Application of Improved Ant Colony Algorithm in Optimal Planning of Dynamic Distribution Network

JinXiong Liu1 *, TieZheng Huang2 and Xi Duan3

1 State Grid Shanxi electric power company, Shanxi Taiyuan, 030000
2 State Grid Shanxi economic and Technology Research Institute of electric power company, Shanxi Taiyuan, Beijing 030000
3 Duan Xi Shanxi electric power company, Shanxi Taiyuan, 030000

*Corresponding author e-mail: sjjww449@163.com

Abstract. In this paper, the analysis is carried out in order to optimize the dynamic distribution network. The analysis is based on the basic principles of distribution network planning technology. It summarizes the ant colony algorithm and the improved ant colony algorithm, and proposes an improved ant colony algorithm for the distribution network planning the mathematical model construction method, and finally verifying the example. The results show that the improved ant colony algorithm has more advantages than the traditional ant colony algorithm, and it is more in line with the basic principles. The digital model of the distribution network planning has been successfully implemented, and it has a good performance in the calculation examples. The application of improved ant colony algorithm to optimize the planning of dynamic distribution network can improve the quality of the planning scheme, indicating that the algorithm has higher application value.

Keywords: Ant Colony Algorithm, Improved Ant Colony Algorithm, Dynamic Distribution Network Optimization Planning

Introduction

In the traditional dynamic distribution network optimization planning work, workers generally use ant colony algorithm to carry out their work, but soon people found the ant colony algorithm, but the shortcoming is that the algorithm is easy to fall into the dynamic distribution network optimization planning. "Dimensional disaster" and the "trap" of the local optimal solution lead to quality problems in the results of dynamic distribution network optimization planning. Therefore, how to optimize the dynamic distribution network optimization planning is the main research object in related fields. After a long period of research, modern researchers have proposed an improved ant colony algorithm. This algorithm has more advantages than the general ant colony algorithm and has been widely used. The research in this paper mainly focuses on the application of the improved ant colony algorithm. The method and application performance are analyzed to verify the use value of the improved algorithm.
1. **Technical Principles of Distribution Network Planning**

First, the principle of reliability

At present, China's distribution network has problems such as outdated equipment and low voltage quality. These problems will cause the reliability of the distribution network to decrease. Therefore, the planning technology used in the dynamic optimization planning of the distribution network must have the ability to improve the distribution network Reliability function Grid reliability is one of the principles of reliability. At the same time, as far as the distribution network planning technology itself, if there is a reliability problem in the distribution network planning technology itself, there will be a problem of unstable technical efficiency. The energy efficiency of this technology is flawed. The use of this technology will only have the opposite effect. In short, the planning technology must meet the principle of reliability in the dynamic distribution network optimization planning [1].

Second, the reasonable capacity-load ratio principle of the distribution network

The capacity-to-load ratio of the distribution network refers to the maximum load ratio of the available distribution network under the conditions that the reliability of the distribution network is met. It corresponds to the available capacity and can be used to calculate the power supply capacity and macro-control of the power grid. The role of variable capacitance. However, if the distribution network planning technology is applied too much, the distribution network capacity will be too large, which will cause the available grid capacity to be too large, causing the grid construction costs to be invested prematurely. If the distribution network capacity is too small, it will lead to insufficient available capacity, affecting the adaptability of the power grid, prone to power outages and blackouts, and increasing the difficulty of power dispatching. The distribution network planning technology used in the dynamic optimization planning of the distribution network must have guarantees the function of the distribution network capacity ratio is reasonable, which is the embodiment of the rationality of the distribution network capacity ratio.

Third, the principle of meeting user needs

Under the application of any kind of distribution network planning technology, the distribution mode of the distribution network will change. This change will inevitably lead to changes in the power supply mode. At this time, if the power supply network fails due to the impact of the technology, some users the power voltage quality changes, affecting the normal power consumption of users, and the power demand may not be met. This is a typical quality problem of the distribution network and easily causes complaints from power users. Therefore, any kind of distribution network planning the use of technology must ensure that the distribution network can meet the needs of users, which is able to meet the needs of users.

Fourth, reactive power compensation of distribution network

Inductive current is easily generated during the operation of the distribution network. This current is reactive current. The presence of reactive current will bring certain reactive power loss to the operation of the power grid, leading to problems such as shortening the service life of power grid equipment and reducing Work power. The greater the losses in the distribution network, the more reactive power compensation must be done in the planning of the distribution network. In this case, the distribution network planning technology must be compatible with and monitor the reactive power compensation device, which is the embodiment of the reactive power compensation principle of the distribution network.

