

Particle Swarm Optimization based Optimal Power Flow for Units with Non-Smooth Fuel Cost Functions

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Abstract

This paper presents a Particle Swarm Optimization (PSO) based algorithm for optimal flow with generating units having non-smooth fuel costs curves while satisfying the constraints such as generator capacity limits, power balance, line flow limits, bus voltages and transformer tap setting. The conventional load flow and incorporation of the proposed method using PSO has been examined and tested for standard IEEE 30 bus system. The PSO method is demonstrated and compared with conventional OPF method and the intelligence heuristic algorithm such as genetic algorithm, evolutionary programming. The superiority of the method over other methods has been demonstrated on two test cases.

From simulation results, it has been found that PSO method is highly competitive for its better general convergence performance.

Keywords: load flow, optimal power flow, particle swarm optimization, non-smooth fuel cost functions, valve point effects.

1. Introduction

In power system operation, the economic dispatch (ED) problem is an important optimization problem. Moreover, it has complex and nonlinear characteristics with heavy equality and inequality constraints. Generally, there are two types of ED problem, i.e. static and dynamic. Solving the static ED problem is subject to the power balance constraints and generator operating limits. For the dynamic ED, it is an extension of the static ED problem. The dynamic ED takes the ramp rate limits and prohibited operating zone of the generating units into consideration. [1]

The methods for solving this kind of problem include traditional operational research algorithms (such as linear programming, quadratic programming, dynamic programming, gradient methods and Lagrange relaxation approaches) and modern methods (such as simulated annealing and evolutionary algorithms). Some of these methods are successful in locating the optimal solution, but they are usually slow in convergence and require heavy computational cost. Some other methods may risk being trapped to a local optimum, which is the problem of premature convergence. [2]

Recently, intelligence heuristic algorithms, such as genetic algorithm, evolutionary programming, and meta-heuristic algorithms have been proposed for solving the OPF problem. Like other meta-heuristic algorithms, particle swarm

optimization (PSO) algorithm was developed through simulation of a simplified social system such as bird flocking and fishing school. PSO is an optimization method based on population [3], and it can be used to solve many complex optimization problems, which are nonlinear, non-differentiable and multi-modal. The most prominent merit of PSO is its fast convergence speed. In addition, PSO algorithm can be realized simply for less parameters need adjusting. PSO has been applied to various power system optimization problems with impressive success. The results for a 30-bus system shows that PSO is an effective method to solve OPF problem [4].

The main objective of this study is to introduce the use of Particle Swarm Optimization (PSO) technique to the subject of power system economic load dispatch. In this paper, the PSO method has been employed to solve economic dispatch problem with a valve point effects. A valve point effects is the rippling effects added to the generating unit curve when each steam admission valve in a turbine starts to open. More-over, to assure accurate results for this model, an additional term representing the valve point effects should be added to the cost function. The addition of the valve point effects poses a more challenging task to the proposed method since it increases the non-linearity of the search space as well as the number of local minima. (See Fig. 1).

2. Problem Formulation

2.1. The OPF with quadratic fuel cost functions

The optimal power flow problem is concerned with optimization of steady state power system performance with respect an objective F while subject to numerous constraints. For optimal active power dispatch, the objective function F is total generation cost as expressed follows:

$$F = \sum_{i=1}^N C_i(P_{Gi}) = \sum_{i=1}^N a_i + b_i P_{Gi} + c_i P_{Gi}^2 \quad (1)$$

Where:

N: total number of generation units

ai, bi, ci: cost coefficients of generating unit.

Pgi: real power generation of ith unit. i= 1, 2 ... to N.

Subject to:

Equality constraints as:

$$F = \sum_{i=1}^N P_{gi} = P_D + P_L \quad (2)$$

Inequality constraints as:

Branch flow limits: