Chapter 8
Improved Pseudo-Gradient Search Particle Swarm Optimization for Optimal Power Flow Problem

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ABSTRACT
This paper proposes an improved pseudo-gradient search particle swarm optimization (IPG-PSO) for solving optimal power flow (OPF) with non-convex generator fuel cost functions. The objective of OPF problem is to minimize generator fuel cost considering valve point loading, voltage deviation and voltage stability index subject to power balance constraints and generator operating constraints, transformer tap setting constraints, shunt VAR compensator constraints, load bus voltage and line flow constraints. The proposed IPG-PSO method is an improved PSO by chaotic weight factor and guided by pseudo-gradient search for particle’s movement in an appropriate direction. Test results on the IEEE 30-bus and 118-bus systems indicate that IPG-PSO method is superior to other methods in terms of lower generator fuel cost, smaller voltage deviation, and lower voltage stability index.

INTRODUCTION
Optimal power flow (OPF) is to determine the optimal settings of control variables including real power generation outputs, generator bus voltages, tap setting of transformer and shunt VAR compensators outputs to minimize the generator fuel cost function subject to power balance, and generator operating and network constraints. The objective functions are generation fuel cost with valve-point loading effects and

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Voltage deviation for voltage profile improvement while satisfying the power flow equations, generator bus voltage, real power generation output and reactive power generation output, transformer tap setting, shunt VAR compensators, load bus voltages, and transmission line loadings constraints. OPF has long been developed for on-line operation and control of power system.

So far, various conventional programming techniques such as Newton’s method, gradient-based methods, linear programming (LP), nonlinear programming (NLP), quadratic programming (QP), and interior point methods (IPMs) (Lai & Ma, 1997; Abido, 2002; Roa-Sepulveda & Pavez-Lazo, 2003; Kennedy & Eberhart, 1995; Abou El Elaa & Abido, 1992; Thanushkodi et al., 2008) have been applied to solve OPF problems. Even though these methods can quickly find a solution, they are highly sensitive to the starting points and may converge prematurely. Moreover, these methods cannot handle non-convex objective function. Therefore, these techniques may not be practical because of nonlinear characteristics of objective function and constraints. To overcome these difficulties, the artificial intelligence and evolutionary based methods including improved genetic algorithm (IGA) (Lai & Ma, 1997), improved evolutionary programming (IEP), tabu search (TS) (Abido, 2002), simulated annealing (SA) (Roa-Sepulveda & Pavez-Lazo, 2003), gravitational search algorithm (GSA) (Duman et al., 2012), biogeography-based optimization (BBO) (Bhattacharya & Chattopadhyay, 2011) were proposed to solve OPF problems. However, the solutions were still far from the optimal solutions.

Recently, PSO has been proposed for solving economic dispatch (ED) (Abou El Elaa & Abido, 1992; Thanushkodi et al., 2008; Park et al., 2006; Chen & Yeh, 2006), reactive power dispatch (RPD) (Chaturvedi et al., 2008; Yoshida et al., 2001; Krost, Venayagamoorthy, & Grant, 2008), optimal power flow (OPF), and optimal location of FACTs devices (Swarup, 2006; El-Ela, & El-Sehiemy, 2007; Sutha & Kamaraj, 2008; Abido, 2002). PSO with time-varying inertia weighting factor (PSO-TVIW), PSO with time-varying acceleration coefficients (PSO-TVAC), self-organizing hierarchical PSO with TVAC (SPSO-TVAC) (Ratnaweera & Halgamuge, 2004), PG-PSO (Le & Dieu, 2012), and stochastic weight trade-off PSO (SWT-PSO) (Chalermchaitarbha & Ongsakul, 2013) have been proposed to obtain better and faster solutions of OPF problem. In addition, the pseudo-gradient based PSO (PG-PSO) method was also applied for solving optimal reactive power dispatch (ORPD) (Le & Dieu, 2012) and ED problem (Dieu et al., 2013). The PG-PSO is based on SPSO-TVAC with guiding position by using pseudo-gradient (PG) for searching the suitable direction towards the optimal solution. The PG-PSO method uses constant weighting factor which may not be effective in solving optimal power flow analysis.

In this paper, an improved pseudo-gradient search particle swarm optimization (IPG-PSO) algorithm is proposed with new linearly chaotic weighting factor and pseudo gradient search algorithm. The proposed IPG-PSO method is tested on the IEEE 30-bus and IEEE 118-bus systems with three different objective functions including quadratic fuel cost function with valve-point loading effects, quadratic fuel cost function with voltage deviation, and quadratic fuel cost function with voltage stability index. The obtained results are compared with PSO-TVIW, PSO-TVAC, SPSO-TVAC, PG-PSO, SWT-PSO, ACO (Allaoua & Laoufi, 2009), IEP (Ongsakul & Tantimaporn, 2006), EP (Yuryevich & Wong, 1999), gravitational search algorithm (GSA) (Duman et al., 2012), differential evolution (DE) (Abou El Elaa & Abido, 2010), modified differential evolution (MDE) (Sayah & Zehar, 2008), evolving ant direction PSO based approach (EADPSO) (Vaisakh et al., 2013), and biogeography-based optimization (BBO) (Bhattacharya & Chattopadhyay, 2011).

The organization of this paper is as follows: Section II describes the OPF problem formation. Improved Pseudo Gradient Search Particle Swarm Optimization is proposed in Section III. Numerical results of the non-convex OPF problem using the proposed IPG-PSO method on the IEEE 30-bus and 118-bus systems are demonstrated in Section IV. Finally, Section V concludes the paper.