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Tuning of Acceleration Coefficients of Particle Swarm Optimization for Economic Load Dispatch

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ABSTRACT
Economic load dispatch (ELD) is one of the most common power in-dustry optimization problems. Particle swarm optimization (PSO) is the most effective technique to solve ELD problems. Since the invention of PSO, tuning PSO control parameters has gained a lot of attention among the researchers that improves the performance of PSO. In this study, local and social acceleration coefficient (C1 and C2 respectively) of PSO has been tuned for ELD problem. The study found that the best fuel cost is 1597.989 $/hr. for the load demand of 150 MW. The obtained results also reveal that the equal values of local and so-cial coefficients (C1 = C2 = 2) provide best fuel cost and less average power loss in 20 trial runs. However, higher value of local coefficients (C1 = 3 and C2 = 1) provides consistent results and higher value of social coefficients (C1 = 1.5 and C2 = 2.5) give results in less run time.

KEYWORDS
Economic Load Dispatch (ELD);
Particle Swarm Optimization (PSO);
Local Acceleration Coefficient,
Social Acceleration Coefficient.

1. INTRODUCTION

Economic load dispatch (ELD) is a major optimization problem in the electricity market. It is essentially the process of figuring out the best way to combine the power output of participating generator units to satisfy all operational limitations while meeting the consumer's power demand at the lowest feasible fuel cost [1]-[10].

PSO is one of the best modern optimization algorithm discovered by Eberhart and Kennedy in 1995, through social behavior observed in nature that are used for variety of optimization problems [11]-[14]. It has several advantages over other existing techniques [15], [16] such as simple to understand its algorithm; fewer control parameters etc. [17]-[19]. However, PSO effectively solve the ELD problems, the performance of PSO algorithm can be improves by tuning its control parameters [20]-[24].

In the present study, ELD problem has been solved using PSO algorithm. The proper tuning of local and social acceleration coefficient (AC) has also been presented to improve the effectiveness of PSO algorithm. The best combinations of these coefficients have been obtained based on various criteria like best fuel cost, consistent result, less run time and less average power losses. The rest of the study is organized as follows. Section 2 deals with ELD problems whereas section 3 describes the PSO algorithm. In section 4, results and discussions have been presented while conclusions of the study have been included in section 5.

2. ELD PROBLEM

The ELD is the core optimization problem of power system where the power plant's producing units are scheduled to have the lowest generation cost possible for certain power demand while still adhering to operational limitations [2]-[4]. The following is the statement of the ELD problems:

Minimize

$$F = \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c_i) + K^*(P_D + P_L - \sum_{i=1}^{n} P_i) \quad (1)$$

subjected to operational limitations.

Where F is the fuel cost or objective function, n is the number of thermal generating units, P_i is the power produced by i-th generating unit, P_D is the power demand, P_L is the power losses in the system, K is the penalty coefficients and (a_i, bi, c_i) are the cost coefficients of the i-th generating units.

The power loss in the system is computed using power generation and loss coefficients (B_{ij}, B_{i0} and B_{00}) and is presented as follows:

$$P_L = \sum_{i=1}^{n} (\sum_{j=1}^{n} (P_i B_{ij} P_j)) + \sum_{i=1}^{n} (B_{i0} P_i) + B_{00} \quad (2)$$

3. PSO ALGORITHM

PSO is the robust computational optimization algorithm that harnesses the social behavior of natural organisms like fish schooling and bird flocking to find out the optimal solution of given objective function in most effective and simple ways. The PSO algorithm finds optimal solution using movement of swarm of particles in the search space. Each particle has position, velocity, fitness value and track of their local best position and global best position that leads the movement of swarm towards best solutions [23]-[24]. The movement of particles in the search space is controlled by following velocity and position update equations:

$$V^{new} = wV^{old} + C1\, r_1 (P^{best} - X^{old}) + C2\, r_2 (G^{best} - X^{old}) \qquad (3)$$

$$X^{new} = X^{old} + V^{new} \qquad (4)$$

.

where X^{old} and V^{old} are the position and velocity in previous iteration respectively. P^{best} and G^{best} are the best position of the particle and best position of the swarm respectively. *C1* and *C2* are the local and social acceleration coefficients respectively. r_1 and r_2 are the uniformly distributed random numbers between 0 to 1. X^{new} and V^{new} are the position and velocity in current iteration respectively. w is the inertia weight that controls the balance between local and global search.

Shi and Eberhart suggested linearly decreasing inertia weight from 0.9 (w_{max}) to 0.4 (w_{min}) as presented below [23]:

$$w = w_{max} - k\left(\frac{w_{max} - w_{min}}{k_{max}}\right) \qquad (5)$$

where k and k_{max} are the current iteration and maximum allowed iterations respectively.

The pseudocodes of PSO algorithm to find best fitness value are as follows:

PSO control parameters selection;
Input parameters of objective function loading;
Initialization;
While termination criteria not reached.
    Objective function calculation;
    Local and global best position selection;
    Velocity and position updating;
    Operational limitations handling;
End while.
Display optimal results.

4. RESULTS AND DISCUSSIONS

In this study, ELD problem of three generators system has been solved using PSO algorithm. The cost and loss coefficients and load demand of the system have been taken from ref. [25]. The considered control parameters of the PSO algorithm have been listed in table 1. To improve the performance of PSO, tuning of local and social AC has also considered in the study. Five combinations of local and social AC have been taken for analysis keeping in mind that the sum of local and social AC should be equal to 4. The fuel cost (best, average, worst and standard deviation), average of power losses, Iteration performed and run time of 20 trial runs have been calculated for different combinations of local and social AC. The trial runs have been performed using MATLAB platform. The best results and summarized results of 20 trail runs obtained in the study have been presented in table 2 and table 3 respectively considering different combinations of local and social AC. Further, convergences of best results obtained in the study for different combinations of AC have also been displayed in fig. 1. Moreover, best combinations of the AC have also been listed in table 4 on the basis of best fuel cost, consistent result, less run time and less average power losses obtained in the study.

