Application of Modified PSO in Economic Load Dispatch Problem of Thermal Generating Unit

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Abstract: - This paper deals with the problem of economic load dispatch (ELD) in thermal generating unit. The main issue of generating unit to minimize the cost of generation so modified Particle Swarm Optimization (PSO) method is proposed for solving this issue. The modified PSO method was developed through simulation of a simplified social system and has been found to be robust in solving continuous nonlinear optimization problems in terms of accuracy of the solution and computation time The proposed algorithm is applied for the ELD of six unit thermal plant systems and the performance of the proposed modified PSO method is compared with the existing general PSO method and it is observed that this method is reliable, accurate and less iteration process. All results obtained through MATLAB Simulink software. The comparison of results shows that the proposed modified PSO method was indeed capable of obtaining higher quality solutions efficiently for ELD problems within less computation time.

Keywords— Economic Load Dispatch (ELD), Particle Swarm Optimization (PSO), Thermal Generating Unit, MATRIX LABORATORY (MATLAB).

I. INTRODUCTION

The Economic Load Dispatch (ELD) problem is one of the fundamental issues in power system operation. The main objective is to reduce the cost of energy production taking into account the transmission losses. While the problem can be solved easily if the incremental cost curves of the generators are assumed to be monotonically increasing piece-wise linear functions, such an approach will not be workable for nonlinear functions in practical systems. In the past decade, conventional optimization techniques such as lambda iterative method, linear programming and quadratic programming have been successfully used to solve power system optimization problems such as Unit commitment, Economic load dispatch, Feeder reconfiguration and Capacitor placement in a distribution system. For highly non-linear and combinatorial optimization problems, the conventional methods are facing difficulties to locate the global optimal solution. Recently there is an upsurge in the use of modern evolutionary computing techniques in the field of power system optimization. Particle Swarm Optimization (PSO), first introduced by Kennedy and Eberhart, is one of the modern heuristic algorithms. It was developed through simulation of a simplified social system, and has been found to be robust in solving continuous non-linear optimization problems. The PSO technique can generate high-quality solutions within shorter calculation time and stable convergence characteristics than other stochastic methods. All the particles in PSO are kept as members of the population through the course of a run (a run is defined as the total number of generation of the evolutionary algorithms prior to termination). It is the velocity of the particle which is updated according to its previous best position of its companions. The particles fly with the updated velocities.

II. MATHEMATICAL MODEL

A. Objective function

The objective of the economic load dispatch is to minimize the generating cost based on the premise that constraints are satisfied. Coal consumption (standard coal) is selected as the optimization objective in order to emphasize the main aspects, simplify the mathematical model and make the problem comparable. Then the mathematical description of ELD's objective function is:
The objective of the ELD problem is to minimize the total fuel cost. Mathematically it can be represented as

$$\text{Minimize} \quad C_t = \sum_{i=1}^{n} C_i (P_i) \qquad (1)$$

$$C_t = \sum_{i=1}^{n} a_i \; P_i{}^2 + b_i P_i + c_i \qquad (2)$$

Where C_t Fuel cost of the system .
C_i Fuel cost of the generating unit of the system.
a_i , P_i and c_i are cost coefficients of generator i.
P_i Output power generation of unit i.

The ELD problem is subjected to the following constraints, the power balance equation,

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

The total Transmission loss,

$P_L = \sum\sum P_m B_{mn} P_n$ (4)

In addition, power output of each generator has to fall within the operation limits of the generators as shown below,

$P_{Gi}{}^{min} \le P_{Gi} \le P_{Gi}{}^{max}$ (5)

In the power balance criterion, an equality constraint must be satisfied, as shown in equation (3). The generated power should be the same as the total load demand plus total line
Losses .The generating power of each generator should lie between maximum and minimum limits represented by equation (5), where *Pi* is the power of generator *i* (in MW); *n* is the number of generators in the system; PD is the system's total demand (in MW); *PL* represents the total line losses in (MW) and *min Pi* and *max Pi* are, respectively, the output of the minimum and maximum operation of the generating unit i in (MW).

III. Overview of PSO

PSO, as an optimization tool, provides a population-based search procedure in which individuals called particles change their position (states) with time. In PSO system particles fly around in a multi- dimensional search space. During flight, each particle adjusts its position according to its own experience and the experience of neighbouring particles, making use of the best position encountered by it and neighbours. The swarm direction of a particle is defined by the set of particles neighbouring the particle and its history experience. Instead of using evolutionary operation to manipulate the individuals, like in other evolutionary computational algorithms, each individual in PSO flies in the search space with a velocity which is dynamically adjusted according to its own flying experience and its companions flying experience.
Let *x* and *v* denote a particle co-ordinate (position) and its corresponding flight speed (velocity) in a search space respectively. Therefore, each ith particle is treated as a volume less particle, represented as xi= (xi1, xi2 …xid) in the d - dimensional space. The best previous position of the ith particle is recorded and represented as pbesti=(pbesti1,pbesti2,…….. pbestid).The index of the best particle among all the particles is treated as global best particle, is represented as gbestd. The rate of velocity for particle 'i' is represented as vi= (vi1,vi2……...vid). The modified velocity and position of each particle can be calculated using the current velocity and the distance from pbestid to gbestd as shown in the following formulas,

