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Multi objective optimal reactive power dispatch using a new multi objective strategy

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ABSTRACT

This paper presents a new multi objective Chaotic Parallel Vector Evaluated Interactive Honey Bee Mating Optimization (CPVEIHBMO) to find the feasible optimal solution of the multi objective optimal reactive power dispatch (RPD) problem with considering operational constraints of the generators. The optimal RPD problem is an important issue with non-linear structure in power industry that consists of the continuous and discrete control variables. The proposed algorithm is applied to find the settings of continuous and discrete control variables such as tap positions of tap changing transformers, generator voltages, and the amount of reactive compensation devices to optimize three conflicting and non-commensurable objective functions: voltage deviation, the total voltage stability and real power loss. For achieve a good design with different solutions in a multi objective optimization problem, Pareto dominance concept is used to generate and sort the dominated and non-dominated solutions. Also, fuzzy set theory is employed to extract the best compromise solution. The propose method has been individually examined and applied to several test systems. The effectiveness of the proposed approach is demonstrated by comparing its performance with other evolutionary multi objective optimization algorithms. The computational results reveal that the proposed algorithm has excellent convergence characteristics and is superior to other multi objective optimization algorithms. Also, the results confirm its great potential in handling the multi objective problems in power systems.

1. Introduction

The efficient optimum economic operation and planning of electric power generation system have always occupied an important role in the electric power industry. The RPD problem is an important issue in modern power system that control tap ratios of transformers, reactive compensation devices and generator voltages to minimize a certain object while satisfying large number of equality, inequality constraints and maintaining reliability [1]. The RPD problem is modeled as a large-scale MINLP problem because have discrete variables such as transformer tap settings and shunt capacitors/reactors and continuous variables such as reactive power outputs of generators and bus voltage magnitudes [2]. Albeit RPD problem has no production cost, but it affects the overall creation cost by the way of real transmission losses. The aim of practical non-convex RPD problem is to schedule the optimum reactive power units in the power system to minimize the total real transmission losses of supplying power and satisfying power balance equations and different equality and inequality constraints [3,4].

Several traditional techniques such as gradient method, non-linear programming, Newton approach, Jacobian matrix and interior point have been used to find out the optimal solution of non-linear RPD problem [5–8]. These techniques optimize the purpose function by linearising it. In most cases of the traditional optimization techniques, the authors used the Newton–Raphson method to find a solution. This method is noted for its fast rate of convergence; however difficulty can arise when dealing with system constraints. In most cases a nonlinear programming technique can prove quite successful. However, the conventional optimization methods require heavy computation burden and are infirm of providing ideal results in the aspect of rapidity and precision. On the other hand, the search process is susceptible to be trapped in local minima and the solution obtained may not be optimal [4]. In addition, they are further limited by their lack of efficiency, insecure convergence and robustness in a number of practical applications, like RPD problem [8].

Several metaheuristic optimization methods have evolved in the last decades. Population-based optimization methods inspired by nature may be classed in two important categories that are evolutionary algorithms and swarm intelligence. Various algorithms based on these methods such as DE [3], FAPSO [9], RGA [10], TS

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Nomenclature

RPD	reactive power dispatch	IPSO	improved PSO
MINLP	mixed integer non-linear programming.	CLS	chaotic local search
RGA	real genetic algorithms	DFIG	Doubly fed induction generator
PSO	particle swarm optimization	SD	standard deviation
ABC	artificial bee colony	HBMO	Honey Bee Mating Optimization
FAPSO	fuzzy adaptive PSO	IHBMO	interactive HBMO
DE	differential evolution	CPVEIHBMO	Chaotic Parallel Vector Evaluated HBMO
TS	Tabu search	GA	genetic algorithm

[11], PSO [12], IPSO [13], stochastic method [14] and others have been widely applied to the problem of RPD. These methods seem to be good approaches for the solution of the RPD optimization problem. However, when the objective function of the optimization problem is epistatic, (i.e. where parameters being optimized are highly correlated), and when the number of parameters to be optimized is large, then these methods have degraded effectiveness to obtain the global optimum solution. In addition, these techniques are not successful in managing optimization problems of discrete and integer nature and causes to the solutions that may be far from the globally optimal solution.

