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Research on Fault Reconfiguration of Shipboard Zonal Distribution System Based on Improved Moth-flame Algorithm

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Abstract

In order to improve the reliability of zonal distribution power system of ships, an improved moth-flame Optimization (MFO) algorithm is proposed in this paper. The positions of moths relative to flames are updated by ranking the positions of flame positions, and weights are added to make them an adaptive descent function, so as to jump out of the local minimum value and accelerate the convergence rate, and the corresponding fitness values are obtained respectively, so as to obtain the optimal flame positions, which can be used as the optimal reconfiguration path to achieve fault recovery. MATLAB is used to build the model of ship zonal distribution system, and the experimental simulation proves that the improved algorithm can improve the accuracy of finding the optimal reconstruction path and accelerate the convergence speed.

Keywords

Improved moth-flame Optimization algorithm; shipboard zonal distribution system; reconfiguration; fault recovery.

1. INTRODUCTION

The working conditions of the ship power system are complex, and the working environment is bad, so the electrical equipment is also vulnerable to negative impact. With the improvement of ship intelligence, the power system is becoming more and more complex [1]. In order to ensure the safe and reliable operation of ship power system, it is of great significance to study the fault recovery of distribution system.

So as to improve the continuity of power supply, we can reconfigure the path to restore the power supply [2]. In recent years, there are more and more researches on fault recovery of ship power system at home and abroad. In reference [3], an improved particle swarm optimization algorithm is proposed, which can improve the accuracy of fault recovery and the speed of fault reconstruction.

In reference [4], a Petri algorithm is proposed to realize fault reconfiguration by setting induction circuit and simplifying complex algorithm to distributed operation. In reference [5], integer coding strategy is used to generate a certain scale of initial group, then simplify the distribution network, solve the power flow by scanning algorithm, and reconfigured by leapfrog algorithm. In reference [6], a strategy of island division with depth and breadth for first search is proposed, and a reconfiguration model of dynamic behavior of thermal load is established. In reference [7], a harmony search adaptive algorithm is proposed, which randomly generates the initial group of response vectors, regenerates the new response vectors through rules and evaluation process, and updates them by comparing the new response vectors with the worst response vectors to obtain the optimal reconfiguration path. In this paper, an improved moth-flame algorithm is proposed to sort the flame position according to the fitness value of moth

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position, update the moth position, and add the weight factor of adaptive descent, so that the path searching can jump out of the local minimum value, and then get the global optimal reconfiguration path.

2. OPTIMAL DISTRIBUTION MODEL OF SHIPBOARD REGIONAL DISTRIBUTION SYSTEM

2.1. Objective Function

The ship zonal distribution system is composed of multiple regions, and the power generation units are connected to form a ring network. The loads in the zone are relatively concentrated, and the zones are connected by standby lines. The important loads can be supplied by both ends to improve the reliability of power supply. The priority of the loads is marked by 1, 2 and 3, respectively. When power supply is restored, the important loads are given priority. If the capacity is not enough, they must also remove the unimportant load to restore its power supply. During the reconfiguration, the minimum switching times of the circuit breakers and the minimum loss of power load are required to ensure the power supply continuity of the power system. Therefore, the switching times of the circuit breaker and the loss of power load are taken as the objective function.

(1) The goal is to minimize the switching times of circuit breakers during reconfiguration, and its objective function is:

$$\min K = \sum_{i=1}^{n_1} m_i + \sum_{j=1}^{n_2} (1 - m_j) \tag{1}$$

Where, M is the operation signal of the circuit breaker, indicating the opening and closing of the circuit breaker, represented by 0 and 1 respectively; K is the switching times of the circuit breaker.

(2) The goal is to minimize the power loss load, and its objective function is:

$$\min L_{SD} = \min(L_1 + L_2) = \sum_{i_1}^{n_3} (1 - m_i) L_x + \sum_{i_2}^{n_4} \lambda L_s \tag{2}$$

(3) Where, L_{SD} is all non-fault loads without power supply; L_1 is total relief load; L_2 is total load not restored; L_x is relief load; L_s is power supply load not recovered.

