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Security constrained optimal power flow solution using new adaptive partitioning flower pollination algorithm

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ABSTRACT

In this paper, a flexible power system planning strategy using a novel population-based metaheuristic algorithm inspired by the pollination process of flowers named adaptive flower pollination algorithm (APFPA) has been proposed. The proposed power system planning strategy implemented and successfully applied for solving the security optimal power flow (OPF) considering faults at critical generating unit. The main particularity of the proposed variant is that the control variables are optimized based on an adaptive and flexible structure. Also the performances of the standard FPA is improved by dynamically adjusting their control parameters, this allows creating diversity and balance between exploration and exploitation during search process. The robustness of the proposed planning strategy, is demonstrated on the IEEE 30-Bus, and IEEE 57-Bus tests power system for different objectives such as fuel cost, power losses, and voltage deviation. Considering the quality of the obtained results compared with various recent methods reported in the literature, the proposed strategy seems to be a competitive tool for solving with accuracy the security OPF considering critical situations.

1. Introduction

Today there is no a standard and generalized method which is capable to solve various complex real-world optimization problems related to many research areas. As a result, and during the last two decades a hundred of optimization methods have been developed to solve a variety of problems related to energy planning and control. The optimal power flow (OPF) is one of the important sub problems of power system planning. The classical OPF problems have been treated by researchers more than half a century. The objectives of OPF have been changed compared to the classical OPF and depend on the flexible structure of the modern power system characterized by the integration of various types of FACTS technology and many types of renewable sources. The classical OPF consists on the optimal repartition of active power of different type of thermal generating units to minimize the total cost by considering a specified operational and security constraints [1]. The first simplified sub problem of OPF problem is introduced in the large encyclopedia of power system planning by Carpentier in Ref. [2] to solve the basic economic dispatch problem, and by Dommel et al. in Ref. [3] for solving the standard OPF. Consequently, the OPF problem has been widely studied more than half a century using various optimization methods. Earlier, mathematical optimization techniques such as linear programming (LP) [4], nonlinear programming (NLP) [5], quadratic programming (QP) [6], Newton method and interior point methods have been intensively used in the industries [7,8]. A survey of the majority of deterministic techniques based optimization methods applied to solve the OPF has been proposed in Refs. [9–11]. The complexity of practical OPF problem which is non-convex, non differentiable objective functions encouraged researchers to develop a new category of optimization methods susceptible to solve with accuracy the practical optimization problems related to power system planning and control [1]. As a result, a wide variety of meta-heuristic optimization methods have been proposed taking inspiration from evolution and interaction of different types of creatures with the nature, such as birds, insects, fish, ants, bacteria and also those inspired from natural phenomenon such as gravity, galaxy.

Genetic algorithm (GA) is one of the most popular evolutionary methods largely applied to solving various power system planning and control problems. Standard GA and various variants have been proposed to solve a variety of classical OPF problems. In Ref. [12] an enhanced genetic algorithm is proposed to solve the OPF problem, in Ref. [13] an improved genetic algorithms is applied to solve the OPF under normal and contingent operation, in Ref. [14] a genetic algorithm/fuzzy rules successfully applied to improve the

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solution of the OPF problem of the Algerian power system, and in Ref. [15] an adapted genetic algorithm with adjusting population size is proposed for solving the OPF.

Particle swarm optimization (PSO), firstly introduced in 1995 by Eberhart and Shi [16] is also another popular and attractive metaheuristic optimization method applied for solving various multi-objective OPF problems. The standard PSO and various variants are proposed to solve the well known problems such as the environmental economic dispatch problem [17], the optimal power flow [18], in Ref. [19] the optimal reactive power control for power loss minimization is solved using a dynamic PSO, in Ref. [20] the PSO algorithm is applied for solving the optimal location and controller design of STATCOM for power system stability improvement.

Differential evolution (DE) introduced by Storn and Price in [21] is also attracted many researchers, the original DE algorithm and a large number of variants based DE have been applied to solve many OPF problems. In Ref. [22], the DE algorithm is applied to solve the OPF problem, and in Ref. [23] the DE is adapted and applied for solving the optimal reactive power. In the literature, the successive proposed variants based standard algorithms have been proposed to relieve the drawbacks related to the parameters adjustment. Qualitative and quantitative analysis confirmed that the improper selection of the specific control parameters of the majority of these methods affect the efficiency of the algorithm in term of solution quality and convergence characteristics. This important conclusion pushed researchers to develop new optimization methods, with few parameters to adjust and also new hybrid methods. Firstly, many algorithms and improved variants of existing standard metaheuristic methods have been proposed to solve many complex problem related to multi objective OPF. Prominent among these are: gravitational search algorithm [24], Gaussian bare-bones imperialist competitive algorithm [25], artificial bee colony algorithm (ABC) [26], firefly algorithm (FFA) [27], teaching-learning-based optimization algorithm (TLBO) [28,29], brain storm optimization algorithm (BSO) [30,31], league championship algorithm (LSA) [32], grey wolf optimizer [33,34].

