# A COMPARATIVE STUDY OF ECONOMIC LOAD DISPATCH BY USING GA AND PSO

**Pooja Singh**

*Head, Department of Electrical Engineering, J.I.T. Nashik (India)*

**ABSTRACT**

*The economic load dispatch plays an important role in the operation of power system. The main objective of this paper is to determine the optimal combination of power outputs of all generating units so as to meet the required demand at minimum cost while satisfying all types of constraints. In this paper the lambda iteration method and the two main types evolutionary optimization technique genetic algorithm and particle swarm optimization which are generic population based probabilistic search optimization algorithms and can be applied to real world problem are respectively applied to solve an ELD problem and at last the comparison between all three method has been presented. The PSO provides the generation level such that the generation level is coming out to be lower than the cost resulted with genetic algorithm method.*

**Keywords: - Economic Load Dispatch, Genetic Algorithm, Particle Swarm Optimization Algorithm, Swarm Intelligence.**

## I. INTRODUCTION

The Economic load dispatch problem is one of the fundamental issues in power system operation. The economic load dispatch can be defined as the process of allocating generation levels to the generating units, so that the system load is supplied entirely and most economically. For an interconnected system it is necessary to minimize the expenses. Conventionally the cost function for each unit in ELD problem has been approximately represented by a quadratic function and is solved using mathematical programming techniques. Generally for obtaining the global optimum solution these mathematical methods are required some marginal cost information. Unfortunately, the real world input output characteristics of generating units are highly non-linear and non-smooth because of the different types of constraints like valve point effect, prohibited operating zones and multi fuel effects etc. Thus practical ELD problem is considered as a non-smooth optimization problem with equality and inequality constraints, which directly cannot be solved by the mathematical methods. Because these methods are highly sensitive to starting points and often converge to local optima. The ELD problem involves the solution of two different problems. The first of these is the unit commitment or pre dispatch problem wherein if is required to select optimally out of the available generating sources to operate meet the expected load and provide a specified margin of operating reserve over a specified period of time. The second aspect of Economic Dispatch is the online economic dispatch wherein it is required to distribute the load among the generating unit actually paralleled with the system in such manner as to minimize the total cost of supplying to minute requirements of the system. 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 non-linear functions in practical systems. In past decade, conventional optimization techniques such as lambda iteration method, linear & quadratic programming, have been successfully used to solve power system optimization problem such as unit-commitment and economic load dispatch. 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. PSO first introduced by Kennedy and Eberhart, is one of the modern heuristic algorithm. 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 with in shorter calculation time and stable convergence characteristics.

## II. ECONOMIC LOAD DISPATCH

The objective function & subjected constraints can be defined as:

### 2.1 The Problem Formulation: Objective Function-

The objective of economic load dispatch for power system consisting of thermal generating units is to find the optimal combination of power generations that minimises the total generation cost while satisfying the specified equality & inequality constraints. The fuel cost function of generator is represented as a quadratic function of generator active powers.

Objective function=

$$min \sum_{i=1}^{n} Fi(pgi)$$

$$F(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i$$

Where the $F_i(Pg_i)$ is the operation fuel cost of generator i and $a_i, b_i, c_i$ are the cost coefficients for $i^{th}$ unit.

### 2.2 Constraints

The problem is subjected to power balance constraints and generating capacity constraints as follows

### 2.2.1 Power Balance Constraints-Equality Constraints

$$\sum_{i=1}^{NG} P_{gi} = P_D + P_L$$

### 2.2.2 Inequality Constraints

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max}$$

Where $P_D$ is the load demand. $P_{gi}$ is output power of $i^{th}$ generator , $P_L$ is the transmission loss. $P_{gi}^{min}$ And $P_{gi}^{max}$ are the maximum & minimum output powers of the $i^{th}$ generator respectively.

## III. APPLIED METHODS

### 3.1 Lambda Iteration Method

In this method λ is a variable, introduced in solving constraint optimization problem and is already known as Lagrange Multiplier. It is significant to that Lambda can be solved at hand by solving systems of equations. Since all the inequality constraints to be satisfied in each trial the equations are solved by the iterative method.

- Assume a suitable value of $\lambda^{(0)}$.
- The value of lambda should be more than the largest intercept of the incremental cost characteristic of the various generators.
- Compute the individual generations.
- Check the equality constraint, $h = \sum_{i=1}^{ng} P_{gi} - P_d - P_L$ is satisfied.
- If not satisfied, make the second guess λ repeat above steps.

