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Load Balancing Distribution Network Reconfiguration Based on Binary Particle Swarm Optimization

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Abstract

A reconfiguration model for the distribution network with the optimization objective of reducing three-phase disequilibrium is suggested in order to cope with an increasingly serious three-phase unbalance in distribution network. Second, the distribution network reconfiguration problem is transformed into a problem of constructing the spanning tree of the graph by evaluating the distribution network in topology, which is solved by the process of breaking-cycle-basis. Then an improved Binary Particle Swarm Optimization (BPSO) algorithm is suggested to solve the reconfiguration problem by randomly choosing the first-branch and canceling the heuristic value of the network, which will extend the search scope and prevent search stagnation. Relevant examples of verification show that, relative to traditional approaches, the proposed algorithm can achieve the best global solution with less computational time and greater probability. The proposed algorithm is tested in 33 bus system and the results show the load balancing distribution network.

Keywords: Load Balancing, Distribution Network Reconfiguration, Three-Phase Unbalance, Binary Particle Swarm Optimization.
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1. Introduction

Distribution systems (DSs) are typically closed-loop designed and run with an open-loop layout comprising a large number of section switches and a few touch switches. By adjusting the state of these delivery network reconfiguration switches, the network structure can be transformed and the operation parameters optimized. It is an efficient way to minimize distribution network losses, balance load, remove overload, and increase the efficiency of the power supply [1].

A non-linear combined optimization question that can be modelled as a non-deterministic polynomial difficult problem is the optimal configuration of switches in the distribution network. The algorithms can, so far, be divided roughly into the following categories:

- The standard mathematical optimization algorithm [2], which uses current mathematical optimization to explicitly reconfigure the distribution network. The approach would, however, face a "combinatorial explosion" issue with the increase in dimension, and make it difficult for practical use.
- Heuristic methods, which primarily include the method of optimal flow pattern [3] and the method of branch exchange[6-8]. Computing speed is greatly enhanced due to the combination of physical properties of the reconfiguration problem in delivery networks. But the outcome of the reconfiguration is often influenced by the order and the initial state of the network switches. Moreover, in the context of mathematics, each optimization only searches for a part of the subspace of the entire solution, missing global optimality.
- Algorithms of artificial intelligence, such as the simulated process of annealing, genetic algorithm and taboo algorithm, resistant algorithm, family eugenics, etc. This sort of approach works well to ensure that the optimal global solution is obtained. Therefore, these approaches have evolved rapidly in recent years. There are some apparent shortcomings, however, such as some parameters that are difficult to decide, which change with the network size. In addition, these strategies are cumbersome and cost a great deal of time [4-5].

In this paper, a new distribution network reconfiguration technique based on a BPSO algorithm is suggested to balance the load. The BPSO algorithm, with voltage and power flow constraints, calculates the state of section switches and loop switches. Then the load balance index calculation in various networks is the optimal solution, the smallest one.

2. Distribution Network Reconstruction Model

Distribution network reconfiguration is to fulfil the restrictions of distribution network operation by adjusting the state of switches in the network and makes one or a few distribution system artefacts best. Load impel acne can be expressed in this paper as a three-phase load balance by the load balance index (LBI) given by:

$$LBI = \frac{1}{n}\sqrt{\sum (S - S_i)^2} \; , i = 1 \dots n \tag{1}$$

$$Ai = I \tag{2}$$

$$U_{LK} \le U_K \le U_{UK} \tag{3}$$

$$S_i \le S_{imax} \tag{4}$$

$$S_t \le S_{tmax} \tag{5}$$

$$g \in G \tag{6}$$

Where n is the number of main feeders. Si is the standardized load of feeder i (namely the actual load divided by the load limit). S is the mean value of the standardized load Si. Distribution network reconfiguration, including tidal current constraints, voltage constraints, branch power constraints, transformer capacity and radial activity constraints, etc., should satisfy the restriction conditions.

