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Power system reactive power optimization based on MIPSO

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Abstract

In order to improve power quality and reduce network losses, this paper proposes a modified immune particle swarm algorithm for power system reactive power optimization. To overcome the disadvantages in the traditional PSO algorithm about low accuracy and easy to fall into local optimal, MIPSO adopts sinusoidal changing inertia weight strategy to make particles explore the local and global optimization more efficiently. Introduce convergence acceleration factor to improve the convergence rate. Modified immune principle enhances the search capability to avoid premature convergence. Finally, compare the reactive power optimization results of Wuzhong of Ningxia system by MIPSO with other classical PSO algorithms. The experimental results show that the MIPSO algorithm is an efficient and feasible approach for reactive power optimization.

Keywords: reactive power optimization, particle swarm algorithm, sinusoidal changing inertia weight, convergence acceleration factor, modified immune

1. Introduction

WITH the development of the power system, reactive power optimization has become an indispensable approach to guarantee the reactive power balance and to improve grid reliability and security. The researchers hope to maintain the system voltage level, reduce active power losses and improve the reliability of power system through reasonable distribution and optimization of reactive power flow. Reactive power optimization, which belongs to a part of optimal power flow (OPF), is a kind of complicated and combined continuous variables with discrete variables, dynamic, multi-targets, multiple constraints and nonlinear optimization problem.

Over the years, reactive power optimization has always been a central issue. A variety of reactive power optimizations have been proposed successively. Since 1995, particle swarm optimization [1] (PSO) proposed by Eberhart and Kennedy. As a new heuristic search algorithm, this method shows its broad

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prospect in resolving reactive power optimization. The paper [2] proposes a multi-agent particle swarm optimization (MAPSO) to optimize the reactive power. The paper [3] applies standard PSO algorithm to the dynamic reactive power optimization, establishing a dynamic reactive power optimization model. Based on conventional PSO algorithm, the paper [4] puts forward an adaptive PSO algorithm, improving the convergence of the algorithm by changing the parameters automatically. However, there are still many disadvantages in PSO algorithm, such as slow convergence in the later stage, rapid decline in particle diversity with generations and easy to fall into the local premature convergence.

This paper proposes a new convergence acceleration factor and modified immune principle combined particle swarm optimization for reactive power optimization by adopting the sinusoidal changing inertia weight strategy. This method, called MIPSO algorithm, has a faster convergence rate and better particle diversity comparing with other algorithms, avoiding premature convergence phenomenon and improving the search ability of the algorithm greatly.

2. Mathematic Modelof Reactive Power Optimization

The reactive power optimization is on the premise of known active power scheduling, through optimization to get the best reactive power distribution to determine the value of control variables, allowing the system to meet the various operating constraints and some indicators (such as the minimum active power loss, the minimum compensation capacitor, the best compensation, etc) to achieve the best. Reactive power optimization is a kind of dynamic, multi-targets, multiple constraints and nonlinear optimization problem which combines continuous variables with discrete variables.

Reactive power optimization model [5,6] contains the power constraint equations and variable constraint equations. This paper selects the minimum active power loss as the objective function, generator reactive power and load node voltages as state variables, the node voltage generator, transformer ratio and reactive power compensation capacity as control variables. Determining the generator terminal voltage, under-load tap-changing transformer taps and the parameters of reactive compensation equipment can change the reactive power flow distribution and reduce network loss. Detailed mathematical model is as follows.

The state variables should be written in the form of penalty function. The extended objective function is as follows:

$$\min F = P_{Loss} + \lambda_1 \sum_{i=1}^{N_L} \left(\frac{\Delta V_i}{V_{i\max} - V_{i\min}}\right)^2 + \lambda_2 \sum_{j=1}^{N_g} \left(\frac{\Delta Q_{Gj}}{Q_{Gj\max} - Q_{Gj\min}}\right)^2 \qquad (1)$$

in which: P_{Loss} is the system active power loss; λ_1 is the penalty factor of load bus voltage out of range; λ_2 is the penalty factor of generator reactive power out of bound; N_L is the total number of load nodes; N_G is the total number of generator nodes; V_i, V_{imax}, V_{imin} is load bus voltage, voltage upper and lower limit respectively; Q_j, Q_{jmax}, Q_{jmin} is generator reactive power output, output upper and lower limit respectively; P_{Loss} , ΔV_i and ΔQ_j can be obtained by equations (2)- (4).

$$P_{Loss} = \sum_{k=1}^{N_e} g_k (V_i^2 + V_j^2 - 2V_i V_j \cos\theta_{ij}) \qquad (2)$$

$$\Delta V_i = \begin{cases} V_i - V_{i\max}, & V_i > V_{i\max} \\ 0, & V_{i\min} < V_i < V_{i\max} \\ V_{i\min} - V_i, & V_i < V_{i\min} \end{cases} \qquad (3)$$