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Optimal Generation of Active Power for Coal Fired Power Plant using Accelerated PSO

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Abstract: In this article we refer to the application of evolutionary algorithm (EA) to solve the problem of optimum power flow in an efficient way. In this article we propose a new approach that uses the Particle Swarm Optimization search method (PSO) and Accelerated Particle Swarm Optimization (APSO) to solve the problem through the optimal configuration of the control variables. This technique is a population based stochastic optimization technique inspired by social behavior of bird flocking or fish schooling, capable to solve large-scale non convex optimization problems like OPF. Objective function such as minimization of fuel cost is considered for optimum distribution of active power, respectively. The proposed method is implemented and evaluated in the IEEE 30-bus 6 generators system. The results of the proposed simulation approach are compared with those reported in the literature. The results demonstrate the potential of the proposed approach, and demonstrate its effectiveness and robustness to solve the OPF problem.

Keywords: Optimal power dispatch, Particle swarm optimization and Accelerated PSO.

1. INTRODUCTION

In present scenario power engineers are facing a main problem of handling the available power in an effective manner to cope-up with the speedy growing demand of consumers. In power system operation and planning, OPF is a best option to handle such problems. Optimal active power flow is concerned with the minimization of cost of power generation economically**.** Here in OPF solutions, objective is achieved through optimal adjustment of system control variables while satisfying the system constraints at same time. Optimal power problem was started by Carpentier in 1960s. Today computer based techniques are used for the optimization but behind the computer there is always an algorithm that works. Various algorithms are available in mathematics to find the optimum solution of any non-linear function. These are classified as conventional and evolutionary. The power output of each plant is determined by ELD where the overall cost of fuel needed to serve the load for the system under consideration has to be minimized [1,2]. Ramp rate limits, prohibited operating zone and non-smooth cost functions are the various non-linear characteristics of generator were also considered. In order to solve the non-convex economic dispatch problem with a quality control, a hybrid [5] evolutionary programming search algorithm was used by Lin. A zoom feature is applied during the iterative process. The EDP problem is to schedule the generating units output to meet the required load demand at minimum operating cost by using PSO [8-9]. Lamda iteration, base point and gradient method are the classical optimization methods which were used to solve economic load dispatch problem [10-11]. An important position in the electric power industry is occupied by economic load dispatch problem (ELDP) of power generating unit. OPF problem is not a linear one and it is non- differential too [15]. So the problem with conventional methods while solving the OPF problem is the solution may got trapped by local optimum value [9]. Other than this, problem with conventional methods is if the state variables are defined in very short range than solution becomes infeasible.

To overcome these problems Evolutionary Algorithms are introduced as, Stochastic Algorithms e.g. GA, PSO, ACO and SA etc. These all are nature inspired algorithms. These further classified as heuristic and meta-heuristic algorithms. Alan Turing was the first who used heuristic algorithms in 1948. After that, 1960s and 1970s were the two decades of development of Evolutionary Algorithms. Today these are very popular to solve the real-world optimization problems. These algorithms are equally useful in Optimal Power flow problems [3-5]. Genetic Algorithm (GA) [3,4], cuckoo search method, Differential Evolution (DE) [9,10] have been proposed for reactive power optimization, voltage control and minimization of cost of active and reactive power both as an objective function.

In this paper well known evolutionary computation technique PSO has been introduced with some modifications, named as Accelerated PSO. The main advantages of Accelerated PSO algorithm are: simple concept, easy implementation, relative robustness to control parameters and computational efficiency and also have high convergence rate. Unlike the other heuristic techniques, APSO has the flexibility to control the balance between the global and local exploration of the search space.