2.2. Constraint Condition

(1) The power supply of the generator is limited. Therefore, the load capacity to be restored shall be calculated during reconfiguration, which shall not exceed the limit of the power supply capacity. The expression is:

$$\sum_{i=1}^{n} S_i \leq S_{max} \tag{3}$$

(2) The voltage and line current of each node have constraints, which are expressed as follows:

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$$V_{\min} \leq V_i \leq V_{\max} \tag{4}$$

$$I_{\min} \leq I_i \leq I_{\max} \tag{5}$$

3. MOTH-FLAME OPTIMIZATION ALGORITHM AND ITS IMPROVEMENT

3.1. Moth-flame Optimization Algorithm

The moth-flame optimization algorithm is based on the moth flying with the light source, through horizontal positioning, and the light source to maintain the same angle of flight. When they are far away from the light source, it can maintain a straight-line flight, and when they are close to the light source, they will form a spiral flight [8], thus the algorithm is obtained, the convergence of this algorithm is good and conducive to finding the optimal solution.

In this algorithm, moth matrix M is moth position matrix, representing the possible solution, while OM matrix is the fitness value corresponding to the possible solution in M matrix; Flame matrix F is flame position matrix, representing the optimal solution, and of matrix is the fitness value corresponding to the optimal solution in F matrix, in the initial state, moth matrix and flame matrix have the same dimension [9].

The moth-flame optimization algorithm generates moth population through initialization at first, and calculates their corresponding fitness value. According to the order of fitness value from small to large, it generates flame position matrix and corresponding fitness value. Moths update their position around the corresponding flames, and updates moths' position according to the equiangular helix function in equation (6), which is expressed as follows:

$$M_i = S(M_i, F_j) \tag{6}$$

Where, M_i is the moth of number i, F_j is the flame of number j, and S is the equiangular helix function.

The function of equiangular helix function is shown in formula (7), which is expressed as follows:

$$S(M_i, F_j) = D_i e^{bt} \cos(2\pi t) + F_j \tag{7}$$

In the formula, b is the equiangular helix parameter; t is the random number in the interval of [-1,1], which represents the degree of distance from moth to flame, and -1 is the nearest position, and 1 is the farthest position; D_i is the distance from moth to flame. According to formula (8):

$$D_i = |M_i - F_j| \tag{8}$$

In order to avoid falling into the local optimal solution, it is necessary to rank the flames according to the fitness value from small to large, and the moth position is updated according to the corresponding flame position, while the number of flames needs to be adaptively reduced with the increase of the number of iterations, and finally the moth position will be updated around the flame with the best fitness value, according to formula (9):

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$$flame = round\ (N_f - k \times \frac{N_f - 1}{k_{max}}) \tag{9}$$

Where, N_f is the maximum number of flames; K is the current number of iterations, and k_{max} is the maximum number of iterations.

3.2. Improved Moth-Flame Optimization Algorithm

In order to avoid falling into the local optimal solution during the search of moth-flame optimization algorithm, inertia weight ω is added to the equiangular helix function of updating moth position, and formula (10) shows that:

$$S(M_i,\ F_j) = D_i e^{bt} \cos(2\pi t) + \omega F_j \tag{10}$$

Where, the weight ω is obtained from equation (11):

$$\omega = \sin(\frac{\pi}{2} \cdot \frac{k}{k_{max}} + \frac{\pi}{2}) \tag{11}$$

The weight ω value is in the range [0,1], and changes from large to small. In the early stage of search, the search range is wider to avoid missing the optimal solution. In the later stage of search, local search is carried out around the optimal solution obtained in the early stage of search, so as to improve the local search ability and convergence speed and quickly get the global optimal solution.

4. RECONFIGURATION METHOD OF SHIPBOARD ZONAL DISTRIBUTION SYSTEM

So as to speed up the convergence and improve the ability to find the global optimal solution, the improved moth-flame algorithm is used to search the reconfiguration path of the ship power system in case of fault, and large-scale search is carried out at the initial stage, and local search is carried out around the optimal solution at the later stage.

