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MULTI OBJECTIVE ECONOMIC LOAD DISPATCH WITH EMISSION CONSTRAINT USING NEW PSO

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Abstract: Economic load dispatch problem identified the generated output power of each generating power plant, and output power of each generating unit within a generated power plant in such a way to minimize the overall generation cost to provide the system load demand and not violate the constraints limits. In this paper we minimize the environmental emission of harmfull gases in ELD.here we using New PSO with constriction factor for solving ELD .This work is proposed to compare three and six generating using PSO and CPSO.
Keywords: ELD, generating cost, environmental emission

1. INTRODUCTION

In the economic load dispatch the generations are not fixed but they are allowed to take values again within certain limits so as to meet a particular load demand with minimum fuel cost. Economic load dispatch problem is really the solution of a large number of load flow problems and choosing the one which is optimal in the sense that it needs minimum cost of generation. Since total cost of generation is a function of the individual generation of the sources which can take values within different constraints, the cost of power generation is depends on the operating constrains of the sources.

By proper planning and design of power plant can be operate economically and efficiently. Economic load dispatch used for analysis, planning and design of the power system which operate economically and efficiently. Economic load dispatch also used for the study of transient stability and contingency studies of the power plant. Power system fuel cost problem numerically can be analyzed by use of economic load dispatch. The most important objective of the economic dispatch problem is to minimize the total generation cost while satisfying the operational constraints.

In literature many classical methods known as deterministic algorithms were listed such as Lagrange multipliers [16,], Leaner programming method (LP),[6], Quadratic programming (QP)[15], Parametric quadratic programming [14], Harmony search method [17], and Pattern search programming[11] used for the solution of economic load dispatch problem.

A new multi-objective optimization, MOSST, was presented [44]. It is an adaptation of the method for single criterion function optimization. The solution provided by MOSST is a family of points known as the Pareto-optimal set.

Improved harmony search method proposed by the articles of [17] for solving economic load dispatch problems. The harmony search method mimics a jazz improvisation process by musicians in order to seek a fantastic state of harmony.

Classical methods have their own drawbacks such as algorithmic complexity, needs linear mathematical model of problem, convergence characteristics that are sensitive to initial conditions, suffers from bad initial termination and optimality criteria and many more.

Many research articles proposed modern evolutionary techniques for the solution of economic load dispatch problem. Most of the proposed evolutionary techniques were population based optimization techniques, relying on initial randomization associated with logical patterns. These techniques have fast conversation and able to provide global solution of the ELD problem.

In literature many heuristic evolutionary algorithms are listed such as differential evolution (DE)[39], genetic algorithm (GA) [18, 20, 36, 37, 45] particles warm optimization (PSO) [10], improved particle swarm optimization (IPSO)[22], MPSO[7], SHO-PSO[31], neural network[30], [32], Fuzzy logic system [33], BBO[24], and ES[47] used for the solution of nonlinear ELD problem.

The interior point methods, in general, suffer from bad initial, termination, and optimality criteria and in most cases, are unable to solve nonlinear and quadratic objective functions. To overcome the problem of interior point methods proposed improved quadratic interior point (IQIP) method offers great improvements in speed, accuracy, and convergence in solving multi-objective and multi-constraint optimization problems. a self-dual (SHSD) linear programming (LP) interior point algorithm for the solution of ELD problem with security constrained. the interior point method that can obtain an optimal solution for the security constrained economic dispatch problems while taking into account of the power flow constraints.

Genetic algorithms approach proposed by the authors of [18] for solving Economic Load Dispatch (ELD) problem. In year 2005 [20] and [36],[37] proposed genetic algorithm (GA) and an improved genetic algorithm with multiplier updating (IGA_MU) respectively can efficiently search and actively explore solutions, and the MU is employed to handle the equality and inequality constraints of the ELD problem.

