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SOLUTION TOECONOMIC LOAD DISPATCHBY ADOPTING ADVANCED PSO

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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. 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 classical approaches were 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], [5], dynamic programming [8], linear programming [7], quadratic programming[9], Lagrange relaxation method [10], direct search method [12], Newton-based techniques[11], [12] and interior point methods [6],[13] 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) [16], [17], simulated annealing (SA) [18], Tabu search (TS) [19], pattern search (PS) [20], Genetic algorithm (GA) [21], [22], Differential evolution (DE) [23], Ant colony optimization[24], Neural network [25]and particle swarm optimization (PSO) [26], [29], [30], [32]. 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 is a population-based evolutionary technique first introduced by [26], 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 and CPSO for the obtaining optimum solution of then economic load dispatch problem. The CPSO has the ability to explore the solution space than in a standard PSO.The proposed method focuses on solving the economic load dispatch with ramp rate constraint. The feasibility of the proposed method was demonstrated forthree and six generating unit system.

II. PROBLEM FORMULATION

Economic load dispatch is important problems to be solved in the operation and planning of a power system the primary concern of an ELD problem is the minimization of the total generation fuel cost. 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),

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

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

Where,F_T is the Fuel cost function,and a_i, b_i and c_i are the cost coefficients.

CONSTRAINTS

This ELD problem considered the following constraints,

Power Balance Equation
For power balance, an equality constraint should be satisfied. The total generated power should be equal to total load demand plus the total losses,

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

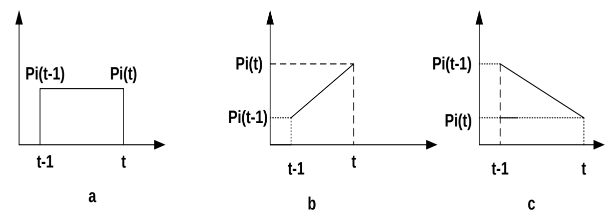
Where,$P_D$is the total system demand and P_L is the total line loss.

power generation 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.

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

Where, Pi is the output power of i_{th} generator ,
$P_{i,min}$ and$P_{i,max}$ are the minimum and maximum power outputs of generator i respectively.

Ramp rate limit
The actual operating ranges of all on-line units are restricted by their corresponding ramp-rate limits. Fig.1 shows three possible situations in which a unit is on-line from time interval (t-1) to t. Fig.1 a shows the unit operating in steady-state conditions, fig.1 b, shows the unit increasing its power generation whereas Fig.1 c shows the unit decreasing the power generation output.



a. Shows steady state operation,
b. Shows increasing the level of the power generation and
c. Shows decreasing the power output

Fig. 1. Three possible situations of on-line generation limit

1) As generation increases

$P_i(t) + P_i(t-1) \le UR_i$ (5)

2) As generation decreases

$P_i(t-1) - P_i(t) \ge DR_i$ (6)

When the generator ramp rate limits are considered, the operating limits For each unit, output is limited by time dependent ramp up/down rate at each hour as given below.

$P_i^{min}(t) = \max(P_i^{min}, P_i(t-1) - DR_i)$ and (7)

$P_i^{max}(t) = \min(P_i^{max}, P_i(t-1) - UR_i)$ (8)

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

III. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization was first introduced by Kennedy and Eberhart in the year 1995 [26]. 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 swarmscollect information from eacharray constructed by their respective positions. The particles update their positionsusing the velocityof 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)

$$V_i^{(K+1)} = WV_i^K + c_1 rand_1 \times (Pbest_i - S_i^K) + c_2 rand_2 \times (gbest - S_i^K) \quad (10)$$

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

Where, V_i^k is velocity of individual i at iteration k, W is the weighing factor,
C_1, C_2 are the acceleration coefficients, $rand_1$, $rand_2$ 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 coefficients $c_1$and c_2 pull each particle towards pbest and gbest positions. Low values of acceleration coefficients allow particles to roam far from the target regions, before being tugged back. on the other hand, high values result in abrupt movement towards or past the target regions. Hence, the acceleration coefficients c_1 and c_2 are often set to be 2 according to past experiences. The term $c_1*rand_1x(pbest_i - S^k_1)$ is called particle memory influence or cognition part which represents the private thinking of the itself and the term $c_2*rand_2)\times(gbest - S^k_1)$ 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.

W is 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 W decreases linearly from about 0.9to 0.4 quite often during a run, the following weighing function is used in (10)

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

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

3.1 PSO with constriction factor (CPSO)

For getting better solution the standard PSO algorithm, used classical PSO , the constriction factor is used in this algorithm. Updating of velocity used in basic PSO given in (10) can be changed in CPSO as follows,

$$V_i^{(K+1)} = C * [V_i^K + c_1 Rand_1 \times (Pbest_i - S_i^K) + c_2 Rand_2 \times (gbest - S_i^K)] \quad (13)$$

$$C = \frac{2}{|2 - \emptyset - \sqrt{\emptyset^2 - 4\emptyset}|} \qquad (14)$$

Where, C is the constriction factor, $Ø = c_1+c_2$

3.2 ALGORITHM FOR ED PROBLEM USING CPSO

The algorithm for ELD problem with ramp rate generation limits employing PSO for practical power system operationisgiven 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 by using (13)
Step7:-Update position by using (11)
Step8:-Apply stopping criteria.

