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Comparison of Population Based Intelligent Techniques to Solve Load Dispatch Problem

Anirudh Singh[1], Akash Saxena[2] and Bhanu Pratap Soni[3]

[1]Rajasthan Technical University, Kota, Rajasthan, India
[2]Electrical Engineering, Swami Keshvanand Institute of Technology, Jaipur, India
[3]Electrical Engineering, Malaviya National Institute of Technology, Jaipur, India
er.bpsoni2011@gmail.com

ABSTRACT

This paper presents a comparative study of population based intelligent techniques to solve economic load dispatch. In real world economic dispatch problems possess highly non-convex objective function with solid equality and inequality constraints. In this paper optimal load dispatch problem is solved for three and six generator unit system using Particle Swarm Optimization (PSO) and Genetic Algorithm (GA). For both cases, transmission losses are included. The feasibility of these techniques are analyzed on basis of accuracy (minimizing error), time elapsed and its rate of convergence. The consequences of PSO method is compared with GA and is found better. The comparison shows the superiority of PSO to the traditional GA. Results obtained from simulations also confirm its potential to handle power system optimization problem. All in all this paper is an effort to present a comparative study of solving load dispatch problems using intelligent techniques.

Key words Economic Load Dispatch (ELD), Particle Swarm Optimization (PSO), Quadratic Cost Function, Generation unit, Transmission losses, Genetic Algorithm

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INTRODUCTION

Principal intention of economic load dispatch of electric power generation is to allocate optimal power generation levels to each unit so that for a given load demand minimum operating cost can be achieved. Economic Load Dispatch (ELD) is one of the well known optimization problem [1] in power system operation, the main objectives of load dispatch are to ensure minimisation of transfer losses, efficient power generation and low cost operation. All these objectives make the problem, a mixed integer optimisation, ironically these problems increase with the number of units [2]. Practically the input to output characteristics of the generating units are highly non-linear, non-smooth and discrete in nature owing to ramp rate limits, prohibited operating zones, multi fuel effects. Thus the resultant ELD becomes a challenging non-convex optimization problem, which is difficult to solve using the conventional methods, methods like dynamic programming, artificial intelligence, evolutionary programming, and gradient or line search optimization [3-7] are implanted to solve non-convex optimization problems efficiently. Literature reports that few methods like Priority list methods, Dynamic programming, Branch and bound method, Lagrangian relaxation, simulated annealing [8], Expert system/heuristics approach, artificial neural network (ANN) are also employed to solve load dispatch problems.

In this paper two most evolutionary algorithms, GA [3] and PSO [9] are tested to solve economic load dispatch for three and six generating unit system.GA simulates the natural evolution in terms of survival of the fittest.
While comparing GA and PSO following points are worth mentioned here
(i) PSO is equipped with evolutionary programming and evolutionary strategies no selection, crossover, mutation exist in PSO.
(ii) All particles in PSO are members of population through the course of the simulation.
(iii) Inertia weight factor (W) is used to create balance between global and local search which is absent in GA

In this process biological operators such as selection, crossover, mutation come in picture to obtain faster convergence rate. GA is modified in order to improve the performance of conventional GA by several researchers [10]. PSO is based on social interaction independent agents and the social knowledge exchange by them in order to find a global minimum. The difference between GA and PSO is while for the GA the improvement in the fitness is governed by Pseudo biological operators, on the other hand the PSO uses velocity and position update vectors. Different methods of obtaining ELD were suggested by various researchers [11-12] and [14].

In this work a fair comparison is established between GA and PSO methods, the parameters for comparison are error, time elapsed, and reliability of results on successive runs .

