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Application of Intelligent Technique for Economic Load Dispatch for Power System: A Review

Bodla Rajashree[1] ,Poonam Upadhyay[2]

[1]Depatment of Electrical and Electronics Engineering, VNR VJIET, Bachupally, Hyderabad-500090, Telangana, India

[2]Depatment of Electrical and Electronics Engineering, VNR VJIET, Bachupally, Hyderabad-500090, Telangana, India

ABSTRACT

This paper presents the application of the intelligent technique for the economic dispatch of the thermal units. The objective function considered in this paper is the minimization of fuel cost which is the non-convex optimization problem. The conventional lambda iteration method and Particle swarm optimization (PSO) technique was successfully applied to three and six unit thermal plant system. The proposed intelligent method provides the simple approach for implementation even if the number of generating units is more. The PSO method is implemented for different set of population size and the obtained results are compared with the results of conventional Lambda iteration method and other published work.

Keywords: Economic load dispatch (ELD), minimization, particle swarm optimization (PSO), Genetic Algorithm(GA).

1. INTRODUCTION

Economic load dispatch plays a vital role in the operational planning of modern power system. The input-output characteristics of generating units in power system are non linear in nature and the generating cost varies for different load demands. The task of ELD is to allocate the power among the generating units at minimum operating cost by satisfying all the essential constraints. In earlier days conventional methods like lambda iteration, linear programming and Newton-based etc. were used for solving the economic dispatch problem but those methods possess some approximations and limitations while performing mathematical operations. The most used conventional method for ELD is the Lambda iteration method which is an optimization technique that uses Legrangian multiplier in formulating the objective function [1, 2]. The method for solving this type of non linear functions requires an effective algorithm for obtaining the optimal solution. Many heuristics search algorithms are being used in alternate to the conventional methods. Evolutionary techniques and Genetic Algorithms (GA) methods based on various algorithms were used for the minimization of fuel cost of generating units [3,4,17]. Hybrid optimization technique (combining genetic algorithm and evolution strategies) exploiting the advantage of each was proposed [5]. Though many evolutionary methods have been applied for ELD problem, those methods show some deficiency in performance and degradation in efficiency.

The PSO algorithm can be directly applied to any optimization problem without constraints but for the problem whose equality and inequality constraints has to be satisfied each individual search has to be modified. PSO have been applied for ELD problem with and without considering transmission losses for smooth and non smooth cost functions [6, 7, 8, 9, 10]. The optimum value of Legrangian multiplier which is used in formulating the objective function in conventional lambda iteration method is found to minimize fuel cost [11]. Nagendra singh and yogendhra kumar [12] implemented a novel PSO with a moderate random search strategy for solving ELD problem with emission as constraints. Jong Bae Park [13] proposed a modified PSO considering valve-point effects and multi-fuel problems for smooth and non-smooth cost functions. The main advantage of PSO is its simple concept and easy to control parameters. Sometimes all the intelligent techniques may not guarantee the global solution but gives quasi optimum results in less time. PSO was applied to various fields of power system for controlling reactive power and voltage [14], for determining the optimal values of parameters for power system stabilizers [15] and for capacitor placement to reduce distribution losses [16].

2. ELD PROBLEM FORMULATION

The objective of the ELD problem is to find the optimal operation of the generators connected in a system so as to minimize the total cost of the fuel by satisfying equality and inequality constraints. The total fuel cost is the sum of the cost of the each generating unit.

$$F(P_j) = \sum_{j=1}^{N_g} F_j(P_j) \qquad (1)$$

Where,
$F(P_j)$ = Total fuel cost ($/h)
$F_j(P_j)$ = Fuel cost of j^{th} generator ($/h)
N_g = Number of generators
The fuel cost of each generator is simplified and can be represented as a quadratic equation. The fuel cost of i^{th} generator can be expressed as,

$$F_j(P_j) = a_j P_j + b_j P_j + c_j \qquad (2)$$

Where,
a_j, b_j and c_j are fuel cost coefficients of j^{th} generator.

The objective function of the ELD problem is subjected to equality and inequality constraints.