Fuzzy based techniques were proposed by [3] Genetic algorithm [4], micro GA, and PSO proposed by [25], Levenberg marquardt algorithm proposed by [30, 32] in 2006, based on the multi layer feed forward neural network, and a modified bacteria foraging algorithm (BFA) for the solution of ELD problem with environmental emission. ABC algorithm inspired by foraging behavior of honey bees proposed to solve combined economic and emissions dispatch problems is presented [50]

PSO has attracted many attentions and been applied in various power system optimization problems such as economic dispatch [35]. Authors of [10], [25], proposed a particle swarm optimization approach to economic load dispatch problems with non-smooth objective functions.

Typically in simulated annealing method, a higher cost feasible solution is accepted with temperature dependent probability, but other solutions are accepted deterministically. Saber et al. (2005) presented a new approach to unit commitment problem [8] using absolute stochastic simulated annealing method. In every iteration, a solution is taken with a certain probability. However, all the solutions, both higher and lower cost, are associated with acceptance probabilities.

Evolutionary algorithms are heuristic methods that have yielded promising results for solving nonlinear, non differentiable and multi-modal optimization problems in the power systems area [39]. Many research articles proposed modern evolutionary techniques for the solution of economic load dispatch problem. Most of the proposed evolutionary techniques were population based optimization techniques, relying on initial randomization associated with logical patterns. These techniques have fast conversation and able to provide global solution of the ELD problem.

The main focus of this chapter is to review and summarize the various optimization techniques listed in the literature, used for the solution of economic load dispatch problem. Here also focused to provide a deep review of different variants PSO used to solve the problem of economic dispatch

II PROBLEM FORMULATION

Formulation of ELD Problem

The main concerns of ELD problem is the minimization of its objective function. For obtaining optimum results of economic load dispatch problem it is needed to formulate proper mathematical model with their constraints. Mathematical model of ELD problem can be formulated in many way as listed in literature such as, Single objective, multi-objective, Linear model of ELD, nonlinear model, ELD model with emission effect, ELD model with nonconventional sources etc.

(A) Objective I

Single Objective ELD Problems

The main objective of ELD problem given as

Minimize $FC_T = \sum_{i=1}^{N} FC_i(P_i)$ (1)

Where, FC_T is the total generation cost; FC_i is the power generation cost function of the i^{th} unit; N is the total number of generating units.

Generally, the fuel cost of a thermal generation unit is considered as a second order polynomial function [18], [47]. Fig.3.2 and fig.3.3 shows the heat rate and fuel cost curve for the linear ELD problem.

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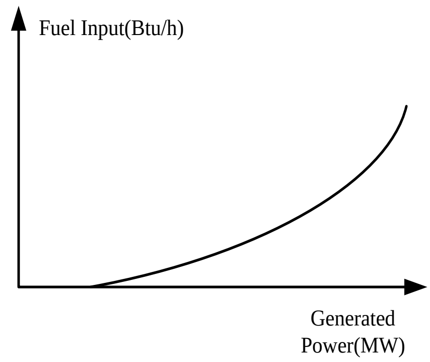


Fig.1 Heat rate curve of thermal generating plants

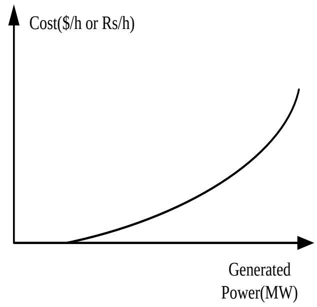


Fig.2 Fuel cost curve of thermal generating plants

The mathematical model of classical and smooth cost function is given as

$$FC_i(P_i) = a_i P_i^2 + b_i P_i + c_i \quad (2)$$

Where, P_i is the generated power of the i^{th} generating unit between the prescribed limit; a_i, b_i, c_i are the fuel cost coefficients of the i^{th} generating unit.

The global warming is a concern for power industry, as it is accountable for the emission of green house gases in environment. As discussed earlier that amendment of clear air act and environmental friendly policies (Carbon Credit System) develops an interest of power sector towards reduction of environmental emissions (of NO_x, So_x and CO_2 gases).