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2. PROBLEM FORMULATION

The objective of optimal power flow is to identify the control variables which minimize the objective function. This is formulated mathematically as follows:

2.1. Minimization of fuel cost

The fuel cost of each fossil fuel fired generator can be expressed as a single quadratic function but the cost function has discontinuities corresponding to change of fuels[5]. Therefore, it is more appropriate to represent the cost function with piecewise quadratic functions. The total fuel cost in terms of real power output can be expressed as[13]:

$$f(Pg) = \sum_{i=1}^{NG} C_i$$

$$f(Pg) = \sum_{i=1}^{NG} a_i Pg_i^2 + b_i Pg_i + c_i \$ / h --- (1)$$

2.2. System Constraints

In this paper following equality and inequality constraints are considered:

2.2.1Equality Constraints

$$\sum_{i=1}^{NG} Pg_i - \sum_{i=1}^{NB} Pd_i - Ploss = 0 --- (2)$$

$$Pg - Pd - Vi\sum_{j=1}^{NB} Vj[Gij\cos(\delta i - \delta j) + Bij\sin(\delta i - \delta j)] - (3)$$

Above equations are the power balance equation and power flow equation. Where i=1,. . .,NB; NB is the number of buses, Pg is the active power generated, Pd is the active power load, Gij and Bij are the transfer conductance and susceptance between bus i and bus j, respectively.

2.2.2Inequality Constraints

Generator Constraints: generator power output is varied in its upper and lower range:

$$Pg_i^{\min} \le Pg_i \le Pg_i^{\max} --(4) \quad (i= 1, 2 ...NG)$$

3. PARTICLE SWARM OPTIMIZATION

1) Overview

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling. PSO is one of the EA, inspired by the social flocking behaviour of birds and the schooling behaviour of fish. As like other evolutionary algorithms, PSO is also initialized with some random solutions. All the particles in the PSO fly through problem space. To have all the particles being located in the optimal position in a multi-dimensional space, is the ultimate goal of PSO technique. The PSO works based on the following three rules:

1. When one bird locates a target or food (or maximum of the objective function), it instantaneously transmits the information to all other birds.

2. All other birds gravitate to the target or food (or maximum of the objective function), but not directly.

3. There is a component of each bird's own independent thinking as well as its past memory.

2) Initialization

In PSO algorithm, each individual "i", called particle, represents a solution to the optimization problem i.e. a vector of decision variables, Xi. The initial particles are generated randomly in between their limits by uniform distribution using following equation [23].

$$X_i = X_i^{\min} + rand()*(X_i^{\max} - X_i^{\min}) \qquad (5)$$

Here, NP shows the number of particles, (i=1, 2.....NP)

3) Velocity of Particles

In PSO algorithm particles follow the fittest member of the swarm and move toward historically good areas of the provided space. In order to achieve this, solutions (individuals) are associated with some velocity, v. Starting from zero value in each iteration velocity is calculated by the global best position in the problem space called as **Gbest** and the best known individual position of a particle called as **Pbest** [23].

$$v_{ij}^{t+1} = wv_{ij}^t + c_1R_1(Pbest^t - X^t) + c_2R_2(Gbest^t - X^t) \qquad (6)$$

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Where V_{ij} is velocity of jth member of ith particle at iteration number t which is bounded in its min-max limits and w is inertia-weight which is given as [18]:

$$w = w^{\max} - \frac{(w^{\max} - w^{\min}) * iteration}{\max iteration} \quad (7)$$

Here, R_1 & R_2 are the random numbers generated between 0 and 1. C_1 & C_2 can vary in range of 0-4 but these are adjusted such as $C_1 + C_2 = 4$. In this paper $C_1 = C_2 = 2$ [23].

