Optimal Load Distribution of Thermal Generating Units using Particle Swarm Optimization (PSO)

Abhinav Saxena, G.M Patil, Prashant, Parveen Poon Terang, Nirmal kumar Agarwal, Arun Rawat

***Abstract*: This paper shows load planning of two thermal generating units feeding a load of 200 MW using Particle swarm optimization (PSO). The PSO involves selection of population size or number of particle, fitness function. The advantages of PSO over conventional method are better and reliable solution, better convergence rate. Initially fitness function, population size corresponding to each variable are decided, thereafter PSO is used for finding most optimal solution of the generating units under different set of iteration. The performance of system using PSO is compared with conventional method in terms of the tolerance band.**

Index Terms: PSO, fitness, population size, thermal.

I. INTRODUCTION

In a thermal power station, as its suggest heat or steam energy is used to generate electrical energy using inverse electromagnetic conversion. Generally, steam turbines are used to drive the synchronous generator at synchronous speed. Steam can be used after it has passed through the turbine by means of a condenser. This process of steam recycling popularly called is known as Rankine Cycle. The division of thermal power stations into various designs is done mainly on the basis of source of heat used for power generation. While fossil fuels are most commonly used, some modern thermal generating units deploy the use of nuclear and solar forms of energy for heat generation. Thermal power stations are sometimes also referred to as 'energy centers' because they convert heat energy into electrical energy. Thermal power stations are designed in such a way that they can also be used to generate heat energy for industrial purposes such as District Heating and Desalination of water [1]

For optimum operation of power plants, it is required to find the optimum parameter of the system with the minimum cost for maximum output ratio. This is processed to consider the financial and economic aspects of the system with different set of optimized iteration levels until desired solution is obtained. Economic Load Dispatch (ELD) is a optimized process which has been in use since the 1951s for finding the perfect operational scheme for the operation of power plants to meet the specified load requirements dynamically[2,3] and to save environment from pollution. ELD is performed by using a different number of methods such as, Fuzzy logic controller, ANN etc.

II. PARTICLE SWARM OPTIMIZATION (PSO)

Particle swarm optimization (PSO) follows the nature of colonies such as swarm of insects, flock of birds, ants, bees, etc[5,6,7,8,9]. The particle represents bee in the colony etc. which uses its own intelligence in search of target while other particles follow the path of target given by adjacent particle. Swarm represents the searching of food or target in a group. The swarm is assumed to be of specific size in a multidimensional search space [10,11,12,13,14,15,19]. Each particle has two properties: position and velocity. PSO concept was given by Kennedy and Eberhart in 1995

Each particle searches for best position and velocity in search of design space. It is given as

$$V_j(i) = V_j(i-1) + c_1 r_1 [P_{best,j} - X_j(i-1)] + c_2 r_2 [G_{best} - X_j(i-1)] \quad (1)$$

$$X_j = X_j(i-1) + V_j(i) \quad (2)$$

Where: G_{best} = Global Best Position.
P_{best} = Self Best Position.
C_1 and C_2 = Acceleration Coefficients.
V_j (i) = Velocity of j^{th} of i^{th} iteration.
X_j = Particle of j^{th} of i^{th} iteration.
j = Number of particle
i = iteration
$X_j(i) = X_j(i-1) + V_j(i)$
r_1 and r_2 are random variables which lie between 0 and1.

III. THERMAL GENERATING UNITS:

Fig.1 shows the structure of three thermal generating units feeding the load of 200 MW through grid connected system. The cost characteristic of thermal power plant varies quadratically with respect to generating units and can be expressed by

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$$F_i(P_i) = aP_i^2 + bP_i + c \quad \text{Rs/h} \qquad (3)$$

$$= F_1(P_1) + F_2(P_2)$$

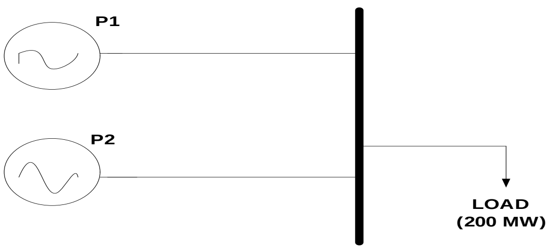

Fig.1 Structure of 2 generating units feeding a load of 200MW

Two generating units namely P_1, P_2 are of rating 200, 150 MW respectively under the constraints as