Various mathematical model formulations are used to represent the emission of green house gases in ELD problem. It can be represented in quadratic form, addition of quadratic polynomials with exponential terms, or addition of linear equation with exponential terms of generated power.

When considered emission constraint the objective function formulated as

(B) Objective II

$$FC_{T1} = FC_i(P_i) + k\,(FE_i(P_i)) \quad (3)$$

$$k = F_{i,Max}/E_{i,Max} \quad (4)$$

Where,

$$F_{i,Max} = a_i P_{i,Max}^2 + b_i P_{i,Max} + c \quad (5)$$

$$E_{i,Max} = d_i P_{i,Max}^2 + e_i P_{i,Max} + f_i \quad (6)$$

Where, FC_{T1} is the cost function with emission effect, $FE_i(P_i)$ is the emission function, and d_i, e_i & f_i are the emission coefficients.

(C) Constraints
Power balance constraint

The classical and non-classical models either with smooth or non-smoothed fuel cost functions are subjected to the following equality and inequality constraints.

$$\sum_{i=1}^{n} P_i = P_D + P_L \quad (7)$$

Each generator is constrained between its minimum and maximum limits, as shown in (8),

$$P_i^{min} \le P_i \le P_i^{max} \quad (8)$$

Where, P_i is the output power of ith generator; P_i^{min} and P_i^{max} are the min/max power outputs of ith generator.

In the economic load dispatch, the network losses should be taken into account as functions of respective generating unit output using B coefficients are given as

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{i0} P_i \quad (9)$$

Where, B_{ij} is the ij^{th} element of loss coefficient symmetric matrix B, B_{i0} is the element of the loss coefficient vector and B_{00} loss coefficient constant.

III OVERVIEW OF SOME PSO STRATEGIES

Particle swarm optimization (PSO)

Initialization of the Swarm

Implementation of PSO algorithm for the solution of ELD problem, each element of the swarm is initialized randomly within the effective real power operating limits of the plant. The particles and velocity of the particles are initialized as follows in terms of generated power limits of thermal generating units.

$$P_{initial} = P_{imin} + rand * (P_{imax} - P_{imin}) \quad (10)$$

$$V_{initial} = V_{imin} + rand * (V_{imax} - V_{imin}) \quad (11)$$

Where, rand is a random positive number between 0 and 1. This position and velocity initialization scheme guarantees to produce new particles satisfying real power operating limit constraints.

Penalized Fuel Cost Function

The nonlinear ELD problems involve many constraints. Out of these constraints, limiting the movement of the particles imposes the effective real power operating limits. The real power balance constraints are handled with objective function as follows

$$\text{Minimize } FC_T = \sum_{i=1}^{N} FC_i(P_i) \quad (12)$$

Subject to

$$\sum_{i=1}^{N} P_i = P_D + P_L \quad (13)$$

where, P_D is the total demand, P_L is the line loss and Pi is the generated power of ith generating units.

Initialization of the best positions

In the strategy of PSO, the particle's best position and global best position are the key factors. The best position of a particle is the position, which gives the minimum value of generated power of the generating units, and the best position out of all the pbest is taken as gbest.

If all exemplars of a particle are its own pbest, it will randomly choose one dimension to learn from another particle's pbest corresponding dimension. At the beginning of the iteration process, the position for all the particles are taken as the same as the initial positions.

Selection of velocity

Maximum velocity given by

$$V_{max} = (P_i^{Max} - P_i^{Min})/N\,, \quad (14)$$

$$V_{min} = -(P_i^{Max} - P_i^{Min})/N \quad (15)$$

Where, N is the numbers of intervals in the dth dimension selected by the user and, are maximum and minimum values found so far by the particles.

Selection of acceleration constants

In literature the value of acceleration constants c_1 and c_2 are considered between 1.2 to 2.4. Maximum number of authors considered c_1 and c_2 =2. In this work we have to consider all these value and optimize the problem and it is seen that when considered c_1 and c_2 =2 get best value out of other value. So the PSO algorithm is run for all case considered in this work, c_1 and c_2 =2.