At first, initialization is carried out to randomly generate the possible solution population of the reconfiguration path, and the corresponding fitness value is calculated. By ranking the fitness value from small to large, the ordered matrix is assigned to the flame matrix. The first flame is the current optimal reconfiguration path, and the possible solution of the reconfiguration path is updated by the equiangular helix function. The inertia weight is added, the search range of the reconstruction path is expanded, and the corresponding fitness value is calculated. The search precision of the reconfiguration path is high, and then the number of flames is reduced by adaptively reducing the flame function. When the number of flames is less than the number of moths, the last moths update their positions around the worst solution in the flame matrix. At last, they update their positions only around the best reconfiguration solution, carry out iterative search, and get the best reconfiguration path. The reconfiguration flow chart is shown in Fig. 1, and the reconfiguration steps are as follows:

(1) Parameter initialization, setting the maximum number of moths and flames, the maximum number of iterations, and the equiangular helix parameter.

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(2) After initialization of the possible solution population, the possible solution population of the reconfigured path is randomly generated as the moth population, and the corresponding fitness value is calculated.

(3) According to the order of fitness value from small to large, the corresponding flame is assigned. The first flame in the flame matrix is the minimum fitness, which is the optimal reconfiguration solution obtained in the current search.

(4) According to equation (10), the possible solution of reconfiguration path is updated corresponding to the corresponding flame position.

(5) Record the current optimal flame fitness value and the current optimal reconfiguration path.

(6) According to equation (9), the flame adaptive reduction is carried out and the iteration is carried out.

(7) If the maximum number of iterations is reached, the optimal reconfiguration path is output, the circuit breaker is switched and the power supply is restored.

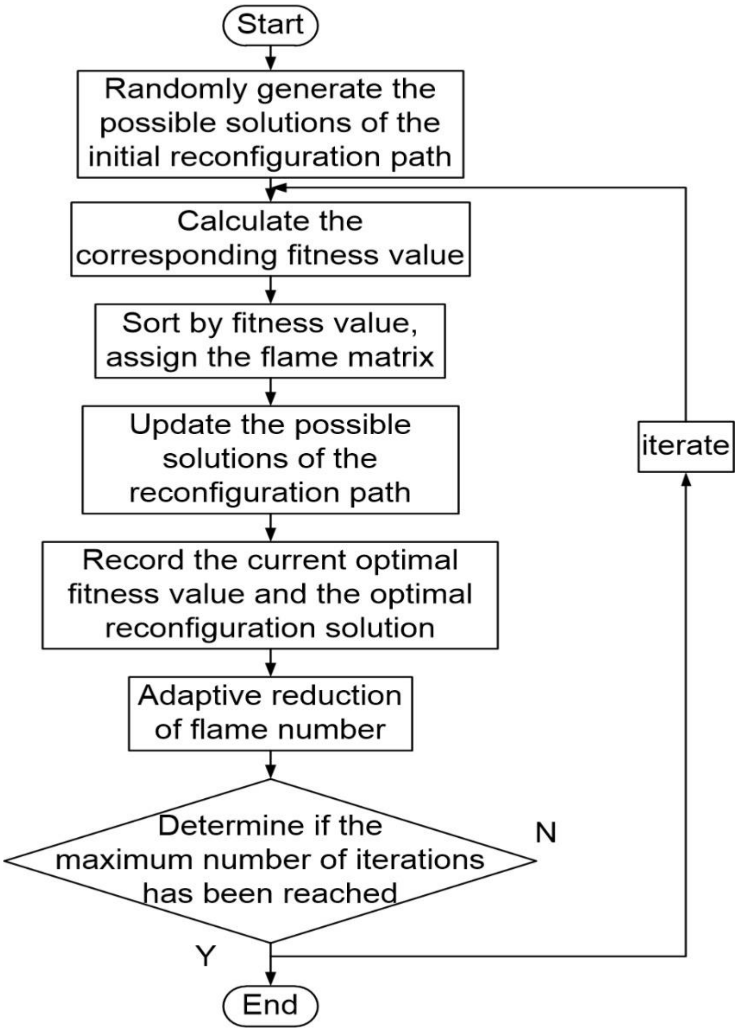

Figure 1. The flow chart of reconfiguration

5. EXAMPLE ANALYSIS

Through the simulation of shipboard zonal power distribution system by MATLAB, the fault modules are respectively set on the incoming line of the upper half of the zone 4, as shown in Fig. 2, and the fault modules are set on the primary side of one of the transformers in zone 1, as

