ISSN: 2251-9246
EISSN: 2345-6221

pp. 139:142

Multi-Objective Distribution Network Analysis Reconfiguration Considering Reliability of Power Supply Based on Particle Swarm Optimization

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Abstract

The distribution dispatcher can modify the overall distribution network configuration without additional investment and resource input by optimizing the switch combination, thus changing the distribution network operating structure. A multi-objective power distribution network reconfiguration model optimization algorithm is suggested in this article. The objective function is chosen as the minimum loss and the optimum reliability index of load balance and power supply, which can meet the conditions of load rate and voltage offset while reducing network loss and improving the efficiency and reliability of power. The objective function is chosen as the minimum loss and the optimum reliability index of load balance and power supply, which can meet the conditions of load rate and voltage offset while reducing network loss and improving the efficiency and reliability of power. Finally, an instance is given to check the efficacy of the proposed The multi-objective reconfiguration system of the network and the optimal solution collection of both security and reliability multi-objective network reconfiguration scheme are obtained.

Keywords: distribution network reconfiguration, multi-objective optimization, power supply reliability.
Article history: Received 25-Feb-2020; Revised 01-Mar-2021; Accepted 02-Mar-2021.

1. Introduction

Optimizing the operating mode of the distribution network can minimize losses and bring benefits, but the effects of load balancing, the quality of the power supply voltage and the safety and reliability of the network must be taken into account and are subject to certain constraints. Therefore, the objective function of optimizing the operating mode of the delivery network is not a single network loss, but a multi-objective problem of decision-making. As a significant measure of the optimization of the power network system, scholars at home and abroad have paid attention to network reconfiguration. The optimization purpose of network reconfiguration at present is typically to reduce power grid line loss and balance load. Popular distribution network reconfiguration algorithms[1-2], such as Analytic algorithm, Heuristic method, Method of branch switching[3-4], etc. With the improvement in power demand and the rapid increase in distribution management system (DMS) research in recent years, More scholars have paid more attention to the reconfiguration of the delivery network as an essential feature of DMS. The primary direction of their exploration is to find a search algorithm which can optimize the distribution network topology structure[5]. Reconfiguration of distribution networks is a multi-objective problem of nonlinear mixed optimization. A single purpose is used for most current algorithms.

Method of reduction of function or dimensionality to pick a main objective and treat all targets as constraints[6]. Multi-objective reconfiguration is seldom implemented, taking into account system safety and reliability. Distribution network reliability assessment specifically involves the empirical approach and the Particle Swarm Optimization (PSO). When the distribution system is complex, the sum of the equation increases exponentially with the number of components, while the complexity of the PSO is not affected. Of the scheme. In this article, for reliability calculation, the PSO of equal distributed sampling is used. The sampling sum is significantly decreased and the measurement time is saved on the basis of ensuring the accuracy of the data. The minimum line loss and the reliability index are taken as the key objectives on this basis, and the requirements of load rate and voltage offset are met [7].

2. Distribution network reconfiguration model

A) Objective Function

The objective function of the distribution system's network reconfiguration is to minimum the loss of power and to maximum the power supply reliability indices[8].

$$P_{loss} = K_i \sum_{i=1}^{n} I_i^2 * R_i \quad (1)$$

$$F_1(X) = \min(P_{loss}) \quad (2)$$

Where P_{loss} is the system's active power loss, ki=1 means branch i is in the closed state, ki=0 means branch i is in the open state, Ii is the current flowing through branch i, Ri is the branch i resistance, the system has n branches.

$$\text{EENS} = \sum_{i \epsilon R} P_{ai} U_i \quad (3)$$

$$F_2(X) = \min(EENS) \quad (4)$$

$$ASAI = \frac{(\sum N_i * 8760 - \sum Ui\ N)}{\sum N_i} * 8760 \quad (5)$$

$$F_3(X) = \max(ASAI) \quad (6)$$

where, ASAI is the Average System Availability Index and EENS is the Expected Energy Not Served, Ni is the number of customers at load point i, Pai is the average load point i, Ui is the annual interruption duration; 8760 hours are the annual hours.

B) Problem restrictions

Power balance constraints, Kirchhoff voltage law constraints, line limit constraints, voltage limit constraints are distribution network line constraints. The conditions for constraints are as follows:

$$V_{j,min} < V_j < V_{j,max} \quad (7)$$

$$V_i - V_j = Z_{ij} i_{ij} \quad (8)$$

Where Vj,max and Vj,min are the upper and lower limits of node j voltage respectively, zijiij are branch ij impedance and current respectively.

$$I_i \leq I_{j,max} \quad (9)$$

Ij,max is the maximum current allowed to flow through branch i.

$$\sum_{i=1}^{k} (P_{ij} + jq_{ij}) = P_{dj} + jq_{dj} \quad (10)$$

Where pij and qij are the active and reactive loads of line ij, pdjand qdjare the active and reactive loads of node j.

