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Distribution Network Reconfiguration Based on Niche Binary Particle Swarm Optimization Algorithm

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Abstract

Distribution network reconfiguration is an important tool to optimize the operating conditions of a distribution network. Niche Binary Particle Swarm Optimization (NBPSO) Algorithm is proposed to overcome the defect of Particle Swarm Optimization prematurity for distribution network reconfiguration. In view of distribution network switch location in order, the weighted hamming distance is redefined for dividing different niche groups. Different niche groups are optimized using PSO, and particles in renewal groups are adapted by sharing mechanism. An IEEE 33-bus radial distribution test system is taken as a study system for performing the test. The results reveal the strong global searching of the proposed method for solving the problem.

*Keywords:*DistributionNetwork;Network Reconfiguration;Niching Techniques;Particle Swarm Optimization;

1. Introduction

Distribution networks are charactered with closed-loop design and open loop operation. They hold numerous the sectionalizing switches (normally closed) and tie-switches (normally open). The network reconfiguration is carried out by changing the on/off status of the sectionalizing switches and tie-switches to achieve goals such as the reduction of power loss, load balancing, eliminating overload lines and stabilizing the voltage quality in normal operating conditions [1].

Distribution network reconfiguration is a highly complex nonlinear combinatorial optimization problem, which is proved to be NP-hard. Different approaches have been used to solve the problem, and are divide into three classes so far as follows:(1)Mathematical Optimal;(2) Heuristic Search;(3)Artificial Intelligence, such as Genetic Algorithm[2],Particle Swarm Optimization Algorithm[3], plant growth simulation algorithm[4].

Considering numerous switches in distribution network, Distribution network reconfiguration is a NP-hard problem with plenty of local minimums. Niche Binary Particle Swarm Optimization Algorithm is proposed to solve it. The algorithm fully utilizes good global searching of PSO and local searching of niche technology, in order to overcome the defect of PSO's prematurity for distribution network reconfiguration.

2. mathematical model for distribution network reconfiguration

Distribution network reconfiguration selects section switches and tie switches as controlled object and changes their on/off status under node voltage constraint, branch current constraint, and radial network constraint, in order to reduce losses, eliminate overload lines and improve the power supply reliability.

With satisfying operating constraints, mathematical model of distribution network reconfiguration by the optimal multiple objective function is set up. Multiple objective function globally considers power losses and loads balancing

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and is as follows.

$$F = a_1 F_{\mathrm{L}} + a_2 F_{\mathrm{B}} \tag{1}$$

In above formula:(1) F_L is power loss function

$$F_{\mathrm{L}} = \frac{1}{P_{\mathrm{L}\Sigma}} \sum_{i=1}^{n} R_i \frac{P_i^2 + Q_i^2}{V_i^2}$$

Where: R_i is resistance of the line i.$P_{L\Sigma}$ is the sum of network active power.n is the number of network nodes.
(2)F_B is loads balancing function normal operations. It applies between different transformers and between different feeder lines.

$$F_{\mathrm{B}} = \frac{1}{n_{\mathrm{t}}} \sum_{j=1}^{n_{\mathrm{t}}} \left| \beta_j - \beta_{\mathrm{ave}} \right|$$

Where: n_t is the number of components, including transformers, feeder lines or the branch line.β_j is rate of load for component j.β_{ave} is mean rate of load for network.S_j,S_{jmax} is respectively actual load capacity and the maximal permissible load capacity for component j.
(3) a_1 is weighted value of power loss function.
(4) a_2 is weighted value of loads balancing function.
Subject to:
(1)Node voltage constraint:
Voltage magnitude at each node must lie within their permissible ranges to maintain power quality.

$$U_{j\ \min} < U_j < U_{j\ \max} \tag{2}$$

(2)Branch current thermal stability constraints:
Current magnitude of each branch (feeder, laterals and switches) must lie within their permissible ranges.

$$I_{i\ \min} < I_i < I_{i\ \max} \tag{3}$$

(3)Kirchhoff 's current and voltage laws

$$\begin{aligned} &g_V(V,K)=0 \\ &g_i(I,K)=0 \end{aligned} \tag{4}$$

(4)Radial network constraint:
The distribution network should be made up of radial structure based on an operational point of view

$$g_k \in G \tag{5}$$

3. Niche binary Particle Swarm Optimization Algorithm

3.1 Binary Particle Swarm Optimization Algorithm

Particle swarm optimization, originally designed by Kennedy and Eberhart in 1995 [5], is an emerging population-based optimization method. PSO is a kind of random search algorithm that simulates nature evolutionary process and has the characteristics of memory. Its basic idea is as follow: every particle represents solution of the problem, which fitness is decided by optimal function, and then According to the cognitive memory, all the particles can adjust their position moving toward their global best position or their neighbor's local best position. Therefore the optimal solutions or near the optimal solutions with a fast convergent speed is found.

$$V_{i\,d}^{k+1} = \omega V_{i\,d}^{k} + c_1 r_1 (P_{i\,d}^{k} - x_{i\,d}^{k}) + c_2 r_2 (P_{g\,d}^{k} - x_{i\,d}^{k}) \tag{6}$$

$$x_{i\,d}^{k+1} = x_{i\,d}^{k} + V_{i\,d}^{k+1} \tag{7}$$

In (6-7), k represents the iterative number,ω is the inertia weight,C_1 and C_2 are learning factors.r_1,r_2 are respectively a random number between 0 and 1. $P_{\mathrm{i\,d}}^{\mathrm{k}}$, $P_{\mathrm{g\,d}}^{\mathrm{k}}$ respectively represent each particle's previous best position remembered and the globally best position in the whole swarm .

The basic particle swarm optimization can not be used to optimize the pure discrete binary combinational problem. To handle this problem, Kennedy and Eberhart proposed BPSO algorithm [6], where the particles take the values of binary vectors of length n and the velocity defined the probability of bit x_{ij} to take the value 1. BPSO reserves the updating formula of the velocity (see (6)) while velocity is constrained to the interval [0.0, 1.0] by a limiting transformation function, that is, the particle changes its bit value by (8-9) in BPSO.