PROBLEM STATEMENT

A given set of N committed units at hour t, the total fuel cost, at that regular hour, is minimized by economically dispatching the units subject to the constraint (5 & 6).The constraint is total generated power must be equal to the demand. The power produced by each unit must be within certain limits. In all practical cases, the fuel cost of any generator unit '*i*' can be represented as a quadratic function of the real power generation.

$$C_i = A_i \times P_i^2 + B_i \times P_i + C_i \tag{1}$$

The incremental fuel-cost curve is a measure of how costly it will be to produce the next increment of power.

$$\frac{dC_i}{dP_i} = 2A_i P_i + B_i \tag{2}$$

By approximating the fuel cost for each generation unit $\{F_i(P_i)\}$, to a quadratic function, can be obtained, thus the total cost function will be changed into the following equation

$$C_t = \sum_{i=1}^{n_g} C_i \tag{3}$$

$$C_t = \sum_{i=1}^{n_g} A_i \times P_i^2 + B_i \times P_i + C_i \tag{4}$$

Here P_i = Output power generation of unit *i*, A_i , B_i , C_i = Fuel cost coefficients of i^{th} unit, C_t = total production cost and n_g= n^{th} generating unit

The constraints considered in this paper are

(a) Equality Constraint (Power Balance Constraint)

Equality constraint of meeting the load demand with the transmission losses is as stated *(Pi)* equals the total system load (P_d) bus system losses (P_L) as stated.

$$C = \sum_{i=1}^{n_g} P_i = P_L + P_d \tag{5}$$

Here P_i = real power generation of i^{th} unit, P_d = total demand and P_L = system losses

To calculate P_L two methods are used one is method of penalty factor and other is use of *B* coefficient. In this work *B* coefficient method is used to calculate transmission losses.

(b) Inequality Constraint

In practical power system all the generating units have their lower and upper production limits, simultaneously reactive power associated with the generating units also exists in a specific range. Both of these facts formulate inequality constraints which are given below

$$P_{gi\min} \le P_{gi} \le P_{gi\max} \qquad i = 1, 2 \ldots n_g \tag{7}$$

Where $P_{gi\min}$ = lower generating limit, P_{gi} = real power generation of ith unit and $P_{gi\max}$ = upper generating limit

Minimum reactive power is limited by the stability limit of machine and maximum reactive power is limited by overheating of rotor therefore generator reactive powers Q should not be outside the range stated by inequality for its stable operation.

$$Q_{gimin} \le Q_{gi} \le Q_{gimax} \tag{8}$$

Here Q_{min} = lower reactive power generating limit, Q_{gi} = reactive power generating limit and Q_{max} = maximum reactive power generating limit

By using the matrix form, the losses formula can be shown as in the following equation.

$$P_L = P^T B P \tag{9}$$

Where *P* = matrix of the output powers of units, *B*=square matrix of transmission coefficients and P^T =transpose of output powers of units.

PARTICLE SWARM OPTIMIZATION

The PSO is an analogous evolutionary computation technique urbanized by Kennedy and Eberhart [9] and is based on the correspondence of swarm of bird and school of fish. Each particle in PSO makes its decision using its own experience and its neighbor's experiences for development. Particles approach to the optimum through its current velocity, previous experience, and the best experience of its neighbors. The best experiences for each particle in iterations is stored in its memory and called personal best (P_{best}).The best value of P_{best} less values in iterations determines the global best G_{best}. The flow of algorithm is shown in Fig.1.

$$V_i^{k+1} = W\, V_i^{\,k} + c_1 r_1 *(P_{besti}^{\;k} - X_i^k) + c_2 r_2 * (G_{besti}^{\;k} - X_i^k) \tag{10}$$

$$X_i^{k+1} = X_i^k + V_i^{k+1} \tag{11}$$

Here V_{ik} =velocity of particle i at iteration k, W = inertia weight factor, c_1, c_2= Acceleration coefficients, r_1, r_2= random numbers between 0 and 1 and X_{ik} = particle position of i at iteration k

Steps of Implementation

Step 1. Initialize the Fitness Function which here is total cost function from the individual cost function of the various generating stations.

Step 2. Initialize the PSO parameters, Population size, c_1, c_2, W_{min},, W_{max} error gradient etc.