### 3.2 Genetic Algorithm

A global optimization technique known as Genetic algorithm has emerged as a candidate due to its flexibility and efficiency for many optimization applications. It is a stochastic searching algorithm. The method was developed by John Holland in 1975. GA is inspired by the evolutionary theory which is explaining by the origin of species. Normally in our nature weak and unfit species within their environment are faced with extinction with natural selections. The strong one has greater opportunity to pass their genes to the future generation via reproduction process. In the long run the species those are carrying the correct combination in their genes become dominant in their population. Some times during the slow process of evolution, random changes may occur in genes. If these additional advantages in the challenge for survival, new species evolve from the old ones, unsuccessful changes are eliminated by natural selection. The GA is a search heuristic technique that mimics the process of natural evolution. The heuristics technique is routinely used to generate useful solutions to optimization and search problems. GA belong to the larger class of evolutionary algorithm, which generate solutions to the optimization problems using natural evolution such as mutation, selection, crossover and inheritance. GA offer a new and powerful approach to the optimization problems make possible by the increasing availability of high performance of computers at relatively low cost. These algorithms have recently found extensive applications in solving global optimization searching problems when the closed form optimization techniques cannot be applied. GA are parallel and global search toward the global solution because, it simultaneously, evaluates many points in the parameter space. It does not need to assume that the search pace is differentiable or continuous.

### 3.2.1 Algorithm of Economic Load Dispatch using GA-

1. Read data, such as cost coefficients $a_i, b_i, c_i$ number of iterations, length of strings population size, probability of mutation and crossover, power demand $P^{min}$ and $P^{max}$.
2. Create the initial population randomly in the binary form.
3. Now decode the string, or obtain the decimal integer from the binary string.
4. Calculate the power which generated from the decoded population by using equation.

$$P_i^j = P_i^{min} + \frac{(P_i^{max} - P_i^{min})\, y_i^j}{2^l - 1}$$

$i$ = 1,2...NG

$j$ = 1,2.....NG

$L$ = Number of string or population size.

5. Check $P_i^j$ ,

   If $Pi^j > P^{max,}$ then set $Pi^j = Pi^{max}$

   If $Pi^j < P^{max}$ then set $Pi^{j=}Pi^{min}$

6. Find the fitness or cost function from second equation.
7. Find the population with maximum fitness and average fitness of the population.
8. Perform the reproduction process, which includes these steps

- Set selection rate and number of mating in a pool.
- Define total fitness as the sum of values obtained by using above steps for all chromosomes which are selected.
- Select percentage of each chromosome which is equal to the ratio of its fitness value to the total fitness value i.e. find probability, which can be written as

  Probability=fitness/∑Fitness's.

- Calculate cumulative sum (CS) to normalize the values between 0.0 to 1.0.

9. Perform crossover operation:

- Choose a pair of random numbers between 0 and 1to select one mother and one father chromosome, so as to produce new offspring.
- Pairing the chromosome from different location, for different location the crossover point has to be selected which can be selected randomly. Generate offspring by applying crossover.

10. Perform mutation by randomly selecting the mutation point from the total no. Of bits in the population matrix.
11. Update the population.
12. If the no. Of iteration reaches the maximum then go to step (13) otherwise will go to step (6).
13. The fitness that generates the minimum total generation cost is the solution of the problem.

### 3.3 Particle Swarm Optimization

Kennedy and Eberhart developed a particle swarm optimization behavior (PSO) algorithm based on the behavior of individual (i.e. particles or agents) of the swarm. Its roots are in zoologist modeling of the movement of individuals (i.e. fishes, birds, and insects) with in a group. It has been noticed that members of the group seem to share information among them, a fact that leads to increase the efficiency of the group. PSO as an optimization tool provides a population based search procedure in which individuals called particles change their position (states) with time. In a PSO system particles flying around the multi dimensional space. In particle swarm optimization, each individual makes its decision based on its own experience together with other individual's experience. Particle swarm optimization (PSO) is a population based stochastic optimization technique which is inspired by a social psychological metaphor instead of the survival of fittest individual. During the flight period each particle adjusts its position according to its own experience and the experience of neighboring particles and making use of best position taken by it and neighbors. The swarm direction of a particle can be defined by the set of particles neighboring the particles and its history experience. In PSO we are not using evolutionary operation to manipulate the individuals, in the PSO each individual flies in the search space with a velocity which is dynamically adjusted according to its own flying experience and its companions flying experience also.

#### 3.3.1 Algorithm Of Economic Load Dispatch By Using PSO

The algorithm for economic load dispatch by using particle swarm optimization is given as follows.