2.1 Equality constraint

The equality constraint is the power balance equation in which the total power generated in the system should be equal to the sum of the total power demand and the total transmission losses of the system.

$$\sum_{j=1}^{N_g} P_j = P_d + P_L \qquad (3)$$

Where,
P_j= Real power generation of j^{th} generator
P_d= Total real power demand
P_L= Total transmission loss

In this paper the transmission losses (P_L) are considered to be zero for simplicity.

2.2 Inequality constraint

The output power generated by each generating unit should lie in its minimum and maximum power limits.

$$P_j^{\min} \le P_j \le P_j^{\max} \qquad (4)$$

Where,
P_j^{min}= minimum power generation of i^{th} generator
P_j^{max}= maximum power generation of i^{th} generator

3. OVERVIEW OF PSO

PSO is a heuristic search algorithm which was introduced by Kennedy and Eberhart. It is a random search algorithm, which imitate the behavior of particles in the swarm like fish schooling, birds flocking and the swarm theory. It is a population based search procedure in which individuals called particles approaches to the optimum or a quasi-optimum with some velocity in a multi-dimensional search space based on its own experience and its neighbors experience.
The position and velocity of i^{th} particle in a n-dimensional search space are represented as the vectors X_i = $(x_{i1},x_{i2},\ldots.x_{in})$, and $V_i=(v_{i1},v_{i2},\ldots..v_{in})$, respectively. Let $Pbest_i$ = $(x_{i1}^{best},x_{i2}^{best},\ldots.\ x_{in}^{best})$, and $Gbest=(x_{i1}^{Gbest},\ldots.\ x_{in}^{Gbest})$ respectively, be the local best position of individual 'i' and global best position so far. The velocity of each particle can be updated using the following equation [13]

$$V_i^{k+1} = \omega V_i^k + c1 \times rand1 \times \left(Pbest_i^k - X_i^k\right) + c2 \times rand2 \times \left(Gbest^k - X_i^k\right) \qquad (5)$$

Where,
V_i^k =Velocity of particle at iteration k
ω= inertia weight factor
c1,c2= acceleration coefficients
rand1, rand2= random numbers between 0 and 1
X_i^k = Position of particle at iteration k
$Pbest_i^k$ = best position of particle until iteration k
$Gbest^k$ = best position of the group until iteration k

Each particle in a population moves from the current position to the next position by the modified velocity in (5) using the following equation:

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad (6)$$

Where,
X_i^{k+1}= Position of particle at iteration (k+1)