Selection of inertia Weight

In this work the higher value of inertia weight is considered W_{max} =0.9 and the it is decreases in lower value is W_{min} = 0.4 and it is formulated as

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} \times \text{iteration} \quad (16)$$

Where, W is the inertia weight constant.

Updating the velocity and particle positions

Since in PSO the particles are generated randomly and their velocity also generated randomly for each particles. Many particles that have low velocity they can't reach up to optimum position and hence we can't get optimum solution of the problem. So that it is required to update the velocity of the particles and according to that velocity update the position of the particles. The particles in the swarm are moved to new positions with the help of new velocities. The velocity and the position of the d^{th} dimension of the i^{th} particle are updated as follows.

$$V_i^{(K+1)} = WV_i^K + c_1 Rand_1 \times \left(Pbest_i - S_i^K\right) + c_2 Rand_2 \times \left(gbest - S_i^K\right) \quad (17)$$

$$S_i^{(K+1)} = S_i^K + V_i^{K+1} \quad (18)$$

(3.37)

Fitness Function

For the optimization of economic load dispatch problem in such a way to get the minimum fuel cost of the generation it's required fitness function. This study considers the fitness function such as given:

$$\text{fitness function} = \frac{(\text{Total Demand} - \text{Total power generation})^2}{2} \quad (19)$$

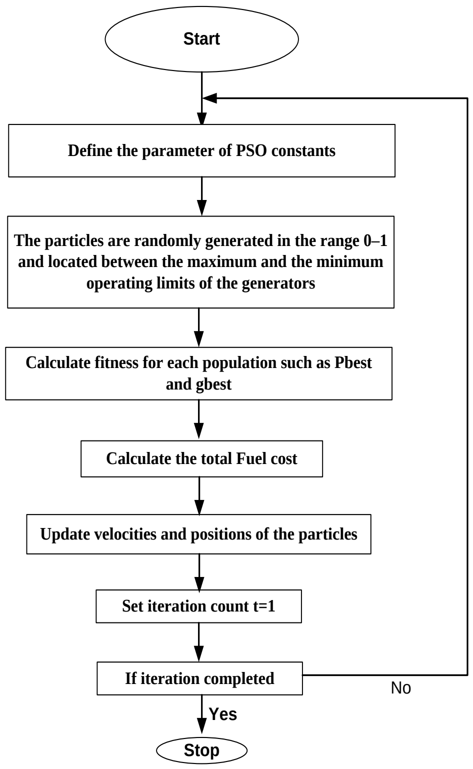
According to this fitness function the objective of proposed problem can be formulated as

$$\text{Objective} = \frac{1}{(1+\text{fitness function})} \quad (20)$$

Stopping Criterion

In this work maximum number of iterations is taken as the stopping criterion.

IV FLOW CHART OF PSO



V TEST DATA AND RESULTS

Test Data

In this case of test data cost coefficients and generator operating limits of various generating units is considered. Constraints such as line loss, environmental emission etc. not considered here only load valance constraints are considered.

Test Data-I

The first test results are obtained for 3-generator Systems in which all units with their Emission constraints. The unit characteristics data are given in Table 5.1 The load demand is 850 MW. The best solutions of the proposed PSO and CPSO.

Table 1
Capacity, cost coefficients and Emission Coefficient of 3 generator systems, for the demand of 850MW

Unit	a_i	b_i	c_i	P_i^{max}	P_i^{min}	*di*	*Ei*	*Fi*
1	0.05	2.47	105	200	50	.0126	-1.355	22.983
2	0.05	3.51	44.1	400	100	.01375	-1.249	137.370
3	0.05	3.89	40.6	600	100	.00765	-.0805	363.704

Table 2

Line loss coefficient (in MW^{-1}) for 3 generator system

B_{ij}	0.0006760	0.0000953	-0.0000507
	0.0000953	0.0005210	0.0000901
	-0.0000507	0.0000901	0.0002940
B_{i0}	-0.007660	-0.00342	0.01890
B_{00}	0.40357		

