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Solution of optimal reactive power dispatch of power systems using hybrid particle swarm optimization and imperialist competitive algorithms

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ABSTRACT

Management of reactive power resources is essential for secure and stable operation of power systems in the standpoint of voltage stability. In power systems, the purpose of optimal reactive power dispatch (ORPD) problem is to identify optimal values of control variables to minimize the objective function considering the constraints. The most popular objective functions in ORPD problem are the total transmission line loss and total voltage deviation (TVD). This paper proposes a hybrid approach based on imperialist competitive algorithm (ICA) and particle swarm optimization (PSO) to find the solution of optimal reactive power dispatch (ORPD) of power systems. The proposed hybrid method is implemented on standard IEEE 57-bus and IEEE 118-bus test systems. The obtained results show that the proposed hybrid approach is more effective and has higher capability in finding better solutions in comparison to ICA and PSO methods.

Introduction

The optimal reactive power dispatch problem (ORPD) is impressive on safe and economical operation of power systems. In fact, it plays an important role for secure operation of power systems. It is a sub-problem of the optimal power flow (OPF) calculation, which adjusts all kinds of controllable variables, such as generator voltages, transformer taps, shunt capacitors/inductors, and handles a given set of physical and operating constraints to minimize transmission losses or other concerned objective functions [1–3]. The value of reactive compensators and transformer tap settings are discrete variables while reactive power outputs of generators and bus voltage magnitudes are continuous variables, which makes the ORPD problem mixed integer nonlinear programming problem. Many classical optimization techniques such as linear programming (LP) [4,5], gradient search (GS) [6], interior point methods (IP) [7], and quadratic programming (QP) [8], have been applied for solving ORPD problems in power systems.

Modified interior point (MIP) method has been proposed for determining the optimal values of reactive power sources to minimize the total system real power losses in [9]. In [10], Lagrangian decomposition based method has been proposed for solution of the ORPD problem in multi-area power systems. In this paper the cost of the reactive power exchanges among areas are also considered.

These classical methods have some drawbacks, such as converging to the closest local optima. These methods are also unable of handling nonlinear and non-convex constraints and discontinuous functions and problems having multiple local minimum points. In the past, computational intelligence-based techniques, such as improved GA [11], genetic algorithm (GA) [12], real parameter GA [13], evolutionary programming (EP) [14], adaptive GA [15], particle swarm optimization (PSO) [16], bacterial foraging optimization (BFO) [17], hybrid PSO [18], differential evolution (DE) [19–21], gravitational search algorithm (GSA) [22], seeker optimization algorithm (SOA) [1] have been applied for solving ORPD problem. These methods present extremely superiority in obtaining the near-global optimum and in handling non-convex and discontinuous objectives and have effectiveness in overcoming the disadvantages of classical algorithms. In [23], a new optimization algorithm has been proposed for solution of ORPD problem, which is based on the mass interactions and law of gravity.

Total loss minimization, voltage deviation reduction and voltage stability improvement are the main objective functions considered in solution of ORPD problem [24]. In [25], biogeography-based optimization (BBO) algorithm presented for solving multi-objective ORPD problems. In [26], harmony search algorithm (HSA) proposed to solve ORPD problem. In [27], an improved GA

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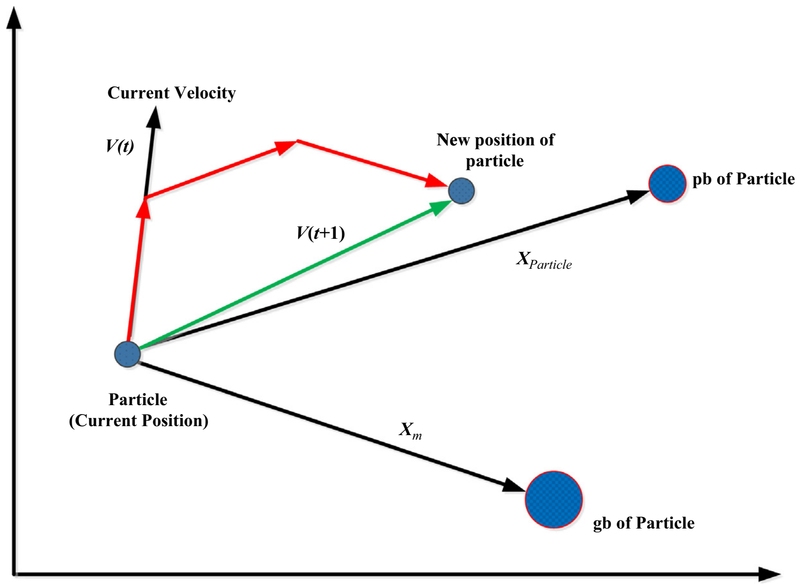

Fig. 1. Particle swarm optimization principle (PSO).