Fifth is the best cost, the best investment cost, operating cost, and efficiency****

The ant colony algorithm described below is to summarize and analyze the investment under different operating conditions such as different reliability, capacity-to-capacity ratio, and reactive power compensation, and propose the optimal method. Therefore, there should be descriptions of cost, discount rate, unit electricity price, investment in different planning schemes, construction time limit, equipment use time limit, etc., in order to reflect the relationship between ant colony algorithm and planning in the paper.
2. Ant colony algorithm and improved ant colony algorithm

2.1 Basic Theory of Ant Colony Algorithm

The ant colony algorithm is a bionic algorithm, that is, the researchers found that the ants will always find the shortest foraging path in the process of watching the ants foraging. The reason for this phenomenon is that when the ants forage, they will use a random chaotic model to act, and then call your companions through your own pheromone. Finally, more and more ants will gather on the shortest path. According to the principle of ant foraging, if the ants are compared to an operator, the "length" of each path can be obtained through multiple calculations, and the pheromone is left according to the calculation result. The shorter the road, the higher the pheromone concentration left. So that other operators can be gathered to enter the road, and play the role of aggregating operators. Finally, when all operators are gathered on the same road, the optimal solution on the road is explained.

In principle, assuming that ant k is located at point i, point j can be accessed according to formulas (1) and (2).

Formula (1): $j = \left\{ \begin{array}{ll} \text{arg max} \left( \left\{ \tau_{ij}(t) \right\}^\alpha \cdot \left( \eta_{ij} \right)^\beta \right) \right\}, & q \leq q_0 \\
\text{otherwise} & j \in \text{allowed}_k
\end{array} \right.$

Formula (2): $p_{ij}(t) = \left\{ \begin{array}{ll} \frac{\tau_{ij}(t)^\alpha \cdot \eta_{ij}^\beta}{\sum_{p \in \text{allowed}_k} \tau_{ip}(t)^\alpha \cdot \eta_{ip}^\beta} & j \in \text{allowed}_k \\
0 & \text{otherwise}
\end{array} \right.$

In the formula, $\tau_{ij}(t)$ the pheromone representing the $(i, j)$ edge arc; $\eta_{ij}$ the point distance between points; $q \in [0,1]$ the random number; $\alpha, \beta, q$ the user-defined parameter, $\alpha, \beta$ which is the probability of the ant choosing a road under the action of the accumulated information and information inspired by the ant colony operation; $q_0 (0 \leq q_0 \leq 1)$ The importance of verifying information with new paths. At that time, the ants would choose the road based on the verification information, and if this condition was not met, they would choose the road according to J's random ratio.

The rules of the ant colony algorithm are:

(1) Perceived range
From the perspective of the ant, it observes that everything is a square. Therefore, the relevant parameter in the ant’s world is the radius of the speed. The value is generally 3, and the range of its observation and movement is 3x3 squares [2].

(2) Environmental information
When an ant encounters anything during its action, it will leave a corresponding pheromone. For example, if an ant encounters food, it will leave food pheromones, and if it encounters an obstacle, it will leave obstacle pheromones. These pheromones can help ants identify the actual situation, while helping other ants identify. In addition, the pheromone disappears at a certain rate, and the disappearance time is determined by the pheromone intensity [3].

(3) Foraging rules
According to the pheromone, when the ant perceives the food pheromone during the foraging process, it will move in the direction of the pheromone. If two or more food pheromones occur at the same time, it will move in the direction of the higher pheromone concentration. In addition, ants do not necessarily move in the direction of the largest pheromone during foraging, and there will be a small probability of errors [4].

(4) Movement rules
If the ants do not have pheromone guidance during the movement, they will advance in the original...
direction according to the principle of inertia, which can prevent the ants from turning in place. At the same time, the ant will remember the nearest place during the movement.

(5) Obstacle avoidance rules
If the ant encounters an obstacle during the movement, it will randomly choose another direction to move until it avoids the obstacle. This rule is lower than the principle of improving pheromones, that is, if there are pheromone guidelines, the obstacle avoidance rule does not take effect [5].

2.2 Introduction to Improved Ant Colony Algorithm
Faced with the shortcomings of ant colony algorithm, an improved ant colony algorithm was obtained through the work of researchers. The difference between this algorithm and ant colony algorithm is that the pheromone on all roads is restricted, and the limit interval is \([r_{\text{min}}, r_{\text{max}}]\). Among them, \(r_{\text{min}}\) can effectively avoid the stagnation of the algorithm and solve the problem of local optimal solution; \(r_{\text{max}}\) can effectively avoid the phenomenon of too much information on a road and solve the problem of "dimensional disaster". With the application of the improved ant colony algorithm, all roads will be calculated in a loop, and a certain amount of roads will be screened to "too long". After the loop is completed, the shortest road will be obtained, and only the ants on the shortest road will be in each loop. \(k\) can \(\tau_0(t)\) The modification strategy is shown in formula (3).

\[
\tau_{ij}(t + n) = \begin{cases} 
\tau_{\text{min}} & \\
\tau_{ij}(t) & \\
\tau_{\text{max}} & 
\end{cases}
\]

3. Construction of mathematical model for distribution network planning
Model according to formula (3). First, the pheromone intensity is determined by the road pheromone increment in each cycle. The pheromone increment value is taken from the ratio of the information intensity and the path length. At the same time, a random fuzzy value is obtained according to the pheromone performance coefficient and the pheromone intensity. Bringing the value into the cloud theory can go to the next step. Secondly, the cloud model is constructed according to the cloud theory, and then the cloud model is used to adjust the pheromone coefficient and the pheromone intensity to adjust the random fuzzy value. This can improve the convergence speed and global search ability of the algorithm. See the adjustment rules below.