In practice, in the form of a penalty function, the disadvantages of inequality are generally converted into unconstrained conditions. To balance the load, feeder reconfiguration is used in the power distribution system. During switch rearrangement, the following principles must be met in addition to electrical restriction conditions:

- In the network, the radial structure must be preserved.
- There is not an island there.
- Except for the opening/closing of the switches, network topology should remain the same.

3. Binary Particle Swarm Optimization

His unit examines the fundamentals of Binary Particle Swarm Optimization and then formulates an intelligent BPSO-based search technique and finds all practicable distribution system configurations that fulfill the objective function. The algorithm preserves a subdivision population, each preserving a distinctive answer. The subdivisions are connected to a randomized speed and are flown through the space of the multi-dimensional search. The initialized subdivision population with random position X_i, velocity V_i and objective function F_i are appraised as input parameters using positional synchronizes and population dimension. Every subdivision keeps track of its location and is called Pbest, which is the best value, achieved so far. At the same time, Gbest is stored as the overall best value obtained by any subdivision so far.

The weight of inertia dynamically affects the effect of the previous velocity on the subdivision's current velocity. Experimentally, the decreasing assessment of inertia weight lengthways the iterations is shown to trigger linear exploration and exploitation.

$$V_{ij}^{t+1} = W * \; V_{ij}^{t} + \; C_1 r_{1j}^{t}\left[P_{best} - X_{ij}^{t}\right] + \; C_2 r_{2j}^{t}\left[G_{best} - X_{ij}^{t}\right] \tag{7}$$

where,

v_{ij}^t is the subdivision's speed

x_{ij}^t is the subdivision's situation

C_1 is the rational parameter and C_2 is the community parameter that reflects the weighting of the term of stochastic hastening that pulls each subdivision respectively to Pbest and Gbest. r_1 and r_2 are the accidental values that ranges from 0 to 1.

$$x_{ij}^{t+1} = \begin{cases} 1, & if \; u_{ij}^t \; < \; s_{ij}^t \\ 0, & if \; u_{ij}^t \; \ge \; s_{ij}^t \end{cases} \tag{8}$$

Where u_{ij}^t is the random number selected from a identical distribution in (0,1), and s_{ij}^t is the sigmoid function denoted by,

$$s_{ij}^t = \frac{1}{1 + \; e^{-V_{ij}^{t+1}}} \tag{9}$$

This function transforms values from incessant to separate. The overhead function differs, so that the values are selected from the set of switches provided by the bus system. The following are the basic sampling steps:

- Initialize the population, location, random velocities, iterations of Pbest, Gbest and Limit, and the matrix from which the values of the switch are chosen.
- The weight of inertia is determined, the velocity is updated and the positions of the subdivisions are updated.
- Radially 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.

- Similarly, Gbest's fitness feature is evaluated and it is modified if the value is less than that of the previous version.
- If the maximum iterations are reached or if no new better, shapes are found, the search algorithm is terminated.
- 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.
- 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. Figure 1 displays the suggested Binary Particle Swarm Optimization flowchart for reconfiguration.