$V_{id}{}^{(t+1)} = \varpi V_{id}{}^{(t)} + C_i\, rand\,()\big(pbest_{id} - P_{gid}{}^{(t)}\big) + C_2\, Rand()\big(gbest_{id} - P_{gid}{}^{(t)}\big)$ (7)

$P_{gid}{}^{(t+1)} = P_{gid}{}^{(t)} + V_{id}{}^{(t+1)}$ (8)

In the above equation, C1 has a range (1.5, 2), which is called self-confidence range; C2 has a range (2, 2.5), which is called swarm range.
The parameter Vd ^{max} determines the resolution, or fitness, with which regions are to be searched between the present position and the target position .If Vd ^{max} is too high, particles may fly past good solutions. If Vd ^{max} is too small, particles may not explore sufficiently beyond local solutions. In many experiences with PSO, Vd ^{max} was often set at 10-20% of the dynamic range on each dimension.
The constants C1and C2 pull each particle towards pbest and *gbest* positions. Low values 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, target regions. Hence, the acceleration constants C1 and C2 are often set to be 2.0 according to past experiences. Suitable selection of inertia weight ' ω ' provides a balance between global and local explorations, thus requiring less iteration on average to find a sufficiently optimal solution. As originally developed, ω often decreases linearly from about 0.9 to 0.4 during a run. In general, the inertia weight *w* is set according to the following equation,

$\omega = \omega_{max} - \left[\frac{\omega_{max} - \omega_{min}}{it_{max}}\right] * it$ (9)

where ω - inertia weight factor
ω_{max} - maximum value of weighting factor
ω_{min} - minimum value of weighting factor
it_{max} - maximum number of iterations
it - current number of iteration

IV. APPLICATION OF PSO METHOD TO ECONOMIC LOAD DISPATCH

In population based optimization algorithm, there is an avid necessity of improving the performance of existing algorithm. This can be implemented by two means. Either the basic operators of algorithm should be redesigned or proper tuning of adjustable parameters should be done. In proposed variant of PSO, proper tuning of adjustable parameters like w, c1 and c2 are done so that it can reach on optimal solution as early as possible. In existing PSO, the values of adjustable parameters like w,c1 and c2 are independent from the values of gbest and pbest.

This is the main reason why PSO converges very slow toward optimal solution. These values are may remain fixed or may vary according to the number of generation. In proposed algorithm, a relationship has been established between adjustable parameters and the values of gbest and pbest and the values of w,c1 and c2 are set accordingly.The value of c1 has been set to pbestval-out /gbestval and c2 has been set to repmat(gbestval,ps,1)-out /gbestval so that particles may exploit good solutions as early as possible. Moreover to improve convergence rate of the algorithm a very high inertia weight equivalent to gbestval- pbestavg/gbestval has set. These values motivate particles to exploit solution around good regions and capture optimal solution as early as possible. The PSO algorithm was utilized mainly to determine the optimal allocation of power among the units, which were scheduled to operate at the specific period, thus minimizing the total generation cost.

A. *Calculation process of the proposed method*

This paper presents a quick solution to the constrained ELD problem using the PSO algorithm to search optimal or near optimal generation of each unit. The sequential steps of the proposed PSO method are given below.

Step 1: Initialize randomly the individuals of the population according to the limit of each unit including individual dimensions, searching points, and velocities. These initial individuals must be feasible candidate solutions that satisfy the practical operation constraints.

Step 2: To each chromosome of the population the dependent unit output Pd will be calculated from the power balance equation and Bmn coefficient matrix.

Step 3: Calculate the evaluation value of each individual Pgi, in the population using the evaluation function given by (2).

Step 4: Compare each individual's evaluation value with its *pbest*. The best evaluation value among the pbests is denoted as *gbest*.

Step 5: Modify the member velocity *v* of each individual *Pg*, according to equation (7)

Step 6: Check the velocity components constraint occurring in the limits from the following conditions,

If $V_{id}{}^{(t+1)} > V_d{}^{max}, then\, V_{id}{}^{(t+1)} = V_d{}^{max}$,

$V_{id}{}^{(t+1)} > V_d{}^{min}, then\, V_{id}{}^{(t+1)} = V_d{}^{min}$,

Where
$V_d{}^{min} = -0.5\, P_g{}^{min}$
$V_d{}^{max} = +0.5\, P_g{}^{max}$

Step 7: Modify the member position of each individual *Pg* according to (8)

Step 8: If the evaluation value of each individual is better than previous *pbest*, the current value is set to be *pbest*. If the best *pbest* is better than *gbest*, the value is set to be *gbest.*

Step 9: If the number of iterations reaches the maximum, then go to step 10.Otherwise, go to step 2.

