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Optimal power flow using differential evolution algorithm

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ABSTRACT

This paper presents an evolutionary-based approach to solve the optimal power flow (OPF) problem. The proposed approach employs differential evolution (DE) algorithm for optimal settings of OPF control variables. The proposed approach is examined and tested on the standard IEEE 30-bus test system with different objective functions that reflect fuel cost minimization, voltage profile improvement, and voltage stability enhancement. In addition, non-smooth piecewise quadratic cost function has been considered. The simulation results of the proposed approach are compared to those reported in the literature. The results demonstrate the potential of the proposed approach and show its effectiveness and robustness to solve the OPF problem for the systems considered.

1. Introduction

In the past two decades, the problem of optimal power flow (OPF) has received much attention. It is of current interest of many utilities and it has been marked as one of the most operational needs. The OPF problem solution aims to optimize a selected objective function via optimal adjustments of the power system control variables while satisfying various equality and inequality constraints.

Several classical optimization techniques have been employed for the solution of OPF problem. For more discussions on these techniques, the reader can consult the comprehensive survey presented in [1,2].

Generally, most of the classical optimization techniques apply sensitivity analysis and gradient-based optimization algorithms by linearizing the objective function and the system constraints around an operating point. Unfortunately, the OPF problem is a highly non-linear and multi-modal optimization problem, i.e., there are more than one local optimum. Hence, local optimization techniques, which are well elaborated, are not suitable for such problem. Moreover, there is no criterion to decide whether a local solution is also the global solution. Therefore, conventional optimization methods that make use of derivatives and gradients may not able to identify the global optimum. Conversely, many mathematical assumptions such as convex, analytical, and differential objective functions have set to simplify the problem. However, the OPF problem is an optimization problem with in general non-convex, non-smooth, and non-differentiable objective functions. It becomes essential to develop optimization techniques that are efficient to overcome these drawbacks and handle such difficulties.

Recently, evolutionary optimization techniques have been used to solve OPF problem to overcome the limitations of classical optimization techniques. A wide variety of heuristic optimization techniques have been applied such as genetic algorithm (GA) [3,4], simulated annealing (SA) [5], tabu search [6], and particle swarm optimization (PSO) [7]. The results reported in the literature were promising and encouraging for further research in this direction.

More recently, a new evolutionary computation technique, called differential evolution (DE) algorithm, has been proposed and introduced [8–11]. The algorithm is inspired by biological and sociological motivations and can take care of optimality on rough, discontinuous and multi-modal surfaces. The DE has three main advantages: it can find near optimal solution regardless the initial parameter values, its convergence is fast and it uses few number of control parameters. In addition, DE is simple in coding, easy to use and it can handle integer and discrete optimization [8–11].

The performance of DE algorithm was compared to that of different heuristic techniques. It is found that, the convergence speed of DE is significantly better than that of GA [10]. In [12], the performance of DE was compared to PSO and evolutionary algorithms (EAs). The comparison was performed on a suite of 34 widely used benchmark problems. It was found that, DE is the best performing algorithm as it finds the lowest fitness value for most of the problems considered in that study. Also, DE is robust; it is able to reproduce the same results consistently over many trials, whereas the performance of PSO is far more dependent on the randomized

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