1. Initialize the individuals of the population according to the limit of each unit including the individual dimension, searching point, and velocities. This initial solution must be feasible candidate solution that satisfies the practical operation constraints.
2. To Each chromosome of the population the dependent unit output $P_D$ will be calculated from the power balance equation and $B_{mn}$ coefficient matrix.
3. Calculate the evaluation value of each individual $P_{gi}$ , in the population using the evaluation function f given by

$$MinimizeFC(i) = \sum_{i=1}^{ng} f_i(P_i)$$

4. Compare each individual's evaluation value with its $P_{best}$. The best evaluation value among $P_{best}$ is denoted as $G_{best}$ .
5. Modify the member velocity v of each individual $P_g$ .

$$v_{id}(t+1) = wv_i(t) + C1Rand()(Pbest(Pg_{id}(t)) = C2Rand()$$
$$(gbest_{id} - Pg_{id}(t))$$

Where i=1,2….n and d=1,2….m

**6.** Check the velocity component constraint occurring in the limits from the following conditions.

$$\text{If } v_{ij}^{(r+1)} > v_j^{max} \text{ then } v_{ij}^{(r+1)} = v_j^{max}$$

$$\text{If } v_{ij}^{(r+1)} < v_j^{min} \text{ then } v_{ij}^{(r+1)} = v_j^{max}$$

Where, $v_j^{max} = -0.5P_j^{min}$

Where, $V_j^{max} = +0.5P_j^{max}$

**7.** Modify the member position of each individual $P_g$ .

$$P_{gid}(t+1) = P_{gid}(t) + v_{id}(t+1)$$

$P_{gid}(t+1)$ Must be modified toward the near margin of the feasible solution.

**8**. If the evaluation value of each individual is better than previous $P_{best}$ , the current value is set to be $P_{best}$ .

If the best $P_{best}$ is better than the $G_{best}$ , the value is set to be $G_{best}$ .

**9**. If the number of iterations reaches the maximum, then go to step 2.

**10.** The individual that generates the latest $G_{best}$ is the optimal generation power of each unit with the minimum total generator cost.

## VI. COMPLETE WORK AND CALCULATIONS.

In this paper the result of economic load dispatch after the implementation of proposed method lambda-iteration method, genetic algorithm (GA) and particle swarm optimization (PSO) are discussed. The programs are implemented in MATLAB 7.6.0. The performance is evaluated with considering the total transmission losses using two generating test system i.e. three generator system, and six generator system whose input and output data are given below.

### Case Study1: Solving Three Generator System By Using Lambda Iteration Method

The coefficients of fuel cost and maximum and minimum power limits are given below. the power demand is considered to be 850(MW). The results corresponding to Lambda iteration GA and PSO are detailed in section.

The cost characteristic of the three units are given as

$$F_1 = .006P_1^2 + 8.4P_1 + 400 \text{ Rs/hr}$$

$$F_2 = .0042P_2^2 + 8.93P_2 + 600 \text{ Rs/hr}$$

$$F_3 = .0045P_3^2 + 6.78P_3 + 650 \text{ Rs/hr}$$

The unit operating constraints are

$$100MW \leq P1 \leq 600MW$$

$$60MW \leq P2 \leq 300MW$$

$$300MW \leq P3 \leq 650MW$$

For the above system considering the load of 550mw, 850mw, 900mw conventional lambda iteration method is applied to obtain the economic load dispatch. The table 1 shows that the economic load dispatch of above mentioned loads neglecting the transmission line losses.

**Table-1: Lambda Iteration Method for Three Generating Unit System.**

| S. no. | Demand (mw) | $P_1$ (mw) | $P_2$ (mw) | $P_3$ (mw) | Lambda | Cost (Rs/hr) |
|---|---|---|---|---|---|---|
| **1.** | 550 | 115.12 | 101.371 | 333.562 | 9.7815 | 6379.82 |
| **2.** | 850 | 194.87 | 215.291 | 439.831 | 10.77 | 9120.5 |
| **3.** | 900 | 208.16 | 234.282 | 457.552 | 10.89 | 9801.00 |