Step 3. Input the, MW limits, Fuel cost Functions, of the generating stations along with the B-coefficient matrix and the total power demand.

Step 4. At the first step of the execution of the program a large no (equal to the population size) of vectors of active power satisfying the MW limits are randomly allocated.

Step 5. For each vector of active power the value of the fitness function is calculated. All values obtained in iteration are compared to obtain P_{best}. At each run all values of the entire population till then are compared to obtain the G_{best}. At every step these values are updated.

Step 6. At each step error gradient is checked and the value of G_{best} is plotted till it comes within the pre-specified range.

Step 7. This final value of G_{best} is the minimum cost and the active power vector represents the economic load dispatch solution.

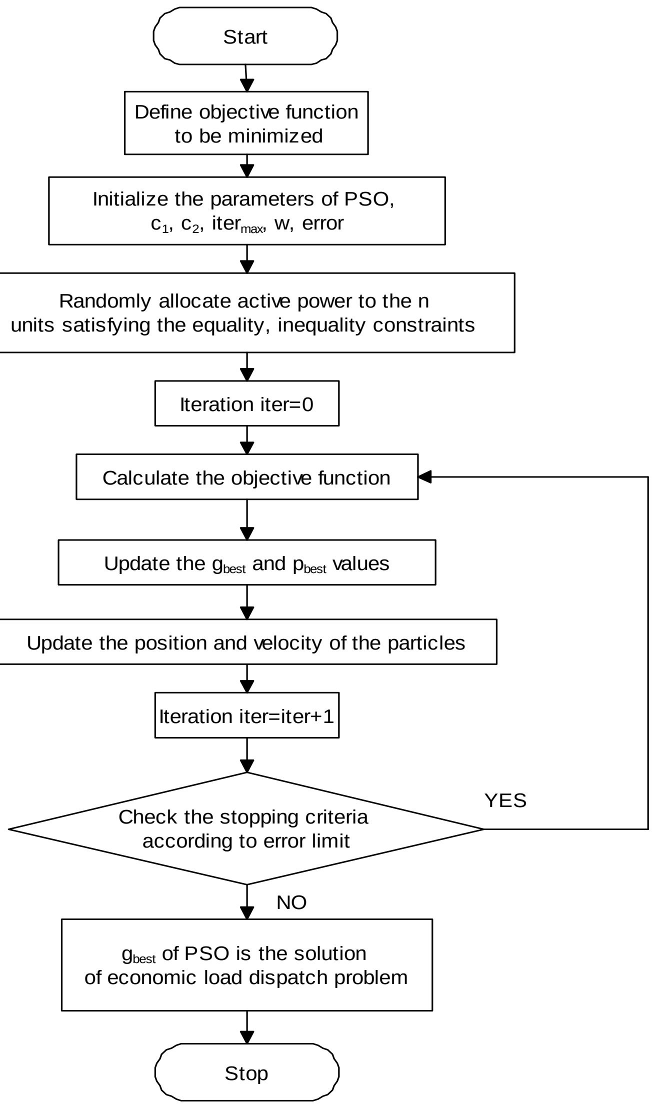

Fig. 1 Flow Chart of Particle Swarm Optimization Algorithm

SIMULATION RESULTS AND ANALYSIS

In this work two power system are considered for testing the feasibility of PSO and GA system 1 is 3 generator system and it has load demand of 150MW and system two which has 6 six thermal units, 26 buses and 46 transmission lines and having load demand of 1263 MW [12] and [13] . To check the quality extent of the solution error is also calculated, Error = sum of all generating units - (power demand + system losses) a reasonable B loss coefficients matrix of power system network was employed to draw the transmission line loss and satisfy the transmission capacity constraints. Following parameters are used to perform simulations.

i) *Genetic Algorithm Method*

- Population point = 100
- Generations = 200
- Crossover Rate (P_C)=0.8
- Mute Rate = 0.01
- Crossover Parameter *(a)* =0.5

ii) Particle Swarm Optimization method

- Population size =100
- Generations =200
- Inertia weight factor w is set, W_{max} =0.9, and W_{min}=0.4
- The limit change in the velocity of the each member in an individual was as V_{Pd}^{max}=0.5, P_d^{max}, V_{Pd}^{min}= -0.5P_d^{min}