3.1 Flowchart of PSO

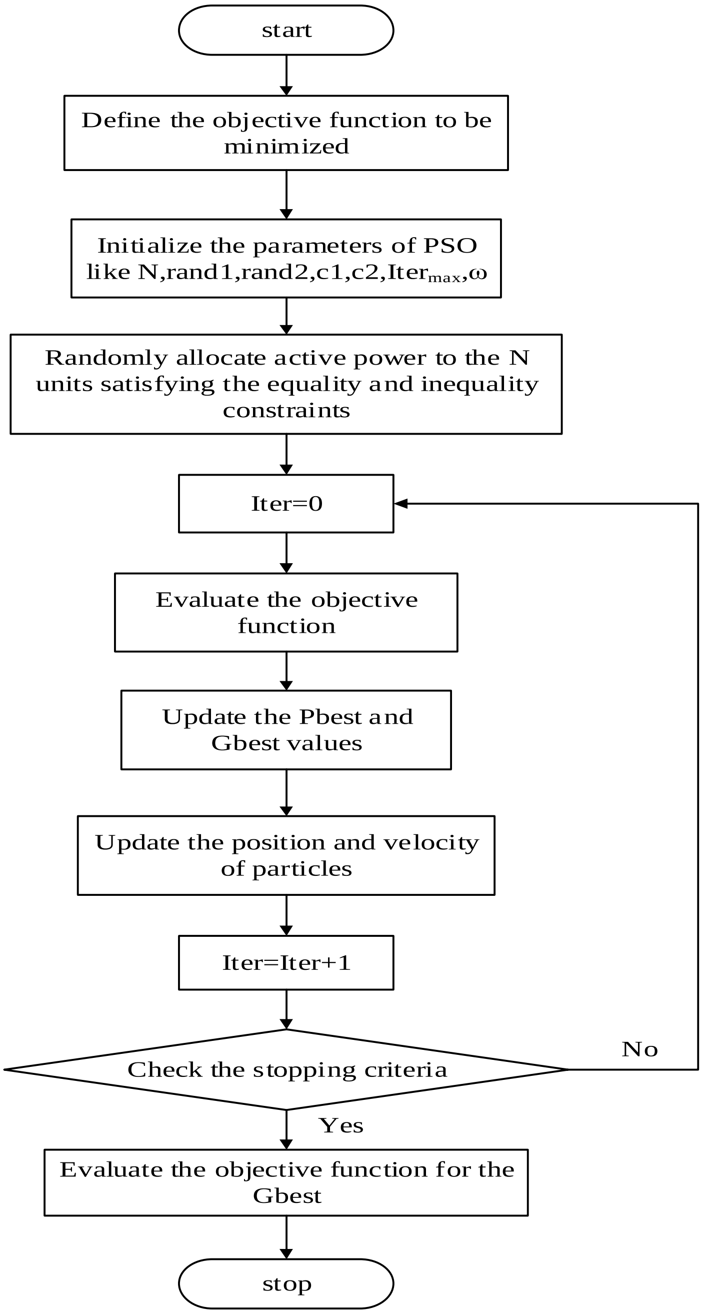

Figure 1 Flow chart of PSO

3.2 PSO Algorithm

This method is applied to obtain the optimal or near optimal location of the each generating unit using PSO algorithm. The sequence of steps of the applied method is given below:

Step 1: Initialize the objective Function and the PSO parameters like Population size N, C1, C2, ω_{max}, ω_{min}, rand1, rand2, iter, $iter_{max}$, MW limits of the generating stations and the total power demand.

Step 2: Initialize the position of each individual (or particle) which satisfy both equal and inequality constraint.

Step 3: Initialize the velocity of each individual by using the following strategy

$$P_j^{\min} - P_{ij}^0 \leq V_{ij}^0 \leq P_j^{\max} - P_{ij}^0$$

Where,

V_{ij}^o= initial velocity of j^{th} element of particle i

P_{ij}^0= initial position of j^{th} element of particle i

Step 4: The initial individual position is the initial local best (Pbest) of each particle. Evaluate the objective function for each individual with initial positions and the position of the particle which gives best solution among all the particles is the initial global best (Gbest).

Step 5: The velocity of each individual can be updated using the eq(5). for the calculation of the velocity of each individual the weight factor is defined as follows:

$$\omega = \omega_{\max} - \frac{\omega_{\max} - \omega_{\min}}{iter_{\max}} \times iter$$

Where,

ω_{min}, ω_{max} are initial and final weights

$Iter_{max}$= maximum number of iterations

Iter=current iteration number

Step 6: The position of each particle is updated using the eq(6). Each element in the particle is checked for its inequality constraint (4), if it violates the limits it is adjusted to its max or min limit value based on its violation.

Step 7: Check whether the summation of all the elements in a individual is equal to total demand using eq(3). If it is not satisfied modify an element (let l=1) in a particle to a value which is obtained by subtracting the sum of remaining elements in a particle from total demand.

Step 8: If the modified element in a particle doesn't satisfy inequality constraint then adjust the value to its boundary value then set l=l+1 and go to step 7. Otherwise go to step 9.

Step 9: Evaluate the objective function at each iteration and update the Pbest and Gbest values.

Step 10: Continue the above mentioned process till stopping criteria ($iter=iter_{max}$) is met. This final value of Gbest gives the optimum solution.

4. CASE STUDIES

To assess the feasibility of PSO for economic load dispatch for small and large size power system with varying number of generating units have been used. The results are obtained for three unit and six unit system using MATLAB on an intel core i3 processor 4GB RAM. With reference to many experiments following PSO parameters have been choosen [6, 7, 13]

The PSO is applied to three generator system and six generator system for economic load dispatch. The total demand for the three generator system is 850MW and for six generator system is 450MW. The data for the three unit system and six unit system is taken from [17] in which Genetic algorithm is applied to the system. The data for the two systems is tabulated in table 1 and table 2.