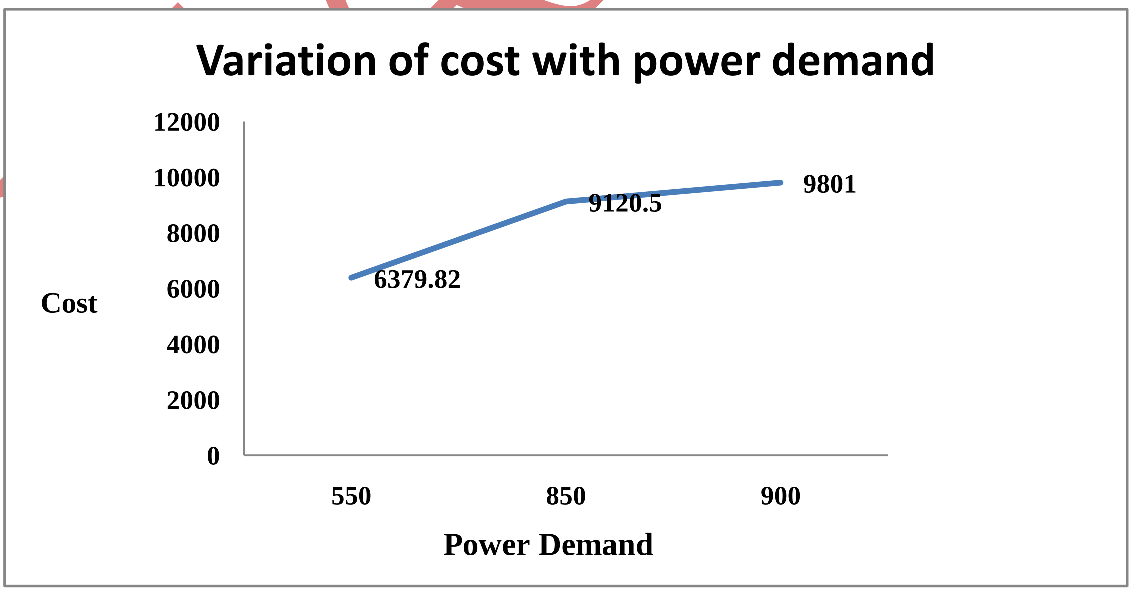


**Fig .1: Variation of Cost with Power Demand for Three Unit System**

**Case Study2- Solving Three Generator Systems By Using Genetic Algorithm Method**

The coefficients of fuel cost and minimum and maximum limits are given in table 2.

**Table:2- Specification For GA Of Three Generating System**

| Unit no. | $a_i$ | $b_i$ | $c_i$ | $P_{min}$ | $P_{max}$ |
|---|---|---|---|---|---|
| **1.** | .0001562 | 7.92 | 561 | 150 | 600 |
| **2.** | .000194 | 7.85 | 310 | 100 | 400 |
| **3.** | .00482 | 7.97 | 78 | 50 | 200 |

**Optimal solution using genetic algorithm for case study (2) –**

Table: 3- Optimal Result of GA

| S.no. | Demand (MW) | $P_1$ (MW) | $P_2$ (MW) | $P_3$ (MW) | Total cost (Rs/hr) |
|---|---|---|---|---|---|
| **1.** | 550 | 190.57 | 60.62 | 300.77 | 6299.00 |
| **2.** | 820 | 211.30 | 88.82 | 519.88 | 9000.60 |
| **3.** | 850 | 395.5 | 325.7 | 128.8 | 8719.55 |
| **4.** | 1500 | 560 | 290 | 650 | 17178.00 |

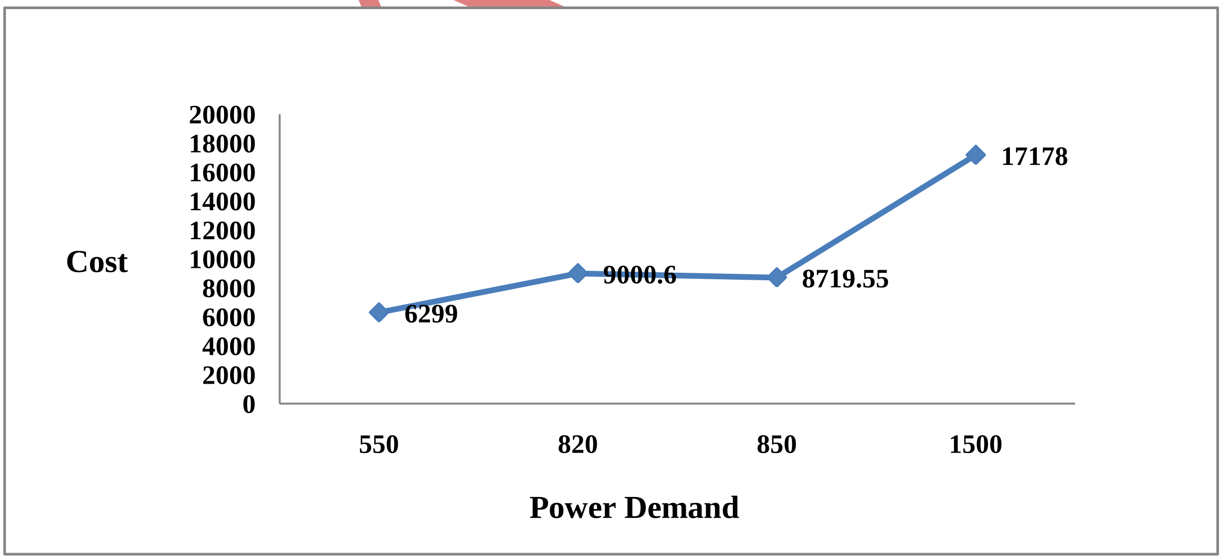


**Fig.2: Cost Variation of Three Unit System By GA.**

**Case Study (3): Solving Three Generator Systems By Using PSO Method**

**Table:4- Specification For PSO Of Three Generating System**

| Unit no. | $a_i$ | $b_i$ | $c_i$ | $P_{min}$ | $P_{max}$ |
|---|---|---|---|---|---|
| **1.** | .0001562 | 7.92 | 561 | 150 | 600 |
| **2.** | .000194 | 7.85 | 310 | 100 | 400 |
| **3.** | .00482 | 7.97 | 78 | 50 | 200 |