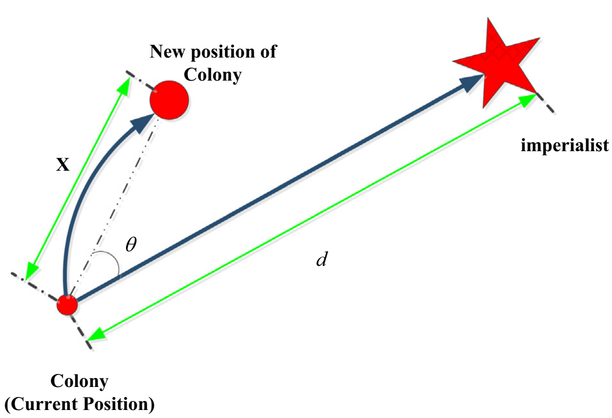

Fig. 2. Movement of colonies toward their relevant imperialist.

approach is presented to solve ORPD problem for enhancing voltage stability. Modified NSGA-II (MNSGA-II) is implemented in [28] to solve multi-objective ORPD problem by minimizing real power loss and maximizing the system voltage stability. In this paper, controlled elitism and dynamic crowding distance strategies are added to the conventional NSGA-II. The load uncertainty is modeled using Monte-Carlo simulations in solving multi objective ORPD problem [29]. In [30] a newly developed teaching learning based optimization (TLBO) algorithm has been proposed to solve multi-objective optimal reactive power dispatch (ORPD) problem by minimizing real power loss, voltage deviation and voltage stability index. A hybrid approach based on binary imperialist competitive algorithm (BICA) and binary particle swarm optimization (BPSO) has been proposed in [31] to find the optimal energy procurement for electricity retailer with multiple procurement options. In [32] hybrid invasive weed optimization (IWO) and modified imperialist competitive algorithm (MICA) has been proposed for solving the optimal reactive power dispatch problem. In this paper, hybrid PSO–ICA is applied for the solution of ORPD problem of power systems. Two IEEE standard power systems, i.e., IEEE 57-bus and 118-bus power systems, are used for solving ORPD problem with objectives of minimization of transmission loss and total voltage deviation (TVD). The simulation results show that hybrid PSO–ICA has better or comparable performance than the other algorithms.

The rest of the paper is organized as follows: In section 'Problem formulation', ORPD problem is formulated. In section 'Proposed methodology', a hybrid PSO–ICA algorithm is described. In section 'Simulation results and discussion', simulation results are presented and discussed. The conclusion is drawn in section 'Computation time'.

Problem formulation

Objective functions

Two different objective functions are considered in this work for ORPD problem. It should be mentioned that these two objectives are considered separately and is not solved as a multi-objective optimization problem.

Minimization of active power loss

One of the main objectives of the reactive power dispatch is to minimize the active power losses in the transmission network, which can be defined as follows:

$$f_1 = \min(P_{Loss}) = \min\left[\sum_{k=1}^{N_{TL}} G_k(V_i^2 + V_j^2 - 2V_iV_j\cos\alpha_{ij})\right] \quad (1)$$

Improvement of voltage profile

The voltage of the system buses are generally considered as constraint. But considering them as constraint results in a system, where all the voltages are at their maximum limits after optimization, which means the power system lacks the required reserves to provide reactive power during contingencies. One of the effective ways to avoid this situation is to choose the minimization of the absolute deviations of all the actual bus voltages from their desired voltages as an objective function. Minimization of TVD of load buses can allow the improvement of voltage profile [33]. This objective function may be formulated as follows:

$$\text{TVD} = \sum_{i \in N_L} \left| V_i - V_i^{ref} \right| \quad (2)$$