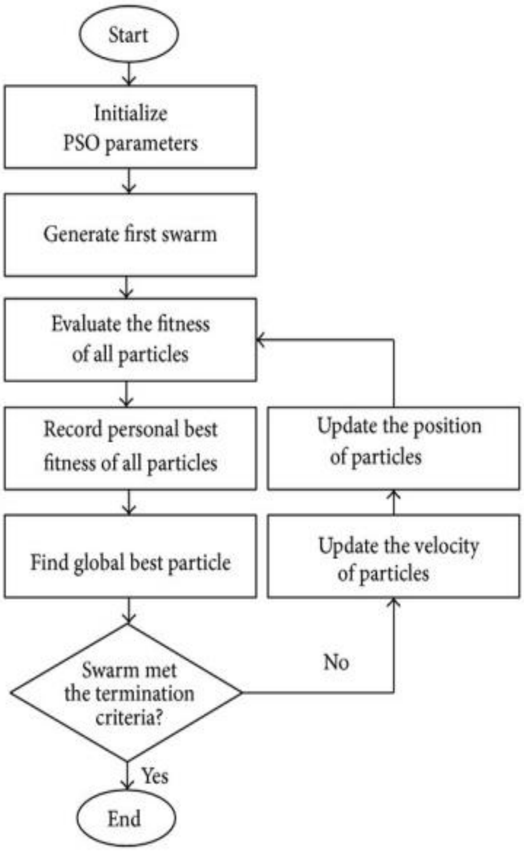

Fig. 1. Basic Flowchart of BPSO

4. Distribution Network Topology Analysis Based On Graph theory

One of the major limitations of the reconfiguration of the delivery network is that there are no closed loops and islands in any operating mode. 'No closed loops' implies that there is only a way for any two nodes to be connected. And "no islands" implies that the nodes are linked to all of the branches.

According to the concept of trees in graph theory, if G doesn't have loops, the graph G itself is a tree. If G has a loop, delete all of the loop's e-branches. If G-e is still linked, repeat the operation above until you get the "spanning tree" subgraph G without loops. In a term, its spanning tree can be obtained for the related graph G by removing each side of the loops in turn. The split circle approach is also called this technique.

The reconfiguration of the distribution network resolved by the split circle approach takes full account of sparse matrix structure characteristics. We can indirectly obtain the spanning tree by solving the branch sets of the graph according to the definition of graph theory. And the method requires only two steps, one is to decide whether the candidate branch is in the other loops, the other is cyclical. So having the spanning tree is a highly efficient and accurate process.

5. Numerical Examples

The IEEE 33 bus distribution network's single line diagram is shown in Fig 2. The network contains of 37 branches and 33 buses, which also include 32 sectionalizing switches (normally closed) and 5 tie switches (normally opened).

A) *Contrast, by hormone or randomization, of first-branch selection:*

The findings are illustrated in the table. I, which means that by randomization, first-branch selection is much stronger than that by pheromone.

B) *Benchmarking with other algorithms:*

The results of the proposed algorithm are shown in Table. II as compared to other algorithms. We can see that the proposed algorithm has greater potential for optimization, and after 8 to 10 iterations, it can achieve convergence. That is to say, at around 10 times of the power flow estimate, the algorithm can achieve the optimal solution. This algorithm will reach the optimal global solution with the highest likelihood, compared to the other two algorithms that can converge 20 to 50 times.

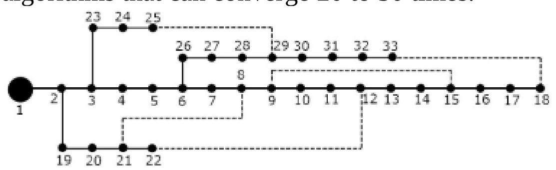

Fig. 2. Single line diagram of 33 bus system before reconfiguration

Table.1.
Results of first-branch-selection by hormone or randomization

Parameter	***First-branch-selection by pheromones***	***First-branch-selection by randomization***
Minimum value	0.1842	0.1574
Maximum value	0.4357	0.1712
Average value	0.1968	0.1627
Standard deviation	0.3339	0.0123

Table.2.
Comparison of the distribution reconfiguration

Parameter	***Disconnected Switches***	***LBI***
Before Reconfiguration	5,12,22	0.2523
Genetic Algorithm	7,15,18	0.1812
Method of this Paper	6,11,24	0.1674

6. Conclusion

In this paper, the problem of reconfiguration of the distribution network was further studied in accordance with the graph theory and the BPSO algorithm characteristics. To quickly obtain the spanning tree, a broken circle technique is suggested. Moreover, to solve the reconfiguration problem, which has implemented the method of first-branch selection by randomization, an enhanced BPSO algorithm is suggested. The results show that this algorithm has a rapid search speed and a higher probability of selecting those parameters to obtain the global optimal solution.

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