**Optimal solution using PSO for case study (3)-**

**Table: 5- Results Of PSO For Three Generating Unit System.**

| | |
|---|---|
| $P_1$ (MW) | 390.732 |
| $P_1$ (MW) | 388.976 |
| $P_1$ (MW) | 178.405 |
| Total power(MW) | 850 |
| Total cost(Rs/hr) | 8716.77 |

**Comparison of Lambda-iteration, GA, and PSO-**

**Table No: 6- Comparison Of All Three Proposed Method**

| **Demand (MW)** | **Cost by Lambda iteration method (Rs/hr)** | **Cost by GA (Rs/hr)** | **Cost by PSO (Rs/hr)** |
|---|---|---|---|
| 850 | 9120.5 | 8719.55 | 8716.77 |

**Case study (4) - Solving six generator system by genetic algorithm method-**

**Table: 7- Specifications Of ELD Problem For GA.**

| S.no. | $a_i$ | $b_i$ | $c_i$ | $P_{min}$ | $P_{max}$ |
|---|---|---|---|---|---|
| **1.** | .0070 | 7.0 | 240 | 100 | 500 |
| **2.** | .0095 | 10.0 | 200 | 50 | 200 |
| **3.** | .0090 | 8.5 | 220 | 80 | 300 |
| **4.** | .0090 | 11.0 | 200 | 50 | 150 |
| **5.** | .0080 | 10.5 | 220 | 50 | 220 |
| **6.** | .0075 | 12 | 190 | 50 | 120 |

The loss coefficient matrix is given as,

B=1e-4*[0.13 0.12 0.12 0.19 0.22 0.17

0.16 0.7 0.12 0.15 0.14 0.4

0.16 0.12 0.66 0.18 0.25 0.18

0.18 0.15 0.16 0.70 0.2 0.23

0.25 0.16 0.25 0.2 0.67 0.30

0.23 0.1 0.18 0.24 0.34 0.82];

**Optimal Solution By Using Genetic Algorithm For Case Study (4)-**

**Table: 8- The Result Of GA For Case Study-4.**

| S.no | Demand (MW) | $P_1$ (MW) | $P_2$ (MW) | $P_3$ (MW) | $P_4$ (MW) | $P_5$ (MW) | $P_6$ (MW) | $P_L$ (MW) | Cost (Rs/hr) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 500 | 242.85 | 54.66 | 94.59 | 54.49 | 58.82 | 51.35 | 6.78 | 6153.03 |
| 2. | 700 | 328.13 | 67.33 | 156.33 | 50.53 | 52.36 | 56.06 | 10.75 | 8357.44 |
| 3. | 820 | 359.50 | 105.43 | 188.76 | 50.16 | 80.13 | 51.15 | 15.15 | 9807.092 |
| 4. | 900 | 382.74 | 112.77 | 201.03 | 65.95 | 106.13 | 50.25 | 18.62 | 10813.59 |
| 5. | 1100 | 429.50 | 191.22 | 266.89 | 144.94 | 167.90 | 90.44 | 41.22 | 13454.052 |

