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Multi objective Economic Load Dispatch with Emission Constraint Using New PSO

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Abstract - Economic load dispatch (ELD) is an important optimization task in electrical system. Economic load dispatch is a way to find out the available generating units and distribute the load demand between them in such a way fulfills the load demand and satisfied the constraints in such way to minimize the fuel cost. In this paper we considered ELD problem as a multi objective problem. Here not only solve the ELD problem but also minimize the SO2 emission. Particle swarm optimization is one of the most popular optimization techniques used for the solving ELD problem. PSO is a population based optimization techniques inspired by sociological behavior of fish schooling. PSO can be applied to solve multi-objective ELD problem. This paper used a novel PSO with constriction factor for solving ELD problem, which enhances the ability of particles to explore the solution spaces more effectively and increases their convergence rates. In this work the usefulness and effectiveness of the CPSO algorithm is demonstrated through its application to three and six generator systems with emission constraints.

Keywords: Economic dispatch, environmental emission, Particle swarm optimization (PSO), Particle swarm optimization with constriction factor (CPSO).

I. INTRODUCTION

Electric utility system is interconnected to achieve the benefits of minimum the generation prize , improve reliability of the operating conditions. The economic scheduling is the on-line economic load dispatch, distribute the load among the generating units which are actually paralleled with the system, in such a way as to minimize the total operating cost of generating units while satisfying system equality and inequality constraints. For any specified of the demand, economic load dispatch can be identified the power output of every plant (and each generating unit within the plant) which will minimize the overall cost of fuel needed to serve the system load [1]. ELD is used in real-time energy management power system control by most programs to allocate the total generation among the available units. ELD focuses upon coordinating the production cost at all power plants operating on the system.

Conventional as well as modern methods have been used for solving economic load dispatch problem employing different objective functions. Various conventional methods like lambda iteration method, gradient-based method, Bundle method [2], nonlinear programming [3], mixed integer linear programming [4], dynamic programming [6], linear programming [7], quadratic programming [9], Lagrange relaxation method [8], Newton-based techniques [10], reported in the literature are used to solve such problems.

Conventional methods have many draw back such as nonlinear programming has complex in nature. Linear programming approach is fast in operation but require linearization of objective function as well as constraints with non-negative variables. Quadratic programming is a special form of nonlinear programming which has some disadvantages associated with piecewise quadratic cost approximation. Newton-based method has a drawback of the convergence characteristics that are sensitive to initial conditions. The interior point method is computationally efficient but suffers from bad initial termination and optimality criteria.

Recently, different heuristic approaches have been proved to be effective with promising performance, such as evolutionary programming approach[11], simulated annealing approach (SA) [12], Tabu search approach (TS) [13], pattern search (PS) [14], Genetic algorithm (GA) [15], Differential evolution (DE) [16], Ant colony optimization [17], Neural network [18], particle swarm optimization (PSO) [19], [20], [21], modified particle swarm optimization MPSO [24],SHOPSO [22], WIPSO [28],MOPSO [29]. Although the heuristic methods do not always guarantee discovering globally optimal solutions in a limited time, but also provide practical solution. EP is rather slow converging to a near optimum for some problems. SA is very time consuming, and cannot be utilized easily to tune the control parameters of the annealing schedule. TS difficult in defining effective memory structures and strategies.. Genetic algorithm lacks a strong ability of producing better offspring and causes slow convergence near global optimum, sometimes may be trapped into local optimum. DE greedy updating principle and intrinsic differential property usually lead the computing process to be trapped at local optima.

Particle-swarm-optimization (PSO) method is a population-based Evolutionary technique first introduced in [21], and it is inspired by the emergent motion of a flock of birds probing for groceries. If it compare with other evolutionary technique like genetic approach, the PSO has comparable or even superior search performance with faster and more stable convergence rates. Now, the PSO has been extended to electrical power systems, NN and fuzzy logic system control.

The main objective of this study is to use of new PSO with constriction factor to solve the power system economic load dispatch as well as reducing the environmental emission. This new development gives particles more opportunity to explore the solution space than in a standard PSO.

The proposed method focuses on solving the economic load dispatch with emission constraint. The feasibility of the proposed method was demonstrated for three and 6 generating unit system. The results obtained by the proposed approach are compared with the results given in the literatures.