4) Update the solution vector
at each iteration (generation) of the process, the position vector of swarms is updated by adding the velocity 'v' [18].

$$X^{t+1} = X^{t} + v^{t+1}$$

4. ACCELERATED PSO

There are various versions of PSO are available like dynamic PSO, Modified PSO or Hybrid PSO. In this paper Accelerated PSO is proposed with only two modifications in basic version of PSO[21, 24]:

a) PSO with Normal distributed Initial velocity:
In simple version of PSO, initial velocity of all the particles is taken as zero but in modified form it is generated by uniform distribution within its min-max limits as follows[24]:

$$v_i = v_i^{\min} + rand() * (v_i^{\max} - v_i^{\min}) \quad (8)$$

Here in this paper Normal/ Gaussian distribution in place of Uniform distribution is used to explore the search space by following:

$$v_i = v_i^{\min} + randn() * (v_i^{\max} - v_i^{\min}) \quad (9)$$

Here, NP shows the number of particles, (i=1, 2.....NP)

b) PSO with Constriction Factor:
With the aim of eliminating velocity clamp and encouraging convergence, Clerc and Kennedy [21] proposed a constriction factor. Constriction factor can lie in interval of 0.5 to 1.0 [23]. This constriction factor represented by k is involved in the formula of velocity update as follows:

$$v_{ij}^{t+1} = k * \{wv_{ij}^{t} + c_1 R_1 (Pbest^{t} - X^{t}) + c_2 R_2 (Gbest^{t} - X^{t})\} ....(10)$$

Table 1 Control parameters of APSO Algorithm

S. No.	Parameter	Value
1.	No. of Variables (D)	06
2.	No. of Particles (N)	30
3.	Penalty Factor (k)	10
4.	Max-iterations count (t)	500
5.	Constriction Factor (K)	0.5

5. SIMULATION STUDY & RESULTS

5.1. IEEE- 30 bus system

Table-2 Optimal setting of control variable for ELD

S. No	Parameter	Initial Value	Optimal value by	
			PSO	MPSO
1	Pg1	104.62	151.72	171.06
2	Pg2	80.00	45.12	44.56
3	Pg5	50.00	33.76	23.34
4	Pg8	20.00	25.35	11.71
5	Pg11	20.00	24.06	19.50
6	Pg13	20.00	14.62	24.44
7	Total Gen. (MW)	294.62	294.63	294.62
8	Total Cost ($/h)	916.29	831.85	815.89

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The proposed approach is implemented and tested on a test bed IEEE- 30 bus 6-gen system, which is shown in the figure-4. This system is consists of 48 branches, 6 generators-buses and 22 load-buses. Here, Bus-1 is considered as slack bus. PV- buses: **2,5,8,11,13** and others are PQ-buses.