Table 1: Generator data for 3unit system

Unit No.	a_i ($/hr/MW^2)	b_i ($/hr/MW)	c_i ($/hr)	P_i^{min} (MW)	P_i^{max} (MW)
1	0.001562	7.92	561	150	600
2	0.00194	7.85	310	100	400
3	0.00482	7.97	78	50	200

Table 2: Generator data for 6unit system

Unit No.	a_i ($/hr/MW^2)	b_i ($/hr/MW)	c_i ($/hr)	P_i^{min} (MW)	P_i^{max} (MW)
1	0.005	2.0	100	10	85
2	0.010	2.0	200	10	80
3	0.020	2.0	300	10	70
4	0.003	1.95	80	50	250
5	0.015	1.45	100	5	150
6	0.010	0.95	120	15	100

The parameter values for the PSO has been selected based on the analysis performed in [13]. The values of c1 and c2 are same as the Pbest and Gbest both are given equal importance in finding the optimum solution. The details of the parameter values considered in PSO application process is tabulated in table 3.

Table 3: Details of the parameter values used in PSO

Parameter	Value
Population size	5,10,15
ω_{max}	1
ω_{min}	0.5
C1,C2	2
Initial Position	Random
$iter_{max}$	100

The results those are obtained for three unit and six unit system by applying PSO are compared with the results of conventional method (Lambda iteration method) and genetic algorithm [17] and are given in table 4, 5 respectively. The population size of PSO is considered to be 10 for comparing with other methods.

Table 4: Comparison of simulation results between Conventional method, PSO and GA for 3unit system

Parameter	Lambda iteration method	PSO (population size=10)	GA[17]
P1(MW)	393.1698	393.1502	393.0103
P2(MW)	334.6038	334.6347	319.2256
P3(MW)	122.2264	122.2151	137.7642
Total cost($/hr)	8194.356121	8194.356125	8195.979

Table 5: Comparison of simulation results between PSO and Conventional method for 6unit system

Parameter	Lambda iteration method	PSO (population size=10)	GA[17]
P1(MW)	85	85	65.197850
P2(MW)	43.9744	43.9744	29.951560
P3(MW)	21.9872	21.9872	11.010200
P4(MW)	154.9145	154.9145	161.028600
P5(MW)	47.6496	47.6496	95.403810
P6(MW)	96.4744	96.4744	87.40800
Total cost($/hr)	1929.01	1929.01	1971.0680

The convergence characteristics of the three unit and six unit system are shown in figure 1, 2 respectively, when PSO is applied with different population size. The figures 2 and 3 also represent the variation of global solution (minimum cost) at each iteration. As the population size of different values are considered the initial groups are also different. The iteration number at which the particle reaches the global solution is different for different population size. After certain iteration number the global solution has been reached when different population size is considered.

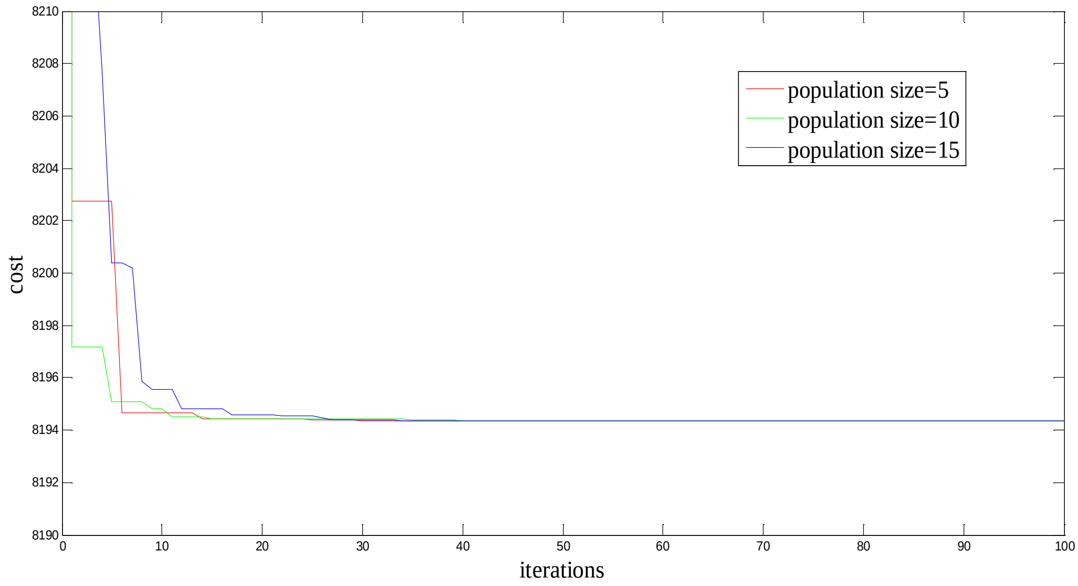

Figure 2 Convergence characteristics of 3unit system for different values of population size