Test Data and Results

TEST CASE 1

The test results are obtained for three-generating unit system in which all units with their fuel cost coefficients. This system supplies a load demand of 150MW. The data for the individual units are given in Table 1. The best result obtained by PSO and CPSO for different population size is shown in Table 1 and table 2.

Table 1: Capacity, cost coefficients and ramp- rate limits of 3 generating unit, Load 850MW.

Unit	a_i	b_i	c_i	P_i^{max}	P_i^{min}	Pi	UR_i	DR_i
1	0.004820	7.97	78	200	50	170	50	90
2	0.001940	7.85	310	400	100	350	80	120
3	0.001562	7.92	562	600	100	440	80	120

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 generating unit system for the demand of 850MW

Unit Power Output	PSO	CPSO
P1(MW)	146.03	145.8978
P2(MW)	337.93	339.9597
P3(MW)	550.17	548.971
Power loss(MW)	183.043	182.7293
Total Power Output	1033.958	1033.7
Total Cost($/h)	9843.228	9841.228
Computation time (Sec)	0.783	0.7501

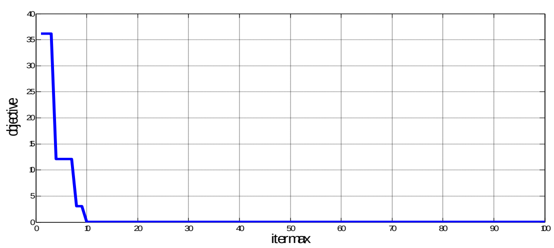


Fig.2. Convergence characteristic of CPSO for 3 generating units.

TEST CASE II

The test results are obtained for six-generating unit system in which all units with their fuel cost coefficients. This system supplies a load demand of 1263MW. The data for the individual units are given in Table 4 the best result obtained by PSO and CPSO for different population size is shown in table 5.

Table 4: Capacity, cost coefficients and ramp- rate limits of 6 generating units, load 1263MW

Unit	c_i	b_i	a_i	P_i^{min}	P_i^{max}	P_i	UR_i	DR_i
1	240	7	0.0070	100	500	440	80	120
2	200	10	0.0095	50	200	170	50	90
3	220	8.5	0.0090	80	300	200	65	100
4	200	11	0.0090	50	150	150	50	90
5	220	10.5	0.0080	50	200	190	50	90
6	190	12.0	0.0075	50	120	110	50	90

Table 5: Results of six generating system for the demand of 1263 MW

Unit Power Output	PSO	CPSO
P1(MW)	423.84	471.66
P2(MW)	115.03	140.03
P3(MW)	265.21	240.06
P4(MW)	136.73	149.97
P5(MW)	180.65	173.78
P6(MW)	85.83	99.97
Loss	11.22	12.38
Total Power Output	1275.46	1275.31
Total Cost($/h)	15489	15454.87
Computation time	0.7621	0.7201

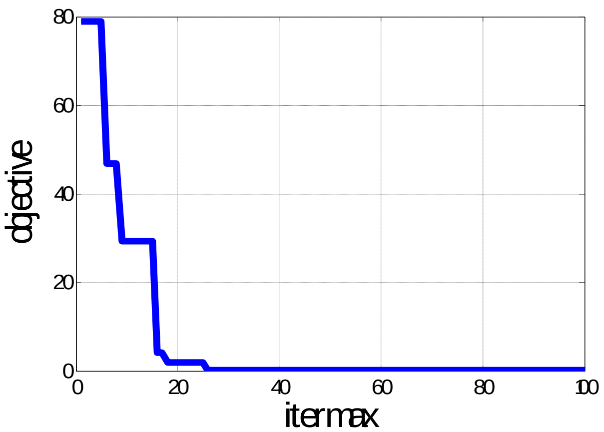


Fig.2. Convergence characteristic of CPSO for 6 generating units.

Result Analysis

To assess the efficiency of the proposed CPSO approaches in this papertested for a case study of3 thermal generating units with ramp rate limits data given in table 1 and table 3. The proposed algorithm runs on a 1.4-GHz, dual to core-2 processor with 2GB DDR of RAM.

The ELD data tested for different population size as shown in table 3 of50 iteration used for obtaining results. Constants are taken in this study are acceleration coefficients are c_1=c=2, W_{max}=0.9 and W_{min}=0.4.

The optimum result obtained by proposed approach for 3 thermal generating units is given in table2 and table 3. The minimum averagecost obtained by CPSO is$9841.228/h for the population size of 50. Fig.1 shows the improvement in each iteration for the six generation unit system respectively.

Similarly result obtained by CPSO for 6 thermal generating units shown in table 5 shows that minimum average cost is $15454.87/h for the population size of 20. Convergence characteristic of CPSO for 6 thermal generating units is shown in figure 2.

IV. CONCLUSIONS

This work used a new PSO optimizationtechnique for the solution of economic load dispatch with ramp rate constraints. The proposed method has been applied totwo different test cases and obtained the optimum solution of the problem. Theanalysis of results has demonstrated that CPSO outperforms the other methods in terms of a better optimal solution.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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