Improvement in Fuel Cost by Particle Swarm Optimization

Utkarsh Acharya[1] Ramesh Babu Mutluri[2]
[1]M. Tech Student (Power Systems) [2]Assistant Professor
[1,2]Department of Electrical Engineering
[1,2]Aryabhatta college of Engineering and Research Center, Ajmer, India

Abstract— In this paper, particle swarm optimization (PSO) which is one of the latest and emerging computing techniques is applied successfully to solve the problem of economic load dispatch (ELD). The fitness function considered here is minimization of fuel cost of generators. A case study of six generator system is presented to show the result. The results show that PSO is a better technique than the lambda iteration method. All the analysis is carried out in MATLAB environment.

Keywords: PSO, ELD, Six Generator System, Lambda Iteration

I. Introduction

The electric utility systems are interconnected in such a way to achieve the benefits of minimum production cost, maximum reliability and better operating conditions. The economic load dispatch is to minimize the total operating cost of generating units while satisfying system equality and inequality constraints. The economic load dispatch (ELD) is most of power system optimization problem which have complex and non-linear characteristics with heavy equality and inequality. An Economic loading dispatch means minimization of fuel cost of generating unit under some constraints and also reduced transmission losses. The main objective of the optimization problem is to reduce the total generation cost of units while satisfying constraints [4]-[6]. To solve these problems, various salient mathematical approaches have been suggested in the past decades and the multi-objective optimization of power plant such as reduction of fuel cost, heat loss rate, minimize the transmission losses and minimization of pollutant emissions [7]-[8].

The PSO algorithm is also easy to implement, flexible mechanism to obtain global optimum solution, sensitive to turning of its parameters, improve the solution quality rapidly and simple in concept [8]. The PSO is employed for complex optimization problem [9]. The PSO method gives the result for lower generation cost compared with other hierarchical methods and provides better solution than others [6]. The PSO is also faster convergence technique. This method considers the maximum and minimum value of each generator limits and line flow. This paper presents the application of PSO method for optimization of Economic Load Dispatch problem of six unified generating units and the results are compared with lambda iteration method.

In power system, the economic dispatch problem is termed as that which minimizes the total operating costs of a system simultaneously meeting the total load with transmission losses within generator limits.

Mathematically,

Minimize

$$F(P_{gi}) = \sum_{i=1}^{NG} a_i P_{gi}^2 + b_i P_{gi} + c_i \text{ Rs./hr} \quad (1)$$

Subject to:

1) The energy balance equation

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

2) The capacity constraints

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \quad (i=1, 2\ldots NG) \quad (3)$$

The way of representing transmission loss as a function of generators is through B-coefficients.

The expression for loss formula through B-coefficient is

$$P_L = \sum_{i=1}^{NG} \sum_{j=1}^{NG} P_{gi} B_{ij} P_{gj} \text{MW} \quad (4)$$

Where,

P_{gi}, P_{gj}= real power generation at the i^{th} and j^{th} buses, respectively

B_{ij} = loss coefficients which cannot be changed in assumed conditions

NG= no. of plants.

The transmission loss formula of Eq. (4.12) is called as the George's formula. The equations from 1-4 are crux of the core for economic load dispatch problem.

II. Particle swarm optimization

Particle swarm optimization (PSO) is a population based stochastic optimization technique, inspired by social behavior of birds and fishes [5].

A. Introduction

PSO shares many similarities with evolutionary computation techniques such as genetic algorithms (GA). In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations, the particle are "flown" through the problem space by following the current optimum particles. Each particle keeps track of its coordinates in the problem space, which are associated with the best solution (fitness) that it has achieved so far. This implies that each particle has a memory, which allows it to remember the best position on the feasible search space that it has ever visited. This value is commonly called pbest. Another best value that is tracked by the particle swarm optimizer is the best value obtained so far by any particle in the neighborhood of the particle. This location is commonly called gbest. The basic concept behind the PSO technique consists of changing the velocity of each particle toward its pbest and gbest position at each time step. This means that each particle tries to modify its current position and velocity according to the distance between its current position and pbest, and the distance between its current position and gbest.

B. Mathematical Formulation

In order to explain the PSO simulation of bird flocking in two dimension space the position of each agent is represented by XY axis position and the velocity is expressed by V_x (the velocity of X-axis) and V_y(the velocity of Y-axis). Modification of the agent position is realized by the position and velocity information. The bird flocking optimizes a certain objective function. Each agent knows its best value so far (pbest) and its XY position. Moreover, each agent knows the best value in the group (gbest) among pbest .Each agent tries to modify its position using the current velocity and the distance from pbest and gbest.