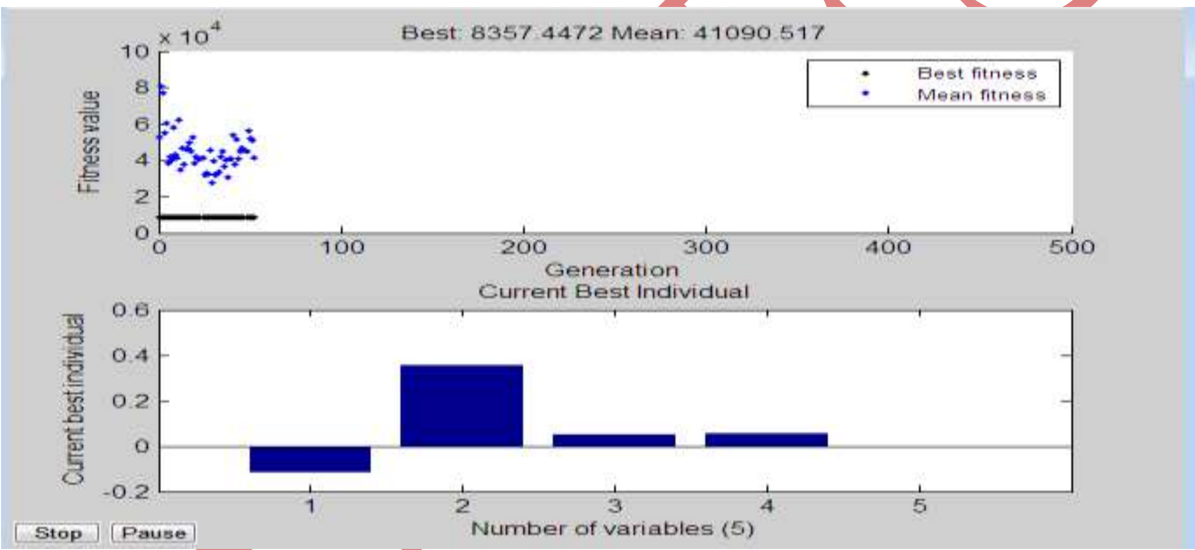


**Fig.3: Convergence Characteristic Of PSO For Six Unit System (700mw Demand).**

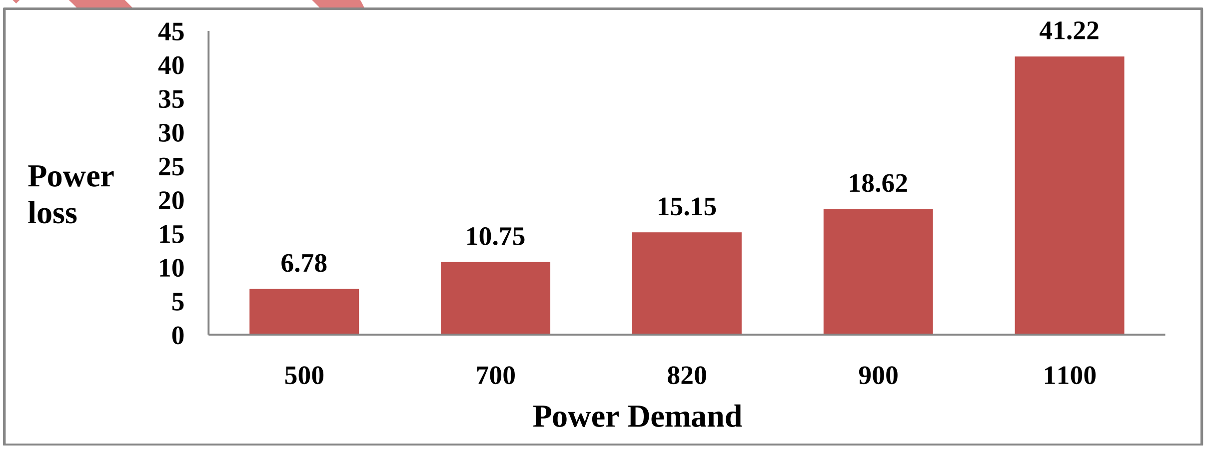


**Fig .4: Variation Of Power Loss With The Load Demand For Six Unit System In GA.**

**Solving Six Generator System By Particle Swarm Optimization Method**

The coefficient of fuel cost and minimum / maximum power limits are given in table 7, a number of power demands are considered here.

### Optimal Solution By Using Particle Swarm Optimization For Case Study (4)

The initial particles are randomly generated within the feasible range. The parameters c1 and c2 and inertia weight are selected for best convergence characteristic. Here c1=1.99 and c2=1.99 are used, and the maximum value of w is chosen to be 0.9 and minimum value is 0.4. The velocity limits are selected as $V_{max}=0.5*P_{max}$ and minimum value is selected as $V_{min} = -0.5*P_{max}$. There are 10 number of particle are selected in the population. For different values of c1 and c2 the cost curves convergences in different region. So the best value is taken for the minimum cost of the problem. If we increase the number of particles then cost curve converges faster. From this solution analysis, it can be observed the loss has no effect on the cost characteristic, it has been observed even if number of units is increased the convergence is less affected.

**Table: 9- Output Result Of PSO For Case Study-4**

| S.No | Demand (MW) | $P_1$ (MW) | $P_2$ (MW) | $P_3$ (MW) | $P_4$ (MW) | $P_5$ (MW) | $P_6$ (MW) | $P_L$(Losses) (MW) | Cost (Rs/hr) |
|---|---|---|---|---|---|---|---|---|---|
| **1.** | 500 | 221.16 | 50 | 84.4 | 50 | 50 | 50 | 5.5842 | 6132.2 |
| **2.** | 700 | 322.81 | 77.01 | 158.56 | 50 | 52.34 | 50 | 10.74 | 8352.61 |
| **3.** | 820 | 361.42 | 103.35 | 185.74 | 52.31 | 82.29 | 50 | 15.13 | 9805.86 |
| **4.** | 900 | 383.04 | 118.76 | 201.21 | 67.42 | 98.04 | 50 | 18.50 | 10812.2 |
| **5.** | 1100 | 436.52 | 115.43 | 239.16 | 103.72 | 137.63 | 56.09 | 28.58 | 13452.42 |
| **6.** | 1300 | 482.67 | 187.68 | 271.81 | 135.90 | 171.39 | 91.76 | 41.26 | 16256.68 |