Table 3
Results of Three Unit System for the demand of 850MW

Unit Power Output	*PSO*	*CPSO*
P1(MW)	145.73	144.8978
P2(MW)	338.45	340.9597
P3(MW)	549.7817	547.8717
Power loss(MW)	183.043	183.7293
Total Power Output	1033.958	1033.7
Total Cost($/h)	9842.228	9839.228
Total Emission(Ton/hr)	887.42	826.84

Test Data II

The second test results are obtained for six-generating unit system in which all units with their Emission constraints. This system supplies a 1263MW load demand. The data for the individual units are given in Table 5.3. The best solutions of the proposed PSO, CPSO are shown in Table 5.4.

Table 4
Capacity, cost coefficients and Emission coefficient of 6 generator systems

Unit	c_i	b_i	a_i	P_i^{min}	P_i^{max}	*Di*	*ei*	*Fi*
1	756.79886	38.53973	.15247	10	125	.00419	.32747	13.8593
2	451.32513	46.15916	.10587	10	150	.00419	.32747	13.8593
3	1049.9977	40.15916	.02083	35	225	.00683	-.54551	.00683
4	1234.5311	38.30553	.03556	35	210	.00683	-.54551	.00683
5	1658.5658	36.32782	.02111	130	325	.00461	-.5116	.00461
6	1356.6592	38.27041	.0179	125	315	.00419	-.5116	.00461

Table 5
Line loss coefficients (in MW^{-1}) for 6 generator systems

$B_{ij}(10^{-4})$	0.17	0.12	0. 7	-0.1	-0.5	0.02
	0.12	0.14	0.09	0.01	-0.06	0.01
	0.07	0.09	0.31	0.000	-0.10	0.06
	-0.01	0.01	0.00	2.4	-0.06	0.08
	-0.05	-0.06	-0.10	-0.06	1.29	0.02
	-0.02	-0.01	-0.06	-0.8	-0.2	1.50
B_{i0} (10^{-4})	-0.3908	-1.297	7.047	0.5910	2.161	-6.635
B_{00}	0.0056					

Table 6
Generator output for six bus system, for 1263 MW load demand

Unit Power Output	*PSO*	*CPSO*
P1(MW)	493.24	471.66
P2(MW)	114.63	140.03
P3(MW)	263.41	240.06
P4(MW)	139.71	149.97
P5(MW)	179.65	173.78
P6(MW)	84.83	99.97
Loss(MW)	12.46	12.31
Total Power Output	1275.46	1275.31
Total Cost($/hr)	15489	15481.87
Total Emission(Ton/hr)	1735.181	1622.026

