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Moth-Flame Optimization Algorithm Based Load Flow Analysis of Ill-Conditioned Power Systems

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ABSTRACT

Using a novel bio-inspired optimization algorithm based on the navigation strategy of moths in a universe called transverse orientation, called the Moth-Flame Optimization Algorithm (MFOA), has been applied to solve the load flow problem for power systems under critical conditions. This mechanism is highly effective for traversing covering expanded radius in straight direction. As a matter of fact, moths follow a deadly spiral path as they get confused by artificial lights. For the tuning of parameters, both exploration and exploitation processes play an important role. MFOA is exercised for load flow analysis of small, medium, and large ill-conditioned power systems. The three different standard ill-conditioned cases considered in order to verify the robustness of the algorithm are IEEE 14-bus, IEEE 30-bus and IEEE 57-bus test systems. The results obtained by the application of MFOA shows that the algorithm is able to provide better results than the results obtained by the application of a biogeography inspired optimization algorithm, namely biogeography-based optimization (BBO) and a nature-inspired optimization algorithm, namely the whale optimization algorithm (WOA). This approves the superiority of the proposed algorithm. Simulation and numerical results demonstrate that the MFO is a potent alternative approach for load flow analysis under both normal and critical conditions in practical power systems especially in case of failure of conventional methods, thereby proving the robustness of the method. To the best of the authors' awareness, it is the first report on application of MFOA load flow analysis.

KEYWORDS

Biogeography-Based Optimization, Evolutionary Programming, Ill-Conditioned Power System, Load Flow Problem, Moth-Flame Optimization Algorithm, Steady State Power, Whale Optimization Algorithm

INTRODUCTION

The load flow (LF) problem, in current power system outlook, has become quite a serious issue. Researchers are in continuous quest of improving the power flow analysis as it is highly essential for desired power system scheduling and operation (Duman, Güvenç, Sönmez, & Yörükeren, 2012). The LF can be considered as an elementary tool that helps in identifying the secure states within the system for economical operation. The importance of LF lies in the fact that it forms the backbone in the assessment of the optimum state of operation of an electric network which can be achieved by the optimization of a fitness function representing the load flow objective maintaining the viable constraints. Some out of the numerous approaches are Newton Raphson (NR), Gauss Seidel (GS), and Fast Decoupled Loadflow method (FDLF), etc. (Scott, 1974), that are frequently used to solve

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nonlinear equations. Due to robustness and fast convergence characteristic, NR is the most popular amongst all the aforesaid techniques. Hence the load flow analysis can be described as an eminently non-extensive and multi-conditional optimization issue (Abou, Abido, & Spea, 2010).

Most of the classical approaches implied for solving the mentioned problem suffer from a few limitations. Some of the limitations are local optima convergence, unsuitable for integer and binary problems, differentiability along with continuity, and in providing solution to systems with large R/X ratios (Stott & Alsac, 1974; Frank, Steponavice & Rebennack, 2012; AlRashidi & El-Hawary, 2009; Bijwe & Kelapure, 2003; Amerongan,1989). Based on classical avenues, load flow algorithms for critical or ill-conditioned power systems have been further developed (Iwamoto & Tamura, 1981; Ajjarapu & Christy, 1992). The problem involved in the conventional approaches is that their performance is highly susceptible to the R/X ratio and their performance gets deteriorated with an increase of R/X ratio, system loadability, complexity and nonlinearity.

Thus, to overcome these problems and have a better solution of load flow, numerous meta-heuristic optimization techniques have been addressed. A few of the techniques available in research literature are genetic algorithm (GA) by Wong et al., particle swarm optimization (PSO), differential evolution (DE), real coded genetic algorithm (RCGA), hybrid differential evolution algorithm (HDE) etc (Wong, Li, & Law, 1997; Karami & Mohammadi, 2008; Fukuyama & Yoshida, 2001; Acharjee & Goswami, 2010; Udatha & Reddy, 2014; Lampinen, 2002; Rout, Swain & Barisal, 2011; Sakr,, EL-Sehiemy & Azmy, 2017). Grey wolf optimization (GWO) introduced by Mirjalili et al. is a powerful meta-heuristic evolutionary optimization technique, based on the social hierarchy and hunting behavior of grey wolves. The technique has been has been able to provide successful result for several power system optimization issues (Bhattacharya & Chattopadhyay, 2010; Herbadji, Slimani & Bouktir, 2013). The biogeography based optimization (BBO) technique (Simon, 2008) is a biogeography inspired evolutionary approach and has proved to be a successful technique in solving the economic load dispatch (ELD) (Bhattacharya, A.,Chattopadhyay, 2010) and optimal power flow (OPF) problems (Herbadji, Slimani & Bouktir, 2013). BBO optimizes a function by improving candidate solutions stochastically and iteratively with respect to some specified measure of quality, or fitness function (Simon, 2008). Based on the fowling habits of humpback whales, whale optimization algorithm (WOA) is a new nature-inspired meta-heuristic optimization algorithm that has been successfully employed to solve the OPF (Bhesdadiya, Parmar, Trivedi, Jangir, Bhoye & Jangir, 2016) and ELD (Touma, 2016) problems.

Load flow analysis carried out by most of the proposed algorithms addressed in the literature so far, have shown improved results. However, most of the above-mentioned population-based techniques suffer from a much heavier computational burden in large-scale problems. Also, when structure intricacy rises with the increment in number of new variables, most of the aforesaid methods are unable to probe the search space adequately.

In the present work, Moth-Flame Optimization Algorithm (MFOA) has been applied for solving the LF problem. MFOA is a new meta-heuristic optimization approach based on the navigation strategy of moths in universe (transverse orientation) (Mirjalili, 2015). Obtaining global solution consistently highlights the usefulness of MFOA technique. Other positive features of this algorithm are the use of roulette wheel selection for achieving faster convergence and the ability of evaluation of both discrete and continuous optimization issues. To verify the effectiveness and robustness of MFOA in solving the LF problem, it is applied on IEEE-14 bus, IEEE-30 bus and IEEE-57 bus standard test systems. Increasing the load, changing line reactance and changing line resistance are the three objective cases that have been considered for optimization using MFOA. With an increase in line resistance or with a decrease in line reactance, the R/X ratio in lines can be increased (Amerongan, 1989). The results confirm that the control variables are optimally adjusted such that they are within their specified limits. Even though BBO and WOA techniques are able to provide good optimization values, MFOA gives even better optimization results which prove the strength of the suggested method. The remaining article consists of the following sections: The problem framework is described Section 2. In Section

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