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shown in Fig. 3, to simulate the two consecutive faults, find out the reconfiguration path by using the algorithm, and recover the power supply of the power loss load.

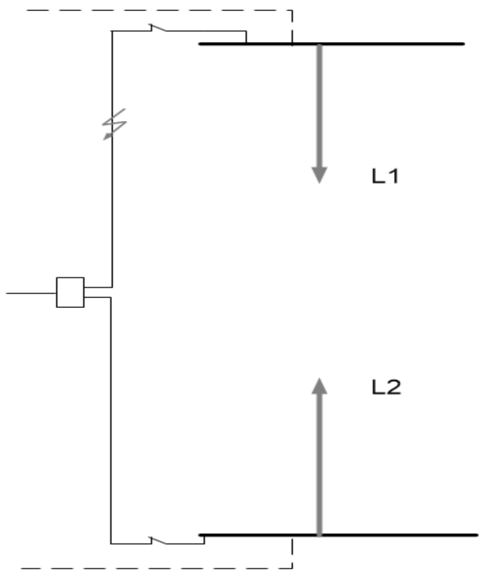

Figure 2. Fault setting diagram of incoming line in zone 4

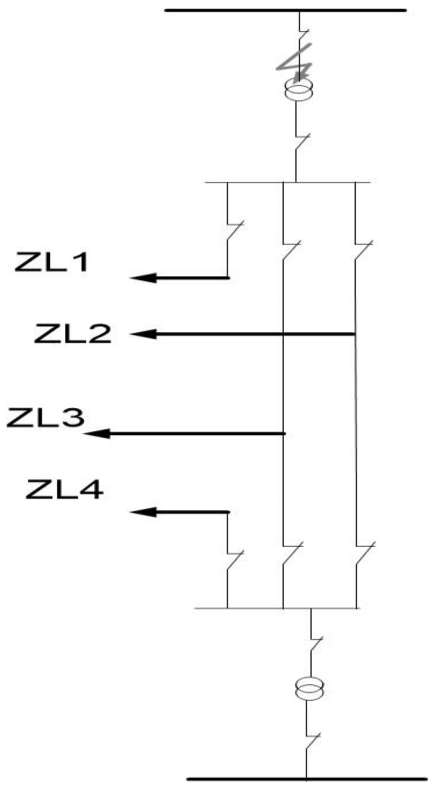

Figure 3. Fault setting diagram of transformer primary side in zone 1

According to the setting value and timing limit protection, when the line current exceeds the range of setting value, the fault is quickly isolated after delay, and the reconfiguration path is searched through the algorithm to recover the power supply of the lost load.

In zone 4, due to the failure of one of the incoming lines, the loads of half of the zone lose the power. After the pre-estimation of the load capacity, the generators that supply power to the adjacent zone have enough capacity to supply power to the power losing zone. Therefore, the upper half of zone 4 can be fully restored to power supply. The dotted line in Figure 2 is shown as the standby line. The power losing load is connected to the adjacent zone through the standby line, and restore power supply.

In zone 1, the load ZL1 and ZL2 are connected to the upper transformer, and the load ZL3 and ZL4 are connected to the lower transformer. When the primary side of the upper transformer fails, the load ZL1 and ZL2 lose power. Because the load ZL2 and ZL3 are important loads, the power supply can be obtained from both ends, but they cannot be supplied by both ends at the same time for avoiding circulation problems. Therefore, under this limitation, the reconfiguration path can't be found for the load ZL1 and the power supply can not be restored, while the circuit breaker above the load ZL2 can cut off and switches to the lower circuit breaker to obtain the power supply. Since the power is supplied by the generator that supplies power to zone 1 before, and after the reconfiguration, there is no need to estimate the load in advance and the reconfiguration can be carried out directly.