II. PROBLEM FORMULATION

In this section, we shall formulate the optimization problems in power system economic load dispatch that have multiple non-commensurable objectives. In what follows, the performance indices together with the equality and inequality constraints pertaining to the power system optimization problems will be described.

Objectives

A. Basic Economic Dispatch Formulation to minimize the fuel cost

ED is one of the most important problems to be solved in the operation and planning of a power system the primary concern of an ED problem is the minimization of its objective function. The total cost generated that meets the demand and satisfies all other constraints associated is selected as the objective function.

The ED problem objective function is formulated mathematically in (1) and (2),

$$F_T = \text{Min } f(F_i(P_i)) \quad (1)$$

$$F_i(P_i) = \sum_{i=1}^{n} a_i \times P_i^2 + b_i \times P_i + c_i \quad (2)$$

Where, F_T is the objective function.

a_i, b_i and c_i are the cost coefficients for the nth generating units..

B. Minimization of Emission

The emission function can be presented as NO*x*, SO2, etc.. this work consider only NO*x* emission. The amount of NO*x* emission is given as a function of generator output and it is represented as given below.

The Emission equation of the ith generating unit is usually described as:

$$E_i(P_i) = \sum_{i=1}^{n} d_i \times P_i^2 + e_i \times P_i + f_i \quad (3)$$

Where d_i, e_i and f_i are the emission co-efficient of the i_{th} unit.

So our final objective using emission constrained can be formulated as (4).

$$P_i^{'}(P_i) = F_i(P_i) + hE_i(P_i) \quad (4)$$

$$h = F_{iMax} / E_{iMax} \quad (5)$$

where,

$$F_{iMax} = a_i P_{iMax}^2 + b_i P_{iMax} + c \quad (6)$$

$$E_{iMax} = d_i P_{iMax}^2 + e_i P_{iMax} + f_i \quad (7)$$

C. Constraints

In this work following constraints are consider

1). Power balance constraints

$$\sum_{i=1}^{n} P_i = P_D \quad (8)$$

Where, P_D is the total system demand.

2). Generator Limits

There is a limit on the amount of power which a unit can deliver. The power output of any unit should not exceed its rating nor should it be below that necessary for stable operation. Generation output of each unit should lie between maximum and minimum limits.

$$P_i^{min} \le P_i \le P_i^{max} \quad (9)$$

Where, Pi is the output power of ith generator,

$P_{i,min}$ and $P_{i,max}$ are the minimum and maximum power outputs of generator i respectively.

III. OVERVIEW OF SOME PSO STRATEGIES

A. Standard Particle Swarm Optimization (PSO)

Particle swarm optimization was first introduced by Kennedy and Eberhart in the year 1995 [21]. It is an exciting new methodology in evolutionary computation and a population-based optimization tool. PSO is motivated from the simulation of the behavior of social systems such as fish schooling. PSO is a powerful optimization approach which scatters particles randomly in the search space. The scatter particles called swarms. The particles update their positions using the velocity of particles. Position and velocity of the particles updated in a heuristic manner using guidance from particles' own experience and the experience of its neighbors.

The position and velocity vectors of the ith particle of a d-dimensional search space can be represented as Pi=(pi1,pi2,………pid) and velocity of the particles is define as vj=(vj1,vj2,………vjd,). We can evaluate pbest and gbest from the swarm represented as pbest=(p1best,p2best…..pibest), and gbest=(g1best,g2best……gibest).

Velocity and position of the particles is updates as follows

$$V_i^{(K+1)} = WV_i^K + c_1Rand_1(\,) \times \left(Pbest_i - S_i^K\right) + c_2Rand_2(\,) \times \left(gbest - S_i^K\right) \quad (10)$$

$$S_i^{(K+1)} = S_i^K + V_i^{K+1} \quad (11)$$

Where, Vik is velocity of individual i at iteration k,

k is pointer of iteration, W is the weighing factor,

C1, C2 are the acceleration coefficients,

Sik is the current position of individual i at iteration k,

Pbesti is the best position of individual i and

The coefficients c1 and c2 pull each particle towards paricle best nad global best positions. The value of c1 and c2 are selected in such a way so that particle cannot move from the search area. The term c1rand1 () x (pbest, -Sk1) is called particle memory influence or cognition part which represents the private thinking of the itself and the term c2Rand2( )×(gbest – Sk1) is called swarm influence or the social part which represents the collaboration among the particles.