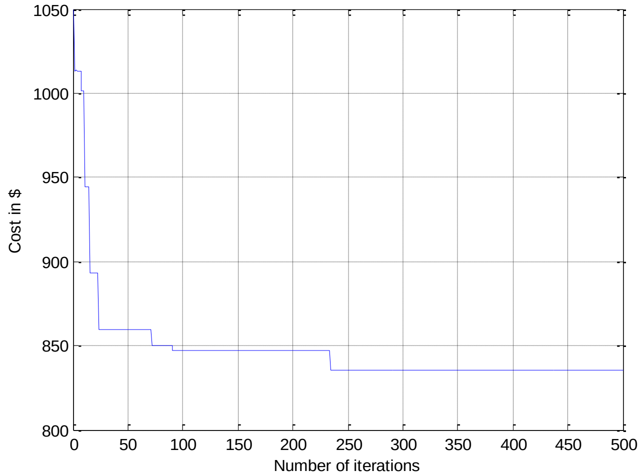

Fig. 1 Plot of fitness vs No. of iterations for fuel cost minimization by PSO

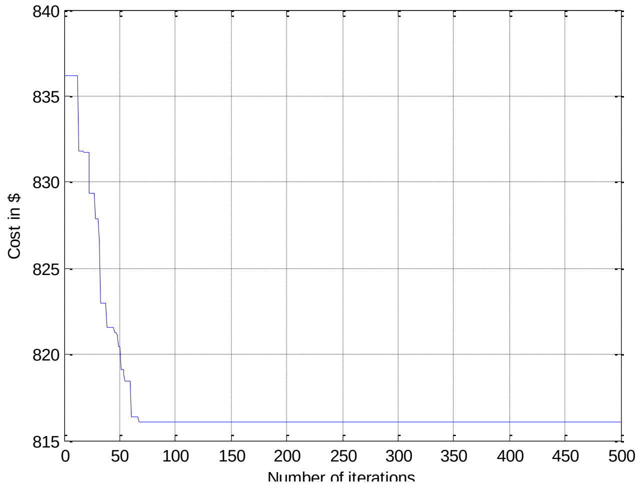

Fig. 2 Plot of fitness vs No. of iterations for fuel cost minimization by Accelerated PSO

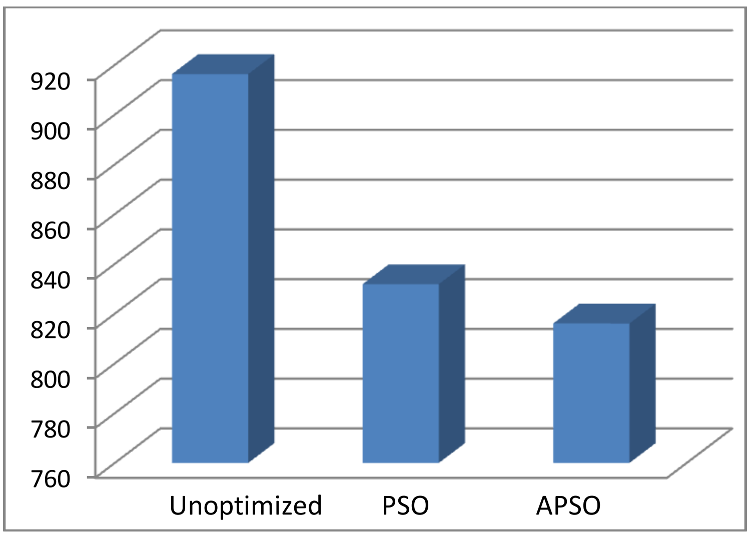

Fig. 3 Comparison of fuel cost minimized

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6. CONCLUSION

In this paper particle swarm optimization technique (PSO) and APSO has been proposed, developed, and successfully applied to solve optimal active power dispatch problem. The OPF problem has been formulated as a constrained optimization problem where objective function has been considered to minimize cost of power generation. APSO algorithm leads to satisfactory results with faster convergence and better accuracy when compared to conventional method and PSO algorithm. The proposed approach have been tested and examined on the standard IEEE 30-bus test system. The above approach resulted with minimization of fuel cost by 11% in comparison of power flow solutions. The simulation results demonstrate the effectiveness and robustness of the proposed algorithm to solve OPF problem.

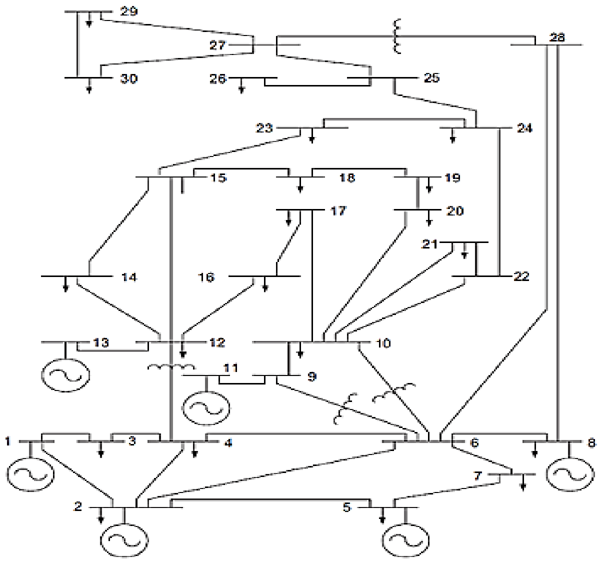

Fig. -4 Single line diagram for IEEE- 30 bus system

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