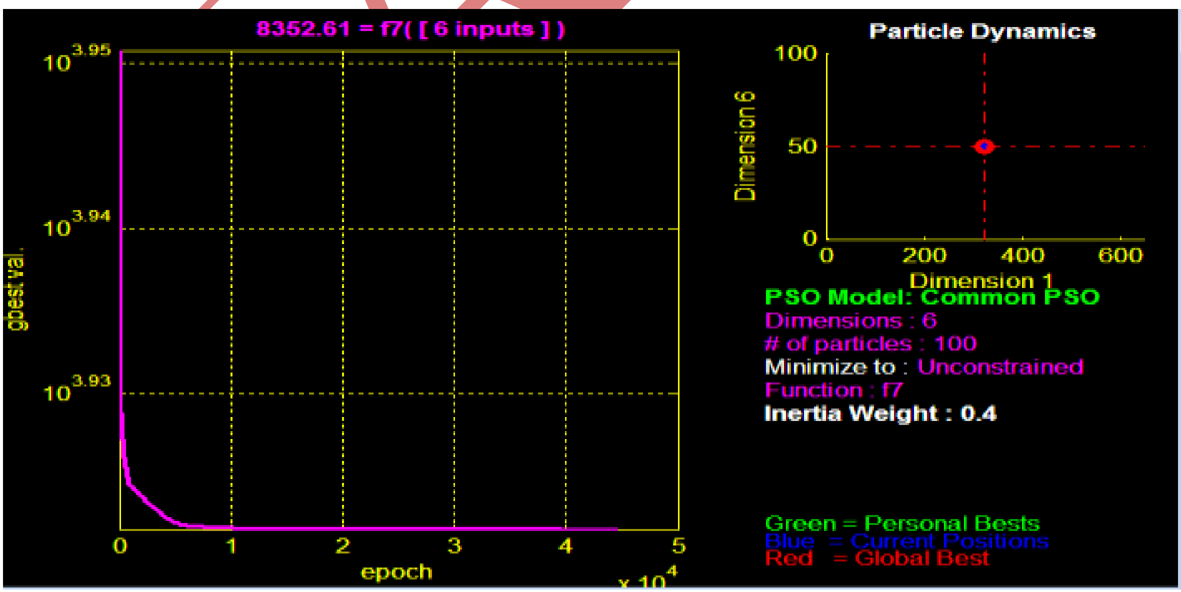


**Fig.5: Convergence Characteristic Of PSO For Six Unit System (700mw Demand).**

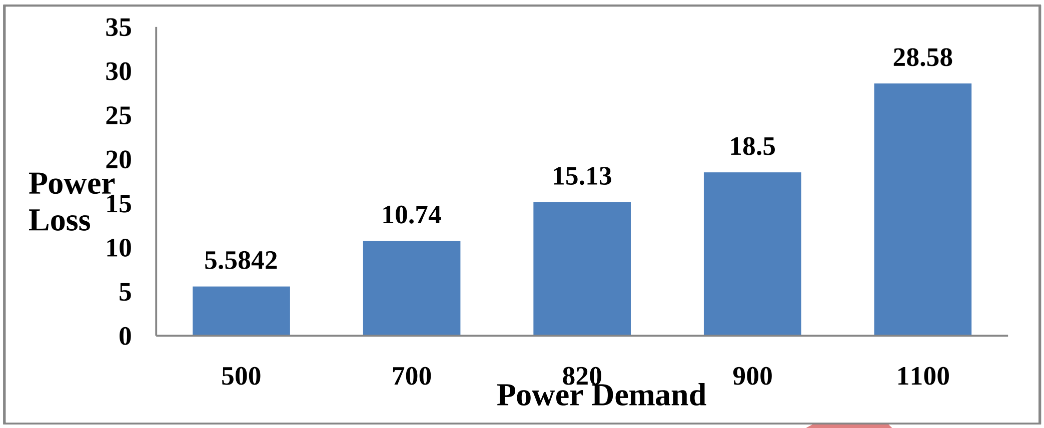


**Fig .6: Variation Of Power Loss With The Load Demand For Six Unit System In GA.**

**Comparison Between GA And PSO-**

**Table No:10- Comparison Of Cost Between GA And PSO.**

| Demand (MW) | Cost by GA (Rs/hr) | Cost by PSO (Rs/hr) |
|---|---|---|
| 500 | 6153.03 | 6132.2 |
| 700 | 8362.66 | 8352.61 |
| 820 | 9807.092 | 9805.86 |
| 900 | 10813.59 | 10812.2 |
| 1100 | 13454.052 | 13452.42 |