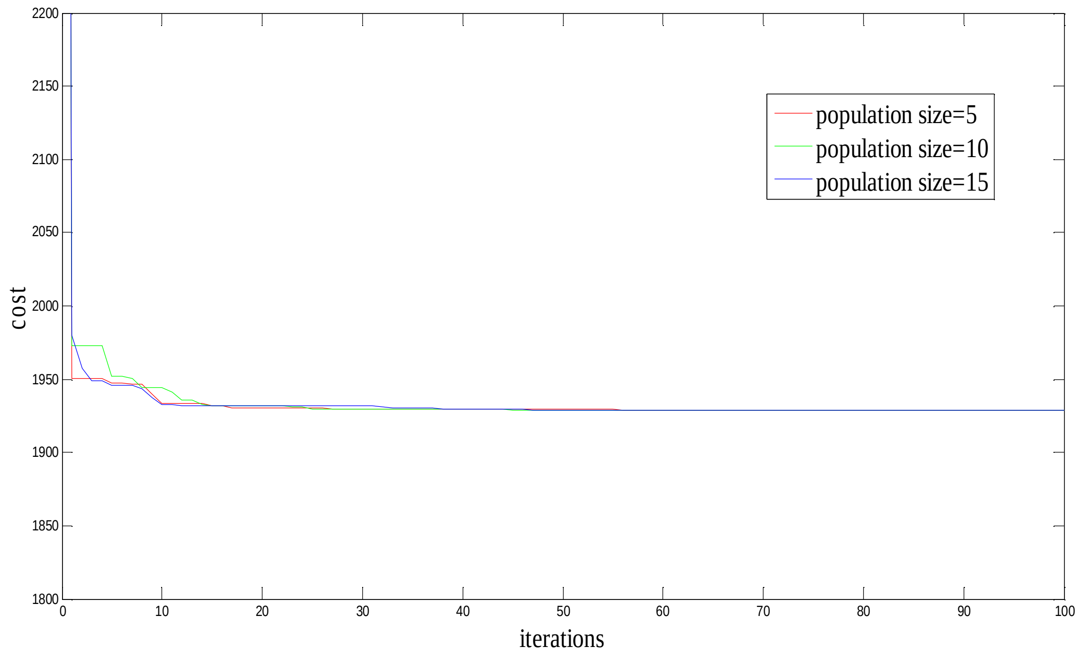

Figure 3 Convergence characteristics of 6unit system for different values of population size

5. CONCLUSION

The lambda iteration method for the Economic Load Dispatch is very old and established method but it requires large computational time when the power system is of large size. The PSO method was successfully applied to ELD problem with all the constraints. The cost of power generation using conventional Lambda iteration, particle swarm optimization technique and Genetic Algorithm [17] for three unit and six unit case are compared and PSO gave better results when compared to the results of Genetic Algorithm. PSO has provided the global solution satisfying the constraints with a high probability. It has been observed that the application of conventional technique becomes complex when the number of units increase. But the intelligent technique (PSO) is very simple in its application even when the number of units is more. It has also been observed that irrespective of the population size considered the global solution is being achieved.

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AUTHORS

Bodla Rajashree pursuing M.TECH in Power systems (Electrical Engineering) in VNR VJIET, Hyderabad, Telangana, India and received B.TECH degree in Electrical and Electronics Engineering from Amrita University, kerala, India, in 2013.

Poonam Upadhyay received the B.E. degree from NIT, Raipur (formally Govt. college of Engineering) and M.TECH degree in integrated power systems from VNIT, Nagpur in 1992 and 1996 respectively and also Ph.D. in Electrical Engineering from JNTU Hyderabad in 2008. Her research interests are in power system, high voltage engineering and also in Applications of Intelligent Techniques in Electrical Engineering. Currently she is associated with VNR Vignana Jyothi Institute of Engineering and Technology of Hyderabad, Telangana, India.