The modification can be represented by the concept of velocity. Velocity of each agent can be modified making use of Eq. 1 and Eq.2.

$$V_i^{l+1} = V_i^l + C_1 \times rand()_1 \times (Pbest_i - S_i^l) + C_2 \times rand()_2 \times (gbest_i - S_i^l) \quad (1)$$

$$S_i^{l+1} = S_i^l + V_i^{l+1} \quad (2)$$

Where

V_i^{l+1} : Velocity of particle i at iteration l+1
V_i^l : Velocity of particle i at iteration l
S_i^{l+1} : Position of particle i at iteration l+1
S_i^l : Velocity of particle i at iteration l
C_1 , C_2 : Constant weighing factors
rand $()_1$: Random number between 0 and 1
rand $()_2$: Random number between 0 and 1
$pbest_i$: Position of particle i
$gbest_i$: Position of the swarm i

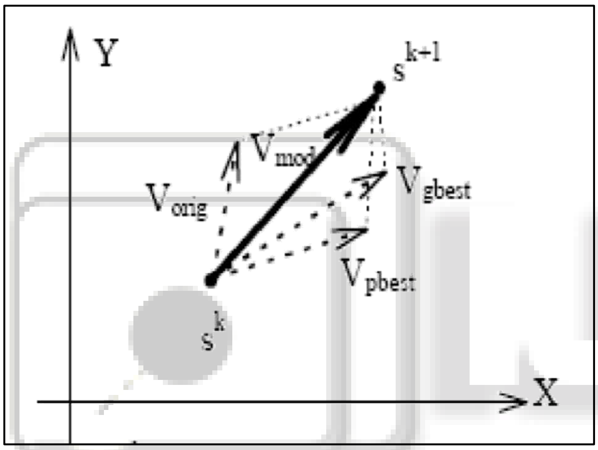

Fig. 1: Modification of global best and personal best

The flow chart for PSO is shown in Fig 2. and the various advantages of PSO that can stated as:

1) It is less susceptible in being trapped on local minima.
2) More immune to indistinguishable objective function.
3) It is more supple and strong.
4) It has no premature convergence problems.

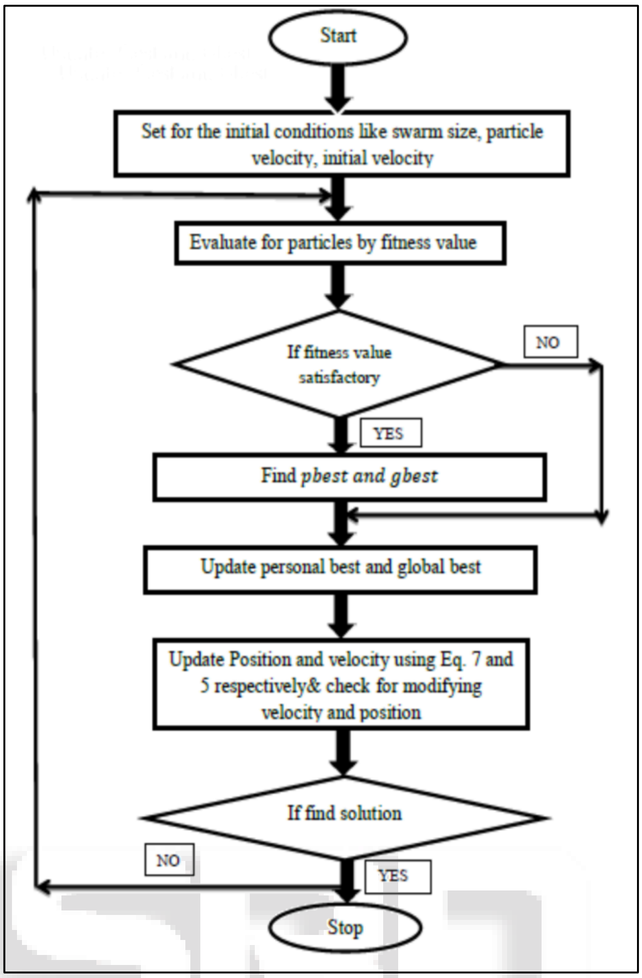

Fig. 2: Flowchart showing PSO algorithm

III. SIMULATION AND RESULTS

In this paper a case study considering six unit generating system is considered to conclude our objective. There are two cases considered first without transmission loss and second with transmission loss. Table I give the data for IEEE six generating unit data is taken from[1,2,3].The convergence characterstics in figure 3 and figure 4 is obtained for load demand of 600 MW