3. Reliability evaluation of distribution network

In order to determine the efficiency of the power system, the PSO approach is currently commonly used. It mainly consists of three components in the application process: system state sampling, system state interpretation, and statistics on system evaluation indices. The primary steps in its assessment are shown in Fig. From 1 below.

Pursuant to Fig. 1, we need to begin with random state sampling of the system when applying the PSO. We may randomly sample the system's state, not involving the state's length and transfer rate. Higher accuracy in the assessment process is expected.The sampling algorithm can be improved in the sampling process to decrease the contrast and increase the measurement accuracy.

The state of the test function needs to be evaluated and measured after the completion of the device state sampling, and the measurement form of the test function corresponds to the indices of the reliability assessment. The analysis of the state of the transmission system is primarily based on two aspects: on the one hand, the analysis of the power flow of the transmission system is important to determine if there is a fault in the system; on the other hand, the analysis of the power flow system is based on the optimization of the actual state of the system, the removal of the fault state of the system, and the stable operation of the system.

Improving the sampling method is important to improve the speed and accuracy of the PSO simulation. There are a number of productive methods of improvement at present. The operating state of the power system is sampled in this experiment by the process of equal-scatter sampling. The following are the basic sampling steps:

1) Initialize the population, location, random velocities, iterations of Pbest, Gbest and Limit, and the matrix from which the values of the switch are chosen.

2) The weight of inertia is determined, the velocity is updated and the positions of the subdivisions are updated.

3) Radiality limit is verified, followed by the Pbest's fitness feature calculation. If the estimated fitness function is lower than the previous best value, Pbest is modified.

4) Similarly, Gbest's fitness feature is evaluated and it is modified if the value is less than that of the previous version.

5) If the maximum iterations are reached or if no new better shapes are found, the search algorithm is terminated.

6) Change the speed of the subdivisions using the preceding speed, the distance to Pbest and the distance to Gbest in equation 12, if the conditions are not met.

7) The location of the subdivisions from the supplied switches is changed. The algorithm is performed from step 3 by this new position regular and speed. Fig. 1 displays the suggested PSO flowchart for reconfiguration.

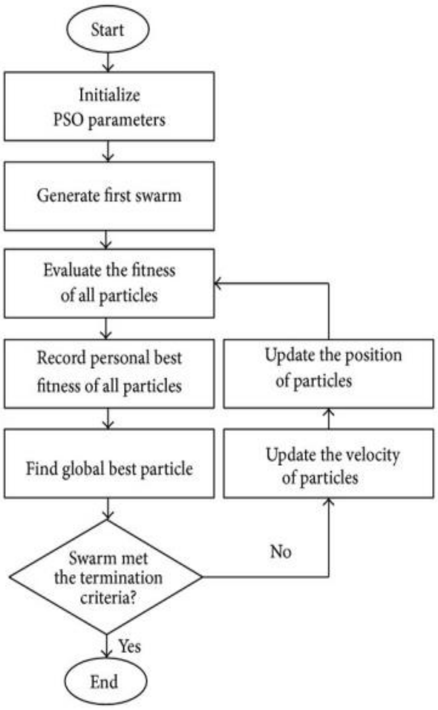

Fig. 1. Basic Flowchart of BPSO

4. An example of multi-objective reconfiguration

The 12-node system in literature is used in this paper as an example to validate the process in this paper. In the instance of the overhead line failure rate, the rate of overhead line failure is 0.00276 f/yr.km and the average repair time is 12.6 h. The failure rate of the transformer is 0.0024 f/yr and the estimated repair time is 26.3068 h. The operating time of the insulation switch is 1h, and 1h is the operating time of the alternative power supply[2]. The structure of the topology of the network frame is shown in Fig. 2. Under different constraints, ten reconfiguration schemes are performed under the reconfiguration calculation of the example to satisfy the initial requirements. The reliability indices of the ten reconfiguration schemes are determined on the basis of equally distributed sampling using PSO. In Table I, the results are shown.

According to the estimate, in Scheme 1, 2, 3, 5, 6, 8 and 9, the load rate of some lines reached more than 70 percent, making the lines run under heavy load and unable to meet the safety and economic requirements. Plans 4, 7 and 10 are then chosen as the final goals.In order to compare the weights of each index in each scenario, the analytic hierarchy method model is implemented and the expert score is added. The optimum reconfiguration method is obtained and Table II displays the results. Additionally, the product of the final grid reconfiguration is shown in Fig. 3.

AISI and EENS scored the highest of all metrics, according to the BPSO algorithm, as can be seen from Table II, while the network failure in item 4 increased by 2.84 percent and 1.28 percent relative to the other two cases, and the AISI reliability index also decreased. The voltage offset for item 10 is lower than for item 7, but the voltage offset for AISI and EENS is lower than for item 4. In view of the effect of different variables, using the BPSO algorithm, item 7 is the best scheme. It can be shown that the effect of multiple factors should be considered comprehensively in the actual reconstruction of the distribution network, and the single factor is far from meeting the actual demand.

5. Conclusion

As the objective feature, the conventional distribution network reconfiguration model is based on minimal line loss, does not take into account the

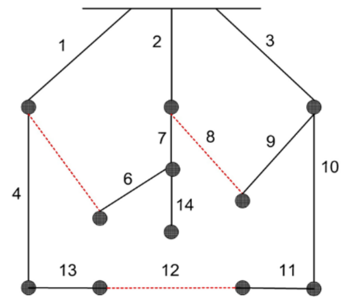

Fig. 2. 12-Node system initial grid construction

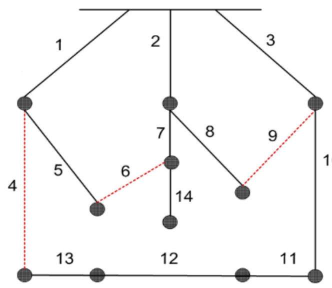

Fig. 3. Structure of the final reconfguration

Table.1.
The results of system reconfiguration

Alternative	Closed	open	Loss P	Loss Q	AISI	ENS	Voltage Offset
1	1-2-3-4-6-7-9-10-11-13-14	5-8-12	0.761	0.91	0.999965	81.14	-1.12
2	1-2-3-5-6-7-9-10-11-13-14	4-8-12	0.958	1.09	0.999964	82.21	-1.24
3	1-2-3-4-5-7-9-10-11-13-14	6-8-12	0.741	0.89	0.999964	81.32	-1.05
4	1-2-3-4-5-8-9-10-11-12-14	6-7-13	0.791	0.89	0.999962	84.78	-0.98
5	1-2-3-4-5-7-8-10-11-13-14	6-9-12	0.782	0.92	0.999964	80.54	-1.13
6	1-2-3-4-5-8-9-10-12-13-14	6-7-11	0.783	0.98	0.999965	79.14	-1.39
7	1-2-3-5-7-8-10-11-12-13-14	4-6-9	0.925	1.05	0.999963	82.98	-1.21
8	1-2-3-4-5-7-8-11-12-13-14	6-9-10	0.850	1.07	0.999963	83.43	-1.47
9	1-2-3-4-5-7-8-10-12-13-14	6-9-11	0.715	0.86	0.999963	84.27	-1.04
10	1-2-3-4-6-7-8-10-11-13-14	5-9-12	0.862	1.11	0.999965	81.93	-1.19

Table.2.
Comprehensive consideration of optimal conditions

Alternative	Closed	open	Loss P	Loss Q	AISI	ENS	Voltage Offset
4	1-2-3-4-5-8-9-10-11-12-14	6-7-13	0.791	0.89	0.999962	84.78	-0.98
7	1-2-3-5-7-8-10-11-12-13-14	4-6-9	0.925	1.05	0.999963	82.98	-1.21
10	1-2-3-4-6-7-8-10-11-13-14	5-9-12	0.862	1.11	0.999965	81.93	-1.19

line load rate, voltage offset and other issues, and can not satisfy the criteria for system protection and reliability.This paper also considers the reliability of the system, in addition to considering the security of the system. The ideal system of reconfiguration is suggested and is more realistic. The reliability assessment method of the distribution network, under the assumption of ensuring the precision of the measurement results, significantly reduces the sampling times and saves the calculation time when measuring the device reliability in this article, based on the equal dispersion sampling PSO. In order to simplify the implementation of the required algorithm, an example study of the distribution network reconfiguration is performed using the 12-node method as proof. The result significantly reduces network failure, optimizes the voltage amplitude, increases the device reliability indices, and obtains the optimal solution set of multi-target grid reconfiguration scheme considering both protection and reliability by comparing the data before and after reconfiguration.

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