Table. 1 Control parameters of PSO algorithm

Control parameters	Value
Population	24
Maximum iteration	2000
Maximum inertia weight	0.9
Minimum inertia weight	0.4
Iteration when IW is 0.4	1500
Error gradient	10^{-6}

Table. 2 Best result obtained for different combinations of AC in 20 trial runs

Acceleration Coefficients		Fuel Cost (in $/hr.)	Power Generation (in MW)			Power losses (in MW)	Iteration Performed	Run Time (in sec)
C1	C2		G1	G2	G3			
3	*1*	1598.681	41.064	61.328	49.999	2.360	49	4.591
2.5	*1.5*	1598.156	34.734	59.515	58.071	2.289	69	4.791
2	*2*	1597.989	32.111	66.804	53.489	2.371	78	5.479
1.5	*2.5*	1599.767	23.815	65.949	62.607	2.333	24	1.740
1	*3*	1598.192	30.562	67.253	54.580	2.369	21	1.525

Table. 3 Summarized result for different combinations of AC in 20 trial runs

Acceleration Coefficients		Fuel Cost (in $/hr.)				Average Power losses (in MW)	Average Iteration Performed	Average Run Time (in sec)
C1	C2	Best	Average	Worst	Standard Deviation			
3	*1*	1598.681	1604.981	1614.561	4.419	2.420	40	2.922
2.5	*1.5*	1598.156	1605.255	1628.088	7.936	2.431	54	3.801
2	*2*	1597.989	1606.950	1646.862	12.72	2.389	48	3.386
1.5	*2.5*	1599.767	1605.014	1625.530	7.776	2.505	41	2.879
1	*3*	1598.192	1605.621	1625.732	7.594	2.479	46	3.159

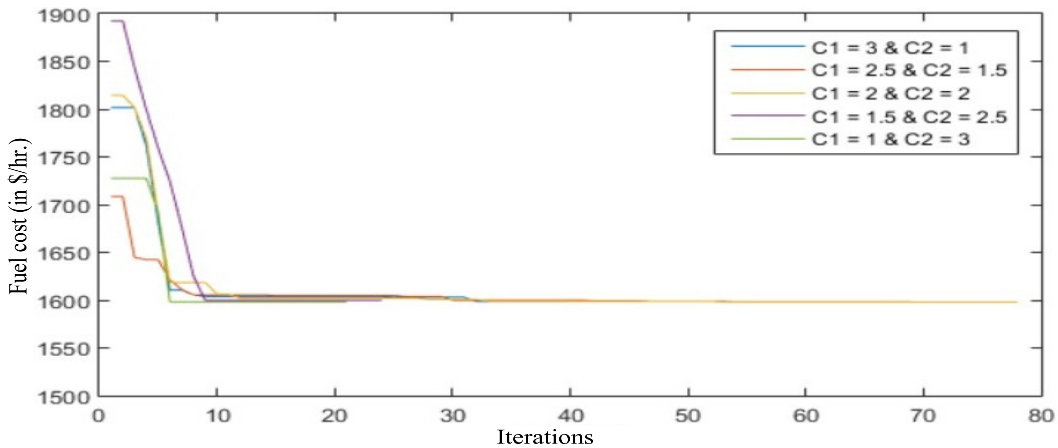

Fig. 1 Convergence of best fuel cost for different combinations of AC.

Table. 4 Best combination of acceleration coefficients

Parameters	C1	C2
Best fuel cost	2	2
Consistent Result	3	1
Less average Run Time	1.5	2.5
Less Average Power Losses	2	2

The study obtained the best fuel cost of 1597.989 $/hr. for a load demand of 150 MW when both the AC are equal i.e. C1 = C2 = 2 (see table 2). In that case, the power generations of 3 generators are 32.111 MW, 66.804 MW and 53.489 MW while power loss is 2.371 MW. This run takes 5.479 sec and 78 iterations to give result. The PSO algorithm converges faster if high value of social AC (C1 = 1 and C2 = 3) is considered as it takes minimum time (1.525 sec) and only 21 iterations to produce result.

The PSO algorithm provides consistent results when high value of local AC (C1 = 3 and C2 = 1) are considered because the standard deviation cost of 20 trial runs is minimum (4.419 $/hr.) among five combinations of AC (see table 3). However, high social AC reduces average run time. The less average run time (2.879 sec) is obtained when C1 = 1.5 and C2 = 2.5. Moreover, best fuel cost (1597.989 $/hr.) as well as less average power losses (2.389 MW) is obtained if both AC are equal to 2.

5. CONCLUSIONS

The ELD problem of 3 generators system has been solved by PSO algorithm in the present study. To improve the study of PSO algorithm, tuning of local and social AC has also been implemented. The study found that best fuel cost of 1597.989 $/hr. for load demand of 150 MW and less average power losses of 2.389 MW in 20 trial runs are obtained when equal value of AC (C1 = C2 = 2). However, consistent results are obtained by PSO algorithm if high value of local AC is considered. Moreover, higher value of social AC in the PSO algorithm reduces the average run time.

Although PSO algorithm solves ELD problem efficiently and proper tuning of local and social AC enhances its performance, still there are several possibilities of tuning other control parameters like inertia weight, constriction factor etc. to improve the performance of the PSO algorithm.

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