(1) When a single qualitative connection rule does not find an optimal solution through successive \(T\) generations, a larger information volatility coefficient and a smaller information intensity are selected.

(2) When a single qualitative connection rule finds the optimal solution through successive \(T\) generations and promotes the algorithm update, a smaller information volatility coefficient and a larger information intensity are selected.

According to the above rules, the method for constructing a mathematical model for distribution network planning can be divided into six steps: (1) initialization parameter input; (2) \(N\) cycles; (3) several ant outputs; (4) load flow calculation; (5) function evaluation; (6) optimal solution generation in a single cycle.

4. Analysis of application examples of improved ant colony algorithm in dynamic distribution network optimization planning
A distribution network contains a total of 3 initial grid nodes and 2 branches, belonging to a 10kV distribution network. The grid needs to be expanded according to development requirements to form a distribution network with 10 nodes and 16 branches. On this basis, this paper first statistics the basic information of the power grid, and the results are shown in Table 1.
Table 1 Statistics results of basic information of calculation grid

| Statistical item               | statistical results |
|--------------------------------|---------------------|
| System equivalent runtime      | 3000h               |
| Discount rate                  | 7%                  |
| Unit electricity price         | 0.5                 |
| Service life of equipment      | 30 years            |

It can be known from Table 1 that the parameters of the improved ant colony algorithm in the application of the algorithm are: the number of iterations 100, ant colony 8, α 0.3, β 0.6, pheromone increment 0, = pheromone increment, = /1024. This rule was then controlled by Chint Cloud Rules. In the rule, the number of cloud drops is 100, the pheromone utilization factor is 0.5, the pheromone intensity is 0.2, and the continuous optimal solution constant algebraic threshold is 3. At the same time, the ant colony algorithm and the improved ant colony algorithm are used to calculate the distribution network planning, and two sets of planning solutions are obtained.

5. Advantages of Improved Ant Colony Algorithm

Compared with the improved ant colony algorithm, the convergence speed of the ant colony algorithm planning solution is slightly slower, and the improvement of the improved ant colony algorithm is faster. The ant colony algorithm planning scheme has a lower annual quarterly electricity price yield, and the improved ant colony algorithm has a higher annual quarterly electricity price yield. It can be seen that the improved ant colony algorithm is superior to the ant colony algorithm in two key indicators, indicating that the improved ant colony algorithm has more application advantages. Figures 1 and 2 show the results of the ant colony algorithm and improved ant colony algorithm planning solutions. Table 2 compares the optimization results.

Figure 1 Ant colony algorithm results

Figure 2 Improved ant colony algorithm results
Table 2 Comparison of optimization results

| Contrast item            | Ant Colony Algorithm | Improved ant colony algorithm |
|--------------------------|----------------------|-------------------------------|
| Total investment         | 113.6                | 110.5                         |
| Active power loss rate   | 91.36                | 82.25                         |
| Active loss cost         | 13.70                | 12.34                         |
| Electricity price income | 21.24                | 22.86                         |
| Minimum node voltage     | 9.6424               | 9.7732                        |

6. Conclusion

In summary, according to the analysis of this article, under the principles of distribution network planning technology, the distribution network planning results generated by the ant colony algorithm do not meet the principle of being able to meet user needs, indicating that the algorithm has defects, and the improved ant colony algorithm meets all the principles. It means that by improving the ant colony algorithm, the distribution network planning can reach the optimal solution, which has higher application value.

References

[1]. Rezaei G, Afshar M H, Rohani M. Layout optimization of looped networks by constrained ant colony optimisation algorithm[J].2014,70(7):123-133.
[2]. Li, Li Sheng, Zhang, Shi Dong, Ji,Xing Quan, et al. A Hybrid GA-ACO Algorithm for Distribution Network Planning Considering Distributed Generators[J].Applied Mechanics & Materials,2014,519-520:1425-1430.
[3]. Huang Min,Cai Na. On the problem of solving the optimization for continuous space based on information distribution function of ant colony algorithm[J].IOP Conference Series Earth and Environmental Science,2017,69(1):012121.
[4]. ZHOU Keping,ZHAI Jianbo. Application of improved ant colony algorithm in route optimization of underground mine's transportation[J].Journal of Central South University,2014,45(1):256-261.
[5]. Ghahreman Rezaei,Mohammad Hadi Afshar,Maryam Rohani. Layout optimization of looped networks by constrained ant colony optimisation algorithm[J].Advances in Engineering Software,2014,70:123 - 133.