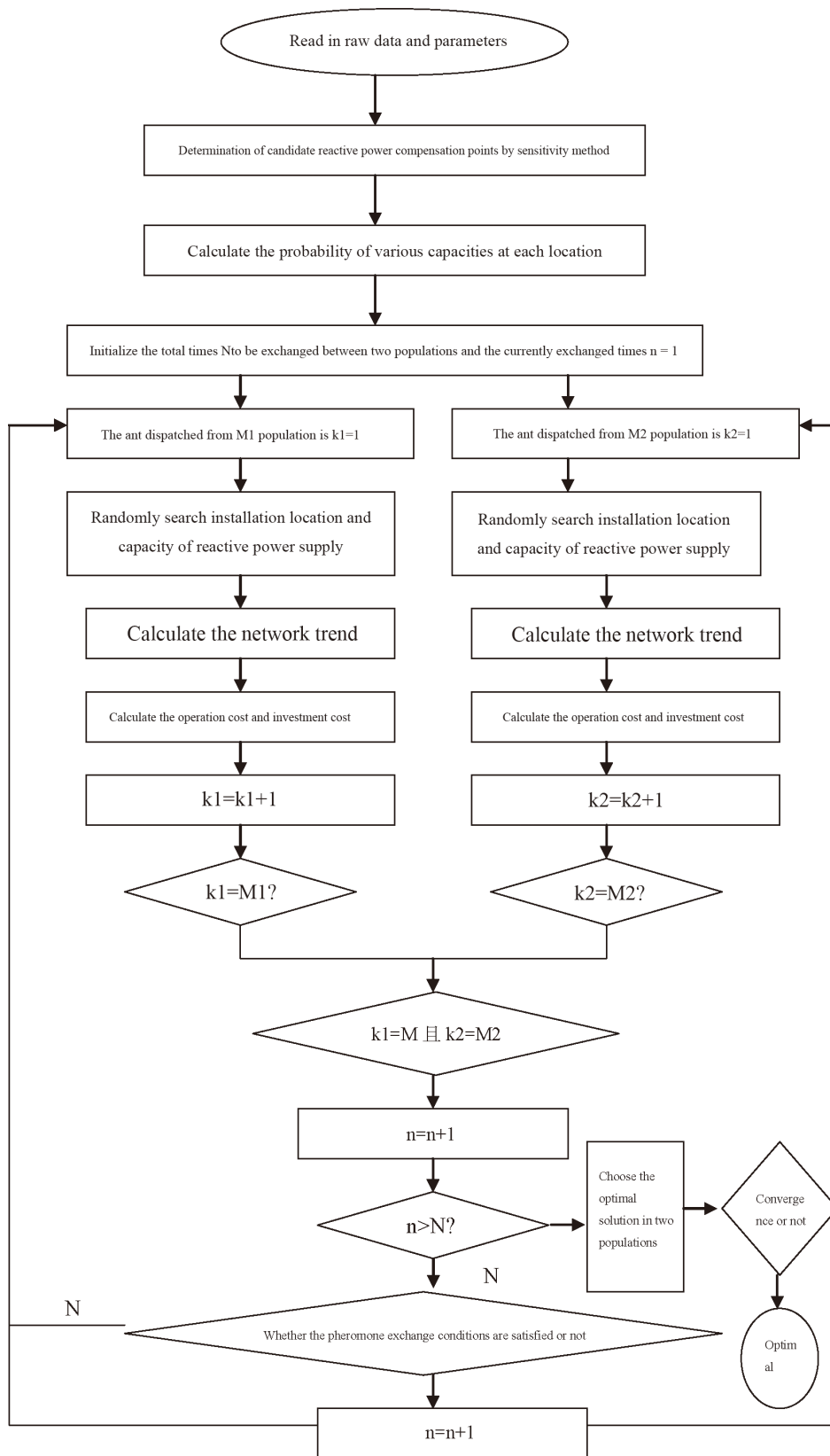
5 Analysis of actual examples

This paper takes an actual 10kV radial line in a county as an example, and quotes the node data and branch parameters of the system. In order to save internal storage and computing time, this line passes through the nodes in the paper and then it forms rules. After the topology analysis again, there are 36 nodes and 20 distribution transformers. The merged network topology is shown in the below figure:
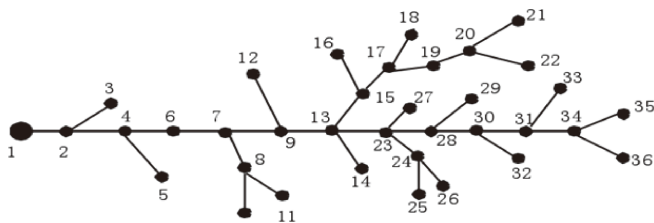
In the actual calculation example, the calculation parameters are selected as follows: the capacity of single capacitor group is 10kvar; the system electricity price is 0.5 yuan / kWh; the improved ant-colony algorithm with dual population is adopted with 50 ants in each population, and the number of pheromone exchange is set as 5 times. Since the actual system of checking calculation is a radial network composed of a root node, the network node 1 is selected as the balanced node and the remaining nodes are PQ nodes for optimization calculation. The calculation results of reactive power optimization are shown in Table 1; the comparison results of system operation cost and network loss before and after compensation are shown in Table 2.

Table 1. Compensation capacity configuration under different operation modes based on this algorithm

Node number	Capacitor capacity (kvar)		
	The largest load (1.0)	General load (0.7)	minimum load (0.5)
7	160	100	60
10	180	130	90
13	100	60	40
17	40	30	30
20	90	60	30
25	300	180	130
26	160	100	90
32	90	60	40
33	60	40	30
34	90	60	50
Total compensation capacity (kvar)	1270	820	590

Table 2. Network loss before and after system compensation

	System losses (kw)		
	The largest load (1.0)	General load (0.7)	minimum load (0.5)
Before the compensation	211.316	141.713	61.237
After the compensation	143.827	73.752	38.416

After reactive power compensation on the electric line, the network loss rate under the three operation modes are 5.070%, 3.328% and 2.556% after compensation, respectively. The data has a significant reduction, in comparison with the network loss rate of 7.449%, 6.395% and 4.074% under those three operation modes before optimization. In this way, the requirement is met that the loss rate of 10kV distribution network should not exceed 6% in national regulations.

It can be seen from Table 2 that the implementation of reactive power compensation significantly reduces the network loss of the system. Through calculation, it is concluded that the annual power loss before compensation is 638000 yuan, the annual power loss

after compensation is reduced to 365000 yuan, and the annual operation expense is reduced by 273000 yuan.

Through the analysis and calculation operation of an actual example, the results show that the improved ant colony algorithm with dual population has higher calculation accuracy and better global search ability. It is applied to the dynamic reactive power optimization of power system and the result is satisfying. Thus, the above shows that the method is feasible and effective.

6 Conclusion

In view of the current characteristics of various types of equipment, huge network loss and poor voltage

quality in distribution network, this paper studies the reactive power optimization of distribution network. In addition, this paper applies the improved dual-population ant-colony algorithm to the dynamic reactive power optimization problem of power system, establishes the mathematical model which meets the actual requirements of distribution network, and develops the reactive power optimization software of distribution network.

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