Case Study

Case 1: Three unit thermal system with losses, Fuel cost in \$/hr of three thermal power plants and six thermal power plant with losses included are

Example 1: 3Unit system

$$C_{1=} 200+7.0P_1+.008P_1^2 \$/Hr$$
$$C_{2=} 180+6.3P_1+.008P_1^2 \$/Hr$$
$$C_{3=} 140+6.8P_1+.008P_1^2 \$/Hr$$

Where P_1, P_2, P_3 are in MW. Plant outputs are subjected to the following limits.

$$10MW \le P1 \ge 85MW$$
$$10MW \le P2 \ge 80MW$$
$$10MW \le P3 \ge 70\ MW$$

And B coefficient matrix is $= \begin{pmatrix} 0.2180 & 0.0093 & 0.0028 \\ 0.0093 & 0.0228 & 0.0017 \\ 0.0028 & 0.0017 & 0.0179 \end{pmatrix}$

The system contains six thermal units, 26 buses, and 46 transmission lines [12]. The load demand is 1263MW. The characteristics of the six thermal units are given in Table 1. In normal operation of the system, the loss coefficient Six unit thermal system with losses, cost coefficients and generator limits are shown in Table 1.

Table -1 Cost Coefficents and Generator Limits of 6 Generator System

P_{max}	P_{min}	*A*	*B*	*C*
500	100	0.007	7	240
200	50	0.0095	10	200
300	80	0.009	8.5	220
150	50	0.009	11	200
200	50	0.008	10.5	220
120	50	0.0075	12	190

Figure 1 shows iteration v/s error curve initially gives a large error although PSO gives large error when iteration is count low but it gives fine results when compared on iteration count 200 the error of PSO is -0.0000000099888 while error with GA is 0.0058. Iteration v/s time elapsed curve shows Figure 2, here it can be observed that time elapsed (in seconds) in case of PSO is less at any iteration count. Generations cost v/s iteration is shown in fig. 3. No. of runs v/s generation cost it is observed that convergence of PSO is much better than GA shown in fig 4. Similar simulation is carried out on 6 generator system fig 5 to fig 6 shows the response for the same. Table 2 and 3 shows the error and real power allocation to the 3 and 6 generator system respectively and Table 4 shows comparisons of computational efficiencies of two methods.

Table- 2 Results of 3 generators by GA and PSO

Si	Method	Power Demand (Mw)	P_1 (Mw)	P_2 (Mw)	P_3 (Mw)	Total Fuel Cost \$	Error	Time Elapsed Sec	Λ
1	GA	150	32.7301	67.9823	51.6916	1597.8	0.0104	13.955459	7.5237
2	PSO	150	32.7266	67.9792	51.6875	1597.7	-00.843	5.061409	7.5236

Table- 3 Results of 6 Generators by GA and PSO

Method	Power Demand (Mw)	P_1 (Mw)	P_2 (Mw)	P_3 (Mw)	P_4 (Mw)	P_5 (Mw)	P_6 (Mw)	Total (Mw)	Fuel Cost $	Error	Time Elapsed (Sec)	Λ
GA	1263	449	173.1	266.05	127.16	174.3	85.92	1275.74	15444.94	0.0102	9.173908	13.29
PSO	1263	449	173.1	266.05	127.16	174.3	85.92	1275.73	15444.8	-4.55E-13	3.724375	13.29

