CALCULATION OF ECONOMIC LOAD DISPATCH WITH CONSTRAINTS USING NEW PSO

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Abstract

Economic load dispatch (ELD) is a process to allocate the demand on the available generating unit at that time in such a way to satisfied the demand and not violate the constraints. The load demand is fulfill by the generating units operated in such that take minimum generation cost. Due to presence of constraints ELD problem is nonlinear in nature. So for calculation of such nonlinear problem needs optimization techniques which give the global solution of such problem. PSO is optimization techniques inspired by sociological behavior of bird flocking. It can be applied to solve many nonlinear engineering problems. This paper used a new PSO to solve the ELD problem. This paper consider EDL problem with various constraints. In this paper the power and usefulness of the CPSO algorithm is demonstrated through its application to three and six generator systems with constraints.

Keywords-Economic load dispatch, Constraints, Particle swarm optimization (PSO), Particle swarm optimization with constriction factor (CPSO).

I. INTRODUCTION

The economic scheduling is the on-line economic load dispatch, wherein it is required to 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. Electric utility system is interconnected to achieve the benefits of minimum production cost, maximum reliability and better operating conditions. For any specified load condition, ELD determines the power output of each 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.

Many conventional and modern techniques used for solve the 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 algorithmic complexity. Linear programming methods are fast and reliable 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 (EP) [11], simulated annealing (SA) [12], Tabu search (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 finite time, they often provide a fast and reasonable 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 is difficult in defining effective memory structures and strategies which are problem dependent. GA sometimes lacks a strong capacity 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 searching for food. In comparison with other EAs such as GAs and evolutionary programming, the PSO has comparable or even superior search performance with faster and more stable convergence rates. Now, the PSO has been extended to power systems, artificial neural network training, fuzzy system control, image processing and so on.

The main objective of this study is to use of PSO with moderate random search technique [27] to solve the power system economic load dispatch to enhance its global search ability. 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 six bus system. The results obtained through the proposed approach and compared with those reported in recent literatures.

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II. PROBLEM FORMULATION

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

Objectives

In optimizing economic load dispatch, the three most important evaluation indices economy and environment impact.

A. Basic Economic Dispatch Formulation to minimize the fuel cost

ELD 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.

B. CONSTRAINTS

This model is subjected to the following constraints,

1). Power balance constraints

The total generated power should be equal to total load demand

$$\sum_{i=1}^{n} P_i = P_D \quad (3)$$

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.

$$P_i^{min} \le P_i \le P_i^{max} \quad (4)$$

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 and birds flocking. It is a simple and powerful optimization tool which scatters random particles, i.e., solutions into the problem space. These particles, called swarms collect information from each array constructed by their respective positions. The particles update their positions using the velocity of articles. Position and velocity are both 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 $P_i=(p_{i1},p_{i2},\ldots\ldots\ldots p_{id})$ and $V_i=(v_{i1},v_{i2},\ldots\ldots\ldots v_{id},)$ respectively. On the basis of the value of the evaluation function, the best previous position of a particle is recorded and represented as $P_{besti}=(p_{i1},p_{i2},\ldots\ldots\ldots p_{id})$, If the gth particle is the best among all particles in the group so far, it is represented as $P_{gbest}=g_{best}=(p_{g1},p_{g2},\ldots\ldots\ldots p_{gd})$.

The particle updates its velocity and position using (10) and (11)

$$V_i^{(K+1)} = WV_i^K + c_1r_1 \times \left(Pbest_i - S_i^K\right) + c_2r2 \times \left(gbest - S_i^K\right) \quad (5)$$

$$S_i^{(K+1)} = S_i^K + V_i^{K+1} \quad (6)$$

Where, V_i^k is velocity of individual i at iteration k, k is pointer of iteration, W is the weighing factor, C_1, C_2 are the acceleration coefficients, r1 and r2 are the random numbers between 0 & 1, S_i^k is the current position of individual i at iteration k, Pbest is the best position of individual i and gbest is the best position of the group.

The term c_1r_1*x (pbest, $-S^k{}_1$) is called particle memory influence or cognition part which represents the private thinking of the itself and the term $c_2 r_2$( )×(gbest – $S^k{}_1$) is called swarm influence or the social part which represents the collaboration among the particles.

In the procedure of the particle swarm paradigm, the value of maximum allowed particle velocity V^{max} determines the resolution, or fitness, with which regions are to be searched between the present position and the target position. If V^{max} is too high, particles may fly past good solutions. If V^{max} is too small, particles may not explore sufficiently beyond local solutions. Thus, the system parameter V^{max} has the beneficial effect of preventing explosion and scales the exploration of the particle search. The choice of a value for V^{max} is often set at 10-20% of the dynamic range of the variable for each problem.