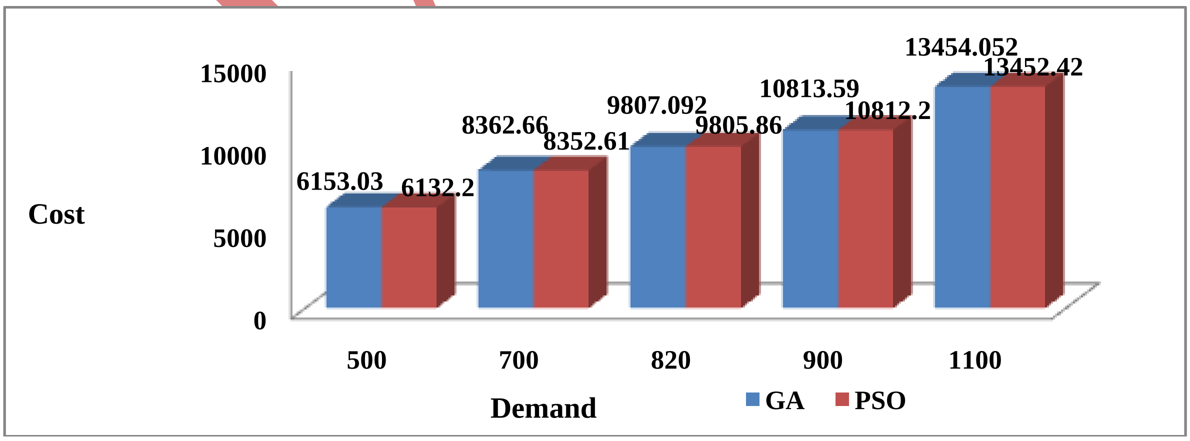


**Fig: 7 Variation Of Cost In Six Generating Unit System By GA And PSO.**

**Comparison Of Losses From GA And PSO-**

**Table No: 11 Comparisons Of Losses Between GA And PSO.**

| Demand (MW) | Losses from GA (MW) | Losses from PSO (MW) |
|---|---|---|
| 500 | 6.78 | 5.5842 |
| 700 | 10.75 | 10.74 |
| 820 | 15.15 | 15.13 |
| 900 | 18.62 | 18.50 |
| 1100 | 41.22 | 28.58 |

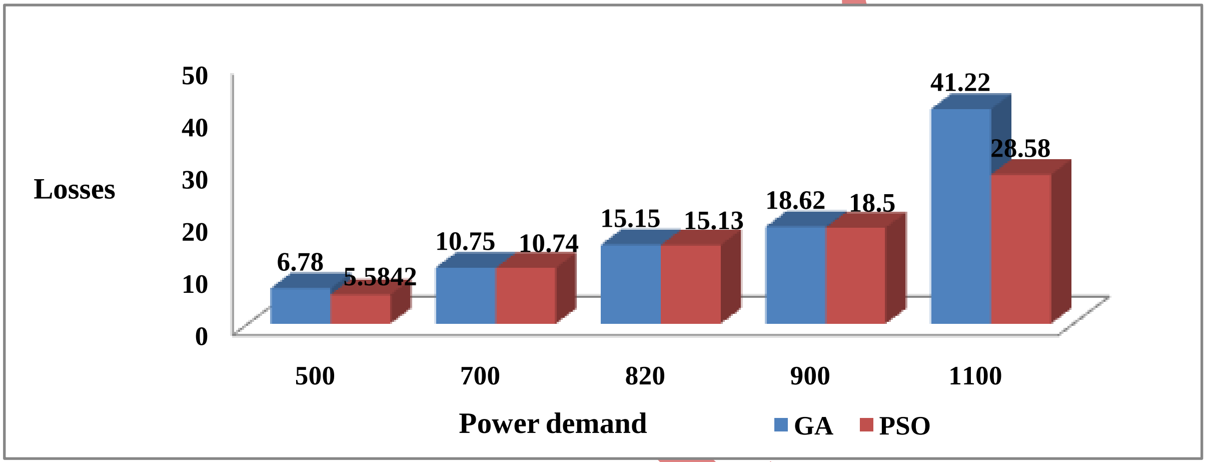


**Fig: 8 Variations Of Losses In Six Generating Unit System By GA And PSO.**

## V. CONCLUSION

In this work the formulation and implementation of solution methods such as Lambda iteration method, Genetic Algorithm and Particle Swarm Optimization, to obtain the optimum solution of economic load dispatch. PSO can be used to solve many of the same kinds of problems as GA. This optimization technique does not suffer, from some of GA's difficulties: interaction in the group enhances rather than takes away from progress toward the solution. Further a particle swarm system has memory, which the genetic algorithm does not have. The change in genetic populations results in destruction of previous knowledge of the problem, except when elitism is employed, in which case usually one or a small number of individuals retain their "identities". The effectiveness of the developed program is tested for three generators and six generator test system. The results obtained from these methods are also compared with each other. It is found that PSO is giving better results than GA and Lambda iteration method.

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