The HBMO technique is a relatively new technique that has been empirically shown to perform well on many of these optimization problems. The standard HBMO method has been used to solve a power system stabilizer problem [15–18], load frequency control [19,20], economic load dispatch [21,22], and multi objective distribution feeder reconfiguration [23]. Unfortunately, the standard HBMO algorithm often converges to local optima, especially while handling problems with more local optima and heavier constraints. In other words, standard HBMO greatly depends on its parameters adjustments, and it often suffers the problem of being trapped in the local optima so as to be premature convergence. For a practical problem, like RPD, the intelligent techniques should be modified accordingly so that they are suitable to solve RPD problem with more accurate multiple cost functions and constraints, and they can reduce randomness. Therefore, some modification has been required for the standard HBMO algorithm to improve its performance.

In order to elude this deficiency, in this paper, a new modified HBMO algorithm is proposed for solving the RPD optimization problem. This work presents the interactive strategy by considering the universal gravitation between queen and drone bees for the standard HBMO algorithm to retrieve the disadvantages, which is called the IHBMO. In other words, the IHBMO introduces the concept of universal gravitation into the consideration of the affection between drone bees and the queen bee within a honey bee colony. By assigning different values of the control parameter, the universal gravitation should be involved for the IHBMO when there are various quantities of drone bees and the single queen bee. In addition, a new definition CLS mechanism is proposed and the IHBMO algorithm is employed to update the particle in search space. By merging chaotic local search with IHBMO, the novel hybrid evolutionary algorithm can ensure the solutions are not trapped in local optima, based on the characteristics of periodicity and regularity of chaos. Also, to give a well distribute of non-dominated solutions during the search process and satisfactory diversity characteristics, a Parallel Vector Evaluated Honey Bee Mating Optimization (PVEHBMO) based multi objective is proposed for the solution of the RPD problem in this paper.

The results show that the proposed method provides more rapid and robust convergence on function optimization problems considered in this study. The proposed method has a diversity-preserving mechanism to find widely different Pareto-optimal solutions. A hierarchical clustering technique is implemented to provide the power system operator with a representative and manageable Pareto-optimal set. A fuzzy-based mechanism is employed to extract the best compromise solution. The potential of the proposed approach to handle the multi objective RPD problem is investigated. Several runs are carried out on a standard test system and the results are compared to the classical techniques. The effectiveness of the proposed approach to solve the multi objective RPD problem is demonstrated. The main contributions of this paper are: presenting a new improve version of the standard HBMO algorithm, combining original HBMO with the universal gravitation, CLS scheme, and applying the proposed CPVEIHBMO approach to the RPD problem with three competing and conflicting objectives.

The remainder of this paper is organized as follows: Section 2 provides a formulation of the RPD problem. Section 3 introduces the proposed algorithm. To demonstrate the advantages of the proposed algorithm in the RPD problem, the proposed algorithm is applied to several test system. Experiments, results and comparison with reported results are brought in Section 4. Finally, the paper is concluded in Section 5.

2. RPD problem formulation

The various objectives of power system are sum of voltage deviations on load busses, system transmission losses, voltage stability, security, etc [24]. These objectives are conflicting in nature and cannot be handled by conventional single objective optimization techniques. Generally, the RPD model can be mathematically described as follows:

2.1. Problem objectives

2.1.1. Objective 1: Minimization of total real power loss

Transmission losses in the network constitute economic loss providing no benefits. Transmission losses are construed as a loss of revenue by the utility. The magnitude of each of these losses needs to the accurately estimated and practical steps taken to minimize them. If we express the transmission losses in term of bus voltages and associated angles, then the losses can be expressed with (Newton–Raphson):

$$J_1 = P_{loss}(x,u) = \sum_{k=1}^{N_L} g_k \left[V_i^2 + V_j^2 - 2V_iV_j\cos(\theta_i - \theta_j)\right] \quad (1)$$

where g_k is the conductance of the line $i-j$, V_i and V_j are line voltages and θ_i and θ_j the line angles at the line i and j ends respectively. k is the kth network branch that connects bus i to bus j, $i = 1,2,\ldots,N_D$, where, N_D is the set of numbers of power demand bus and $j = 1,2,\ldots,N_j$,where N_j is the set of numbers of buses adjacent to bus j. P_G is active power in line i and j. x and u are vector of dependent variables and vector of control variables, respectively.