Secondly, many hybrid methods based on the combination between various methods have been proposed and considered as an alternative solution to improve the solution of many complex optimization problems. In Ref. [35] a modified teaching–learning based optimization is proposed to solve the multi-objective OPF, in Ref. [36] a hybrid bacterial foraging and Nelder–Mead algorithm is applied to solve the optimal location of series FACTS devices for congestion management, in Ref. [37] a hybrid differential evolution with particle swarm optimization is applied to enhance the maximum loadability limit of power system, in Ref. [38] a hybrid fuzzy particle swarm optimization and Nedler-mead algorithm (HFPSO-NM) is applied to solve the OPF under both normal and contingent operation conditions, in Ref. [39] a chaotic improved PSO is applied to solve the multi-objective optimization for minimization of power losses and L index in power systems, in Ref. [40] a hybrid imperialist competitive-sequential quadratic programming (HIC-SQP) algorithm is proposed for solving economic load dispatch with incorporating stochastic wind power, in Ref. [41] a new modified and hybrid modified imperialist competitive algorithms is applied for solving the multi-objective OPF, in Ref. [42] an adaptive biogeography based predator–prey optimization technique is applied to solve the OPF, in Ref. [43] the OPF is solved using a self-evolving brain-storming inclusive teaching–learning-based algorithm, in Ref. [44] a successful hybrid GA-PS-SQP method is applied to solve the power system valve-point economic dispatch problems, in Ref. [45] a hybrid Nelder–Mead simplex based firefly algorithm is applied to solve the optimal reactive power dispatch, in Ref. [46] a combined of ant colony optimization and artificial bee colony algorithm is adapted for probabilistic optimal placement and sizing of distributed energy resources, in Ref. [47] a interactive PSO strategy is applied to solve the OPF considering multi SVC.

Solving the classical OPF considering critical situations such as faults and load growth which is known as constrained security OPF is a vital research area for industrials to enhance the reliability of practical power systems. Very recently, various papers have been proposed to solve the SCOPF. In Ref. [48] a grey Wolf-pattern search algorithms is proposed to solve Blackout risk prevention in a smart grid based flexible optimal strategy, in Ref. [49] a contingency partitioning approach for preventive-corrective security-constrained optimal power flow computation is proposed, in Ref. [50] a modified bacteria foraging algorithm is adapted and applied for solving the security constrained optimal power flow considering wind–thermal generation, and in Ref. [51] a Fuzzy harmony search algorithm is applied to enhance the security OPF problems.

Flower pollination algorithm (FPA) is one of the recent optimization methods developed by Yang [52] inspired by pollination process of flowering plants in nature. The main particularity of this method is the control and balance between exploitation and exploration by using a switching probability thus maintaining solution diversity. Today the original FPA algorithm has been adapted and applied for solving limited specific problems related to power system planning and control. In Ref. [53] a biologically inspired modified flower pollination algorithm is adapted and applied with success for solving the economic dispatch in modern power systems, in Ref. [54] the optimal sizing and locations of capacitors in radial distribution systems is solved using flower pollination optimization algorithm and power loss index, in Ref. [55] a combined economic and emission dispatch solution using flower pollination algorithm, in Ref. [56] the multi-objective dynamic economic dispatch considering the integration of wind source is solved using a hybrid flower pollination algorithm with time-varying fuzzy selection mechanism, in Ref. [57] a flower pollination algorithm is applied for solar PV parameter estimation. Results in term of solution quality and execution time compared to the standard FPA and to the large number of recent methods confirmed its ability and efficiency in solving optimal power system planning problems considering practical constraints related to generating units such as valve point effect. It is important to note that the main drawback of the standard FPA is related to the best choice of switching parameter, in Ref. [58] an important qualitative and quantitative analyses is proposed to show the performances and drawbacks of the standard FPA.

Like many metaheuristic optimization methods, choosing feasible parameters are an important task to achieve the best solution, FPA has only few parameters to adjust; in Refs. [53–55], many authors claimed that the best value of switching probability is 0.8. The qualitative and quantitative results given in Ref. [58] and in the proposed paper, confirmed that fixing the switching parameter at the value 0.8 is not always a good choice. It was observed that the choice of switching probability parameter is important to maintain flexible interaction between exploration and exploitation during search process to achieve the near global solution.

In this paper a new practical planning power system strategy based adaptive partitioning flower pollination algorithm is proposed to solve the security optimal power flow considering critical situations. The contributions of this paper can be outlined as follows:

- A new variant method based on FPA is proposed to improve the solution of OPF problems.
- The performances of the standard FPA in term of convergence characteristics is improved by dynamically adjusting their control parameters in particular, the switching parameter, this allows