Generator	P_{max}(MW)	P_{min}(MW)	a(MW)^2	b(MW)	c
1	125	10	0.15247	38.53973	756.79886
2	150	10	0.10587	46.15916	451.32513
3	225	35	0.02803	40.3965	1049.997
4	210	35	0.03546	38.30553	1243.5311
5	325	130	0.02111	36.32782	1658.569
6	315	125	0.01799	38.27041	1356.6592

Table 1: Six Generating Units Data

A. *Without Transmission Loss*

The results of fuel cost without transmission loss is obtained by PSO is compared with lambda iteration method in TABLE II

S.No.	Load demand (MW)	Lambda –iteration method (Rs/h)	PSO method(Rs/h)
1	600	31445.92	31145.65
2	700	36003.24	36003.17
3	800	40676.10	40676.02

Table 2: Fuel Cost without Transmission Loss

B. With Transmission Loss

For without transmission loss the results fuel cost obtained by PSO is compared with lambda iteration method in TABLE III. The losses obtained for each generating unit using lambda iteration and PSO are compared in Table IV.

S. No.	Load demand (MW)	Lambda – iteration method (Rs/h)	PSO method(Rs/h)
1	600	31445.92	31145.65
2	700	36003.24	36003.17
3	800	40676.10	40676.02

Table 3: Fuel Cost with Transmission Loss

Load Demand (MW)	Power Loss in MW using Lambda– iteration method	Power Loss in MW using PSO
600 MW	14.7988	14.2373
700 MW	19.5114	19.43
800 MW	27.5	25.33

Table 4: Transmission Losses Particular Load

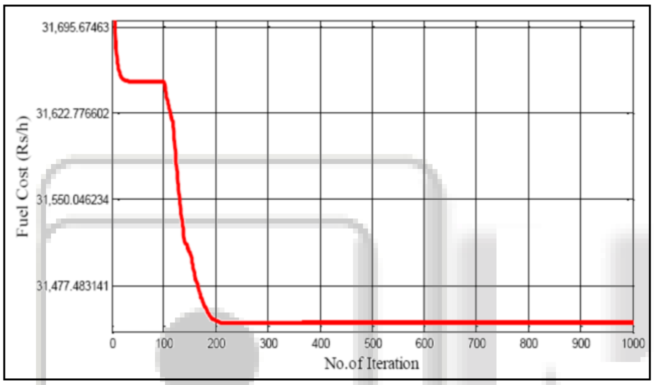

Fig. 3: Convergence characterstics without transmission loss for 600 MW

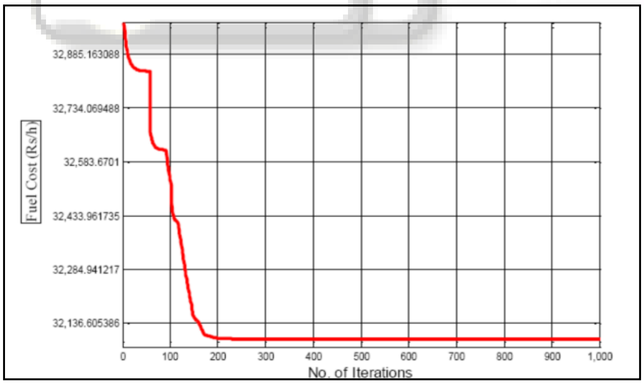

Fig. 4: Convergence characterstics with transmission loss for 600 MW

IV. CONCLUSION

Economic load dispatch in electrical power sector is an important task, as it is required to supply the power at the minimum cost which aids in profit-making. As the efficiency of newly added generating units are more than the previous units the economic load dispatch has to be efficiently solved for minimizing the cost of the generated power.

The important observations and conclusions made are as following:

1) The fuel cost is reduced in case of PSO method thus showing its superiority over lambda iteration method.
2) Convergence has started to occur after few iteration as clear from convergence characterstics. Thus PSO method takes lesser time for convergence.
3) With or without transmission loss both cases yields better results.
4) Transmission losses can be determined accurately by PSO method which is a basic necessity for designing power systems

The above observations and conclusions can motivate the power engineers to utilize PSO for reduction of fuel cost and accurately determine power losses. Furthermore hybridization of PSO can be done to enhance this method's performance.

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