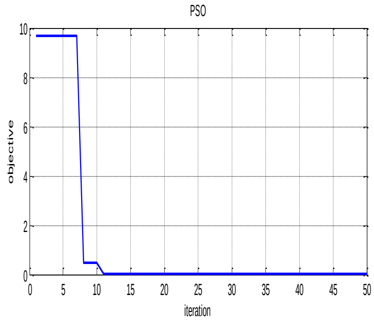


Figure.1. Fitness function of the PSO for three generator system

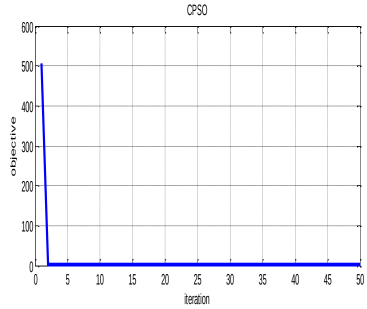


Figure.2. Fitness function of the CPSO for three generator system

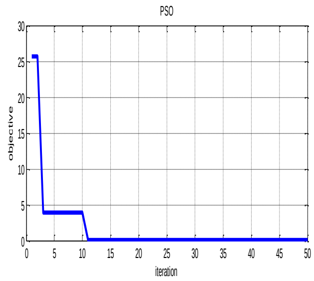


Figure.3. Fitness function of the PSO for six generator system

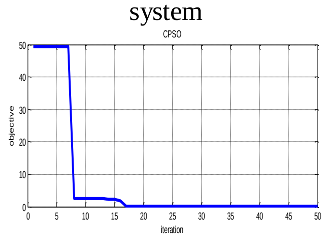


Figure.4. Fitness function of the CPSO for six generator system

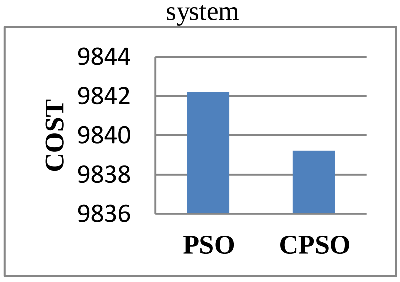


Figure 5. Bar graph for total cost of PSO and CPSO for three generator system

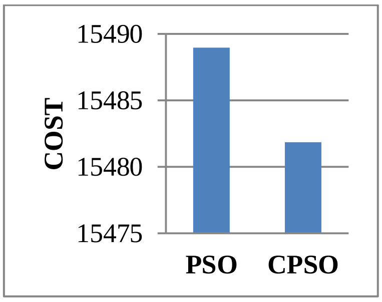


Figure.6 Bar graph for total cost of PSO and CPSO for six generator system

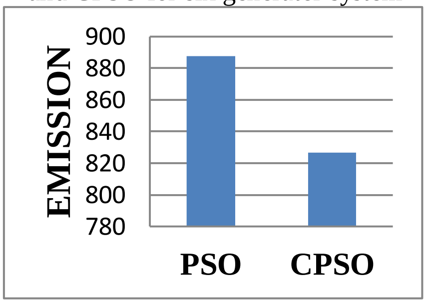


Figure.7 Bar graph for total Emission of PSO and CPSO for three generator system

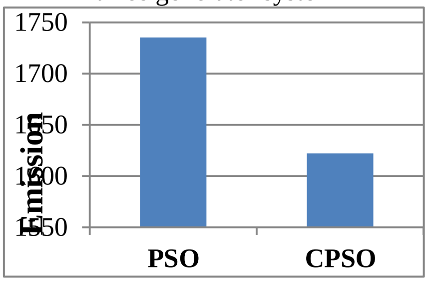


Figure.8 Bar graph for total Emission of PSO and CPSO for six generator system

To assess the efficiency of the proposed PSO and CPSO approaches in this paper, two case studies (3 and 6 thermal units or generators) of ELD problems with environmental emission were applied. The CPSO routine in this article is adopted using the Matlab Optimization Toolbox. All the programs were run on a 1.4-GHz, core-2 solo processor with 2GB DDR of RAM.

In each case study, 50 number of iteration were taken for each of the optimization. The constant used in this study was, acceleration coefficient used in this study are C1=C2=2, α=3.1-4.5, Wmax=0.9 and Wmin=0.4.

Fig.1 and fig.2 show the characteristic of PSO and CPSO for the test data of three generating units respectively and Fig.3 and fig.4 show the characteristic of PSO and CPSO for the test data of six generating units respectively.

Taking IEEE standard data bus system of different generating unit system represented in this chapter. All test data taken for testing of the proposed evolutionary techniques have their generation limits as well as fuel cost coefficients, environmental effect constants and constraints limits.

All the test data presented over in this chapter are tested by PSO and CPSO. Results obtained by each test data by use of these optimization techniques are represented for the comparative analysis. The convergence characteristic of evolutionary techniques for each test case is presented in this chapter.

VI CONCLUSION

In this work, evolutionary techniques such as, particle swarm optimization and CPSO, are formulated and implemented to find the optimum solution of the ELD problem with environmental emission.

PSO works on the principle of minimizing the cost function and this property ensures convergence. These evolutionary techniques have the flexibility to take the objective function and constraints separately. Results obtained by PSO methods do not depend on initialization of particle and weight selection. Its computer implementation is also simple. The internal parameters of PSO are computed using valid subspace approach, which guarantee the convergence of solution at equilibrium points. The PSO algorithm approach yields solutions which are optimal or near to optimal.

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