The reconfiguration results of two consecutive failures are shown in Table 1. The total number of switching times is 2, the total recovery load capacity is 1085.4KVA, and the power loss load capacity is 147KVA. It shows that the improved moth-flame optimization algorithm has strong ability to find the optimal solution, which can meet the objective function, minimize the number of switching times, and the capacity of loss of load, and has a high probability of obtaining the optimal reconfiguration path.

Table 1. The result of reconfiguration

The result of reconfiguration			
Total switching times	The capacity of recovery load	The capacity of power loss load	The probability of getting the optimal reconfiguration path
2 times	1085.4KVA	147KVA	100%

6. CONCLUSION

In this paper, the optimal reconfiguration path is found by the improved moth-flame optimization algorithm, and verified by the experiment of two consecutive faults at the incoming line and primary transformer side. The possible solutions of the reconfiguration path are sorted according to their corresponding fitness values. The first one is the current optimal reconfiguration path, and the possible solutions of the reconfiguration path are updated by the equiangular helix function. The inertia weight is added to the equiangular helix function, and the range of searching and searching speed are controlled by changing the weight, so that the weight changes from large to small, from the first large-scale search to the later local search, and the number of flames is adaptively reduced, and the accuracy and convergence speed of the optimal solution are improved. In this paper, the optimal reconfiguration path is found by using this algorithm to recover the power supply from the loss of power load. It is proved that the improved moth-flame optimization algorithm can recover the power supply through reconfiguration when the shipboard zonal distribution system fails.

REFERENCES

[1] S.L. XUE: Ship Power System and Automatic Control (Publishing House of Electronics Industry, China 2012), p.1-4.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0015

[2] R.R. DENG, D.M. YANG, Y.H. CHEN, et al. Research on Regional Distribution Technology of the Ship Integrated Power System with the New Power Supply, Ship Science and Technology, Vol. 39(2017) No.11, p.111-116.

[3] B. LI, W.L. ZHENG: Research on Reconstruction Algorithm of Fault Recovery in Power Distribution Network of Ship Power System, Ship Science and Technology, (2018) No.6, p.79-81.

[4] M. ZHAO, H.S. HOU, Y. LIU, et al. Research on Reconstruction Algorithm of Ship Power Grid Fault Recovery, Ship Science and Technology, Vol.40 (2018) No.14, p.104-106.

[5] X. DONG, Z. WU, L. CHEN, et al. Distribution Network Reconfiguration Method with Distributed Generators Based on an Improved Shuffled Frog Leaping Algorithm, 2018 IEEE PES/IAS PowerAfrica(Cape Town, South Africa, June 28-29, 2018) P.102-107.

[6] H. WANG, H. ZHANG,L. CHEN, et al. A Method of Distribution Reconfiguration with Micro Grid Considering Dynamic Behavior of Thermal Loads, 2018 International Conference on Smart Grid and Electrical Automation (ICSGEA) (Changsha, China, June 9-10, 2018) p.1-5.

[7] Z.V. MASOUD, O.S. MAHMOUD: A New Method to Reduce Losses in Distribution Networks Using System Reconfiguration with Distributed Generations Using Self-adaptive Harmony Search Algorithm, 2015 4th Iranian Joint Congress on Fuzzy and Intelligent Systems (CFIS) (Zahedan, Iran, September 9-11, 2015).

[8] Z.M. LI, Y.B. MO, S. ZHANG. A Novel Swarm Intelligence Optimization Algorithm: Moth-flame Optimization Algorithm, Computer Knowledge and Technology, Vol.12 (2016) No.31, p. 172-176.

[9] Y. WU, M.Y. WU, K. YANG, et al. Research on the Optimal Allocation Model of Regional Water Resources Based on the Improved Moth-Flame Optimization Algorithm, China Rural Water and Hydropower, (2019) No.09.