Step 10: The individual that generates the latest *gbest* is the optimal generation power of each unit with the minimum total generation cost.

V. Result

To verify the feasibility of the proposed modified PSO method, six generating unit has been taken into consideration. The result of Proposed and existing method is compared in the following tables:-

Table 1:power generations and total cost for different power demond.

P_D (MW)	P_L (MW)	P_{G1} (MW)	P_{G2} (MW)	P_{G3} (MW)	P_{G4} (MW)	P_{G5} (MW)	P_{G6} (MW)	Cost (Rs/Hr)
600	8.007	270.3	054.6	132.9	050.0	050.0	050.0	7205.09
700	10.74	323.3	076.6	158.7	050.0	052.0	050.0	8352.65
800	14.36	354.3	100.5	179.9	050.0	079.5	050.0	9558.72
900	18.48	385.2	117.7	201.5	065.0	098.9	050.0	10812.6
1000	23.26	409.8	137.8	223.6	083.4	118.50	0.500	12110.5

Table 2:the result of Modified PSO and Existing PSO.

$P_{D\,=}$ 700 (MW)	P_L (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	Cost (Rs/Hr)	Iteration
Modified PSO	10.74	323.3	076.6	158.7	050.0	052.0	050.0	8352.65	6000
Existing PSO	10.77	317.4	082.7	159.8	050.0	050.7	050.0	8353.35	33000

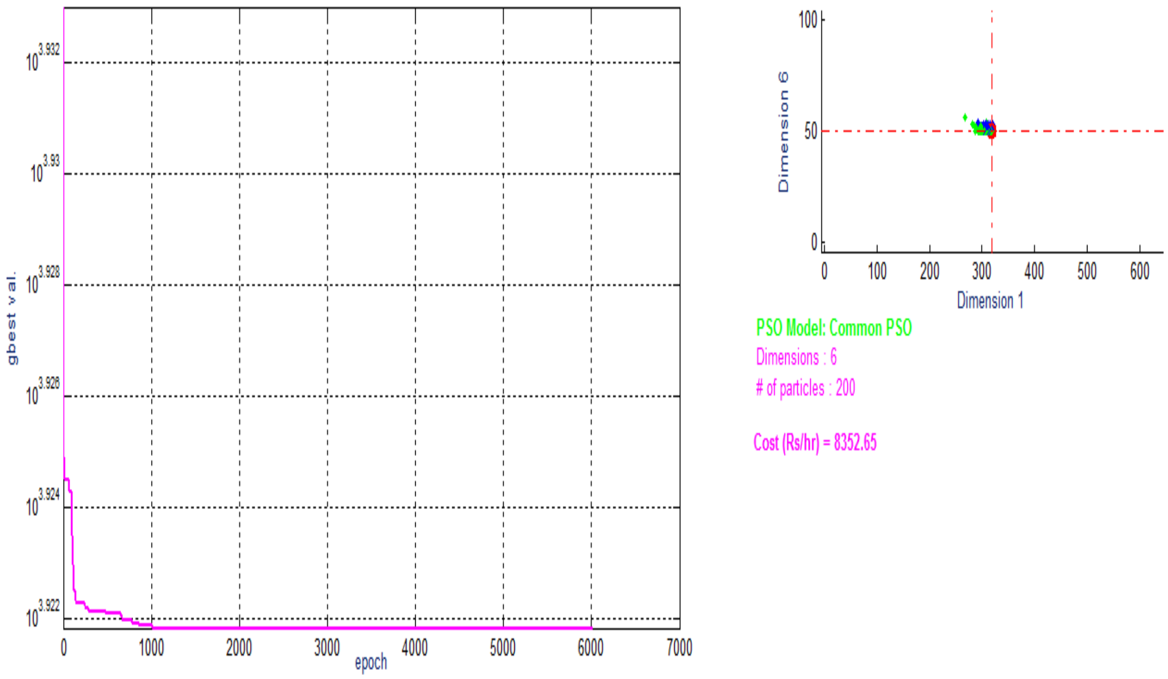

Fig 1: Convergence of 6 generators system with PD=700MW

From the above figure it is clear that the number of iteration of modified PSO is 6000 and the cost (Rs/hr) is 8352.65 which less than the existing general PSO method. The comparative table of both modified PSO and existing general PSO is given in above table.

V. CONCLUSION

In this paper, the proposed modified PSO method was successfully employed to solve the ELD problem with all the constraints. The proposed method has been demonstrated to have superior features including high quality solution, stable convergence characteristics, and less computation time. Many non-linear characteristics of the generators can be handled efficiently by the proposed method. The comparison of results for the test cases clearly shows that the proposed method was indeed capable of obtaining higher quality solution efficiently for ELD problems.

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VII. REFERENCES

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