The inertia weight parameter which provides a balance between global and local explorations, thus requiring less iteration on an average to find a sufficiently optimal solution. Since inertia weight parameter (W) decreases linearly from about 0.9 to 0.4 quite often during a run, the following weighing function is used in (7)

$$W = W_{max} - \frac{W_{max}-W_{min}}{iter_{max}} \times iter \quad (7)$$

Where, W_{max} is the initial weight, W_{min} is the final weight, Iter $_{max}$ is the maximum iteration number and iter is the current iteration position.

B. PSO with constriction Factor

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

$$C = \frac{2}{\left|2-\emptyset-\sqrt{\emptyset^2-4\emptyset}\right|} \quad (8)$$

Where, Ø is define as 4.1≤Ø≤4.2

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

Now the update its velocity using (14).

$$V_i^{(K+1)} = C[WV_i^K + c_1r_1 \times \left(Pbest_i - S_i^K\right) + c_2r_2 \times \left(gbest - S_i^K\right)] \quad (9)$$

ALGORITHM FOR ELD PROBLEM USING CPSO

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

Step1:- Initialization of the swarm: For a population size the particles are randomly generated in the Range 0–1 and located between the maximum and the minimum operating limits of the generators.

Step2:-Initialize velocity and position for all particles by randomly set to within their legal rang.

Step3:-Set generation counter t=1.

Step4:- Evaluate the fitness for each particle according to the objective function.

Step5:-Compare particles fitness evaluation with its Pbest and Gbest.

Step6:-Update velocity and position by using eqn.(9) and (6) respectively.

Step7:-Apply stopping criteria.

IV. TEST DADA AND RESULTS

A. 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 of 3 generator systems.

unit	a_i	b_i	c_i	P_i^{max}	P_i^{min}
1	0.05	2.47	105	200	50
2	0.05	3.51	44.1	400	100
3	0.05	3.89	40.6	600	100

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

B.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 of 6 generator systems.

Unit	c_i	b_i	a_i	P_i^{min}	P_i^{max}
1	756.79886	38.53973	.15247	10	125
2	451.32513	46.15916	.10587	10	150
3	1049.9977	40.15916	.02083	35	225
4	1234.5311	38.30553	.03556	35	210
5	1658.5658	36.32782	.02111	130	325
6	1356.6592	38.27041	.0179	125	315

TABLE IV

Generator output for six bus system

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($/h)	15489	15481.87

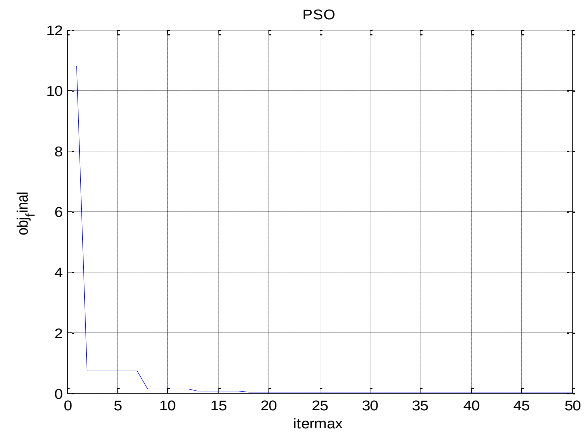

Figure.1. Convergence characteristic of 3 generator system of PSO

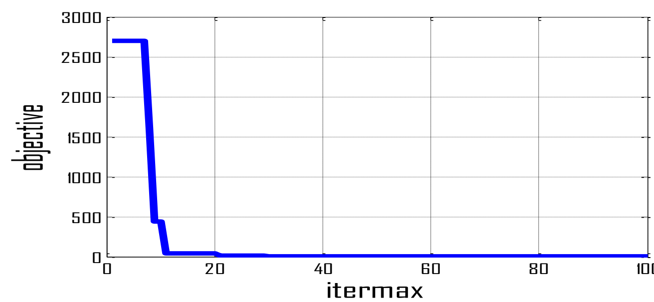

Figure.2. Convergence characteristic of six generator system of CPSO

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 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, W_{max}=0.9 and W_{min}=0.4.

Fig.1, and fig.2 show the improvement in each iteration for the three and six generation unit system respectively.

V. CONCLUSIONS

This paper introduces PSO and CPSO optimization to study the power system economic dispatch with 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 computing times. 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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