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} \times iter \quad (12)$$

Where, Wmax is the initial weight, Wmin is the final weight, Iter max is the maximum iteration number and iter is the current iteration position.

B. Classical PSO

In this section, for getting better solution the standard PSO algorithm, used classical PSO [23],[27],The constriction factor is used in this algorithm given as

$$C = \frac{2}{\left|2 - \emptyset - \sqrt{\emptyset^2 - 4\emptyset}\right|} \quad (13)$$

Where, Ø is define as 4.1≤Ø≤4.2

As $\emptyset$ increases, the factor c decreases and convergence becomes slower because population diversity is reduced.

Now the update its velocity using (14).

$$V_i^{(K+1)} = C[WV_i^K + c_1Rand_1(\,) \times \left(Pbest_i - S_i^K\right) + c_2Rand_2(\,) \times \left(gbest - S_i^K\right)] \quad (14)$$

IV. ALGORITHM FOR ELD WITH EMISSION DISPATCH PROBLEM USING CPSO

The algorithm for ED problem with ramp rate generation limits employing CPSO for practical power system operation is given in following steps:-

- First selects the various constants
- Randomly initialize the particles.
- Similarly initialize the velocity of the particles randomly.
- Now set counter t=t+1.
- Evaluating the fitness function for each particle according to the objective function.
- Compare particles fitness evaluation with its pbest and gbest.
- Updating velocity and position
- Apply stopping criteria.

V. TEST DADA AND RESULTS

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 I The load demand is 850 MW. The best solutions of the proposed PSO and CPSO.

Table I: Capacity, cost coefficients and Emission Coefficient of 3 generator systems.

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 II: Results of Three Unit System

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

TEST CASE 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 III. The best solutions of the proposed PSO, CPSO are shown in Table IV.

Table III: 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	13.85932
2	451.32513	46.15916	.10587	10	150	.00419	.32747	13.85932
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 IV: Results of 6 generating units

Uni tPower 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($/h)	15489	15481.87

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, 100 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, fig.2 and fig.3 show the improvement in each iteration for the three, six and fifteen generation unit system respectively.

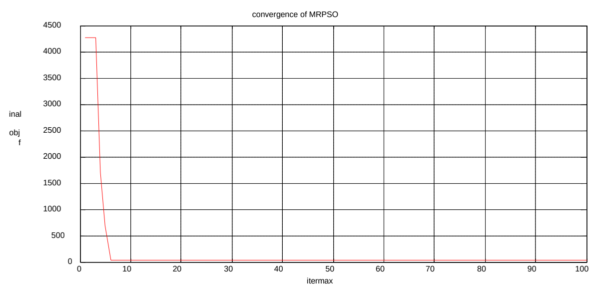

Figure.1. Fitness function of the conversion system for three generator system

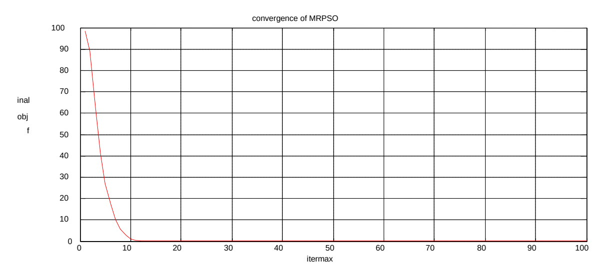

Figure.2. Fitness function of the conversion system for six generator system

VI. CONCLUSIONS

This paper introduces PSO and CPSO optimization to study the power system economic dispatch with ramp rate limit constraints. The proposed method has been applied to test case. The analysis results have demonstrated that CPSO outperforms the other methods in terms of a better optimal solution and significant reduction of computational time. However, the much improved speed of computation allows for additional searches to be made to increase the confidence in the solution. Overall, the CPSO algorithms have been shown to be very helpful in studying optimization problems in power systems.

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