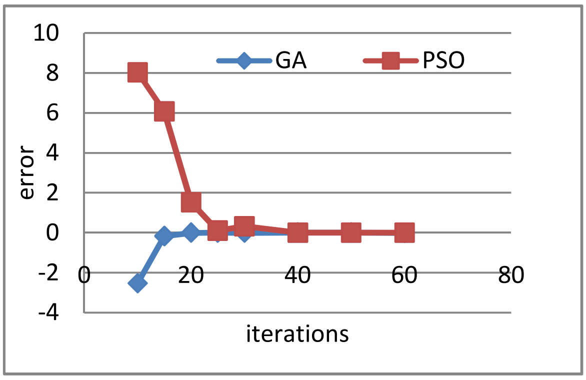

Fig. 2 Iteration v/s error for 3 Generators

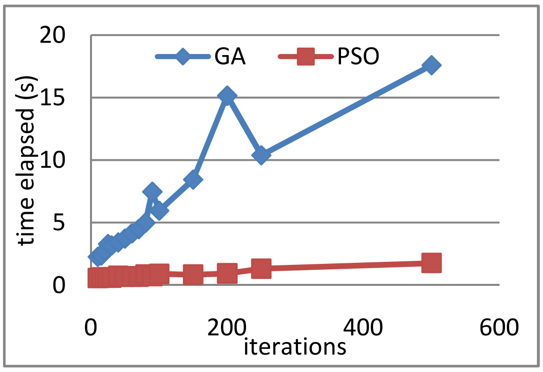

Fig. 3 Iteration v/s time elapsed for 3 Generators

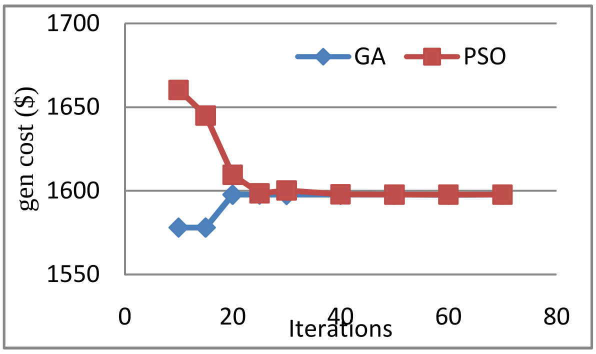

Fig.4 Iteration v/s generation Cost for 3 Generators

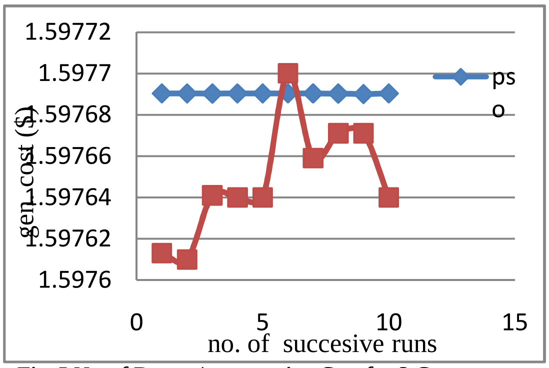

Fig. 5 No. of Runs v/s generation Cost for 3 Generators

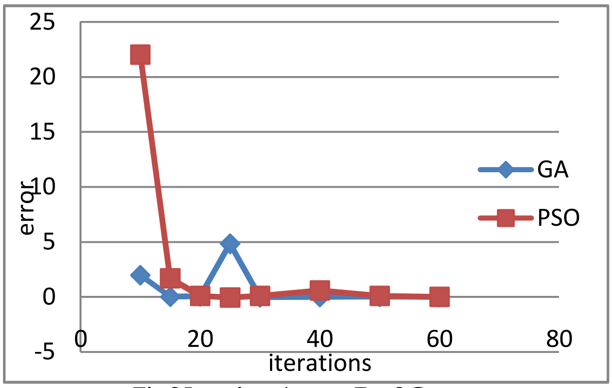

Fig.6 Iteration v/s error For 6 Generators

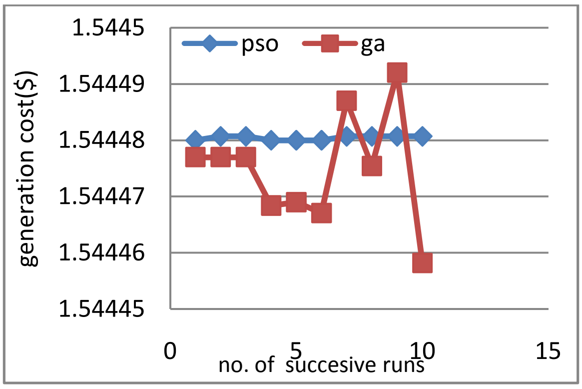

Fig. 7 Iteration v/s generation Cost for 6 Generators

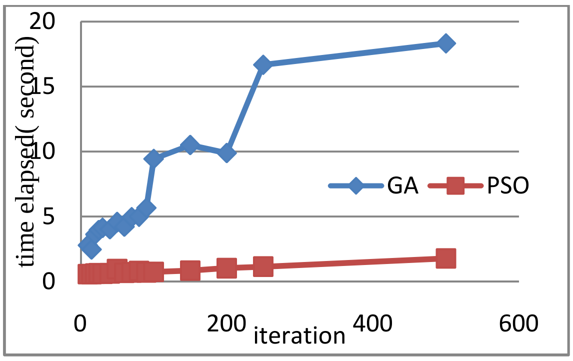

Fig.8 Iteration v/s time elapsed for 6 Generators

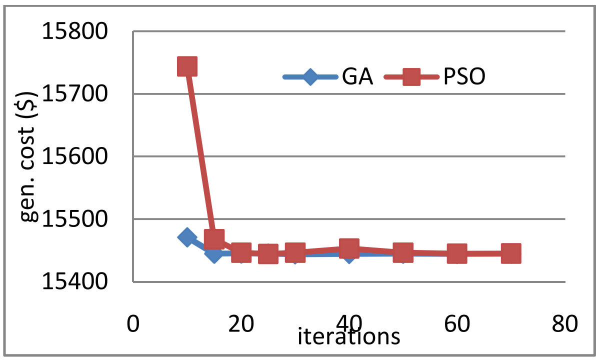

Fig. 9 Iteration v/s generation cost

Table- 4 Comparison of Computation Efficiency of GA and PSO

Example	Method	Generations	20	50	100	150	200
3-UNIT	GA	Generation Cost($)	1597.7109	1597.7249	1597.6431	1597.7535	1597.7351
		CPU Time(Sec)	2.73181	3.732394	5.964074	8.44382	15.15467
	PSO	Generation Cost($)	1609.483	1597.691	1597.69	1597.69	1597.69
		CPU Time(Sec)	0.588216	0.68927	0.901895	0.83907	0.93543
6-UNIT	GA	Generation Cost($)	15445.31	15444.86	15444.926	15445.012	15444.989
		CPU Time(Sec)	3.621933	4.56594	9.43201	10.497703	9.882905
	PSO	Generation Cost($)	15446.2	15446.106	15445.08	15444.807	15444.986
		CPU Time(Sec)	0.606582	0.967139	0.742003	0.83788	1.026361

CONCLUSION

In this paper the problem of economic load dispatch has been investigated on two test cases of real power system. The simulation results have shown that the PSO method is capable in obtaining better optimization results, although the error difference is small but PSO proposed less mathematical complexity due to its simple structure. Following are key points of this work:

Solution Quality: As observed from the responses in figures the PSO method can obtain lower average generation cost than the GA method, thus resulting in the higher quality solution. Almost all generation costs obtained by the PSO method were lower, thus verifying that the PSO method has better quality of solution and convergence characteristic.

Computational Efficiency: The comparison of computation efficiency of both methods is shown in Figs.5 and 9. From the results it can be concluded that the PSO method has better computation performance. In addition, each sample system is performed 100 times at same number of iterations (generations) using both the methods. CPU time elapsed for each sample system is different. Iteration, the graphical representation clearly indicates that time taken by particle swarm optimization is much lesser that time taken by genetic algorithm method hence particle swarm optimization is able to produce faster results than conventional GA method.

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