$$5 < P_1 < 200$$

$$4 < P_2 < 150$$

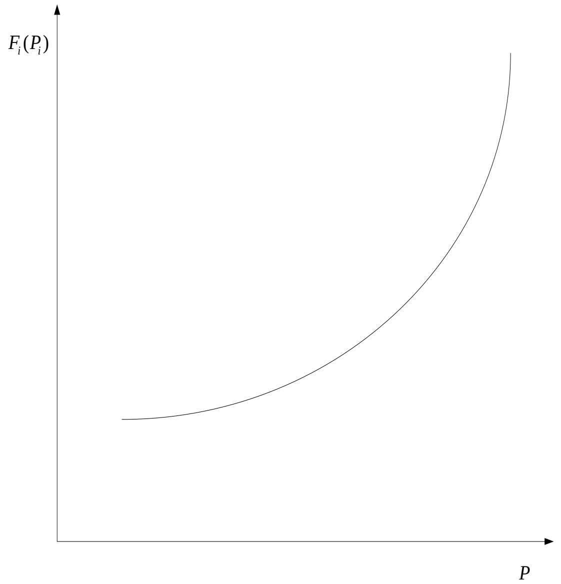

Fig.2.Variation of cost characteristic w.r.t generating unit

Differentiate Eq. (1) w.r.t to P_i

$$\frac{d(F_i(P_i))}{d(P_i)} = 2aP_i + b \qquad (4)$$

On solving Eq.(3) and (4) with some approximation on hit and trail method. It is easy to solve for the value of a, b, c for three generating units and it is given as

$$F_1(P_1) = 0.04P_1^2 + 1.71P_1 + 191 \qquad (5)$$

$$F_2(P_2) = 0.05P_2^2 + 10.72P_2 + 217 \qquad (6)$$

Transmission line losses are given by

$$P_L = \sum_{i=1}^{3}\sum_{j=1}^{3} P_i P_j B_{ij} \qquad (7)$$

Loss coefficient for the system is

$$B_{ij} = \begin{vmatrix} 0.0025 & 0.00030 & 0.00251 \\ 0.0017 & 0.0087 & 0.00912 \\ 0.0068 & 0.0089 & 0.00792 \end{vmatrix}$$

IV. CONVENTIONAL METHOD :

In Conventional method, the economic load scheduling for equalizing incremental fuel cost is given as:

$$L_1 \frac{d(F_i(P_i))}{d(P_1)} = L_2 \frac{d(F_i(P_i))}{d(P_2)} \qquad (8)$$

$$L_1 = \frac{1}{(1 - \frac{\partial P_L}{\partial P_1})} \qquad (9)$$

$$L_2 = \frac{1}{(1 - \frac{\partial P_L}{\partial P_2})} \qquad (10)$$

$$P_D + P_L = \sum_{i=1}^{2} P_i \qquad (11)$$

Tolerance or converging limit

$$\varepsilon = P_D + P_L - \sum_{i=1}^{2} P_i \qquad (12)$$

On solving Eq. (5,6, 7, 8, 9, 10,11), the solution obtained is:

$$P_1 = 150MW, P_2 = 63MW$$

$$P_D = 200MW, P_L = 16MW$$

From this tolerance limit from Eq. (12) is

$$\varepsilon = 3$$

Which is quite far above the acceptable limit. The acceptable is:

$$\varepsilon \leq 0.1$$

The calculated tolerance limit is not lying in the acceptable range.

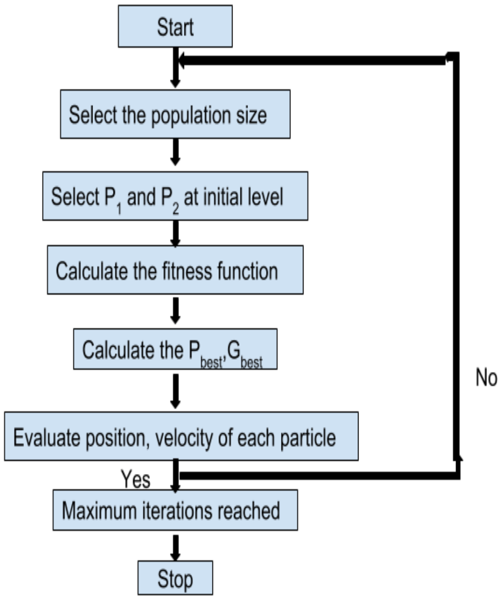

Fig.3. Flowchart representing the GAs for economic Scheduling for three thermal scheduling

V. APPLICATION OF PSO IN GENERATING UNITS

Let apply the concept of PSO in economic scheduling

$F_1(P_1) = 0.04P_1^2 + 1.71P_1 + 191$
$F_2(P_2) = 0.05P_2^2 + 10.72P_2 + 217$
$5 < P_1 < 200$
$4 < P_2 < 150$
Take 4 particles and initial population for generating units
$P_{1,1} = 12$ MW $P_{1,2} = 94$ MW
$P_{2,1} = 18$ MW $P_{2,2} = 39$ MW
$P_{2,3} = 59$ MW $P_{2,4} = 94$ MW
Choose $r_1 = r_2 = 0.5$
$C_1 = 0.7$
$C_2 = 0.9$
Load demand, $P_D = 200$ MW

Table.1. Generating units for initial iteration

Population size particle	P_1	P_2
1	12	18
2	56	39
3	78	59
4	94	72

Table.2. Generating units for first iteration

Population size particle	P_1	P_2
1	10.25	83.5
2	86.1	114.9
3	91.5	109.5
4	187.5	13.5

Table.3: Generating units for 12th iteration

Population size particle	P_1	P_2
1	137.41	83.5
2	99.41	114.9
3	141.61	109.5
4	121.61	13.5

Table.4: Generating units for 39th iteration

Population size particle	P_1	P_2
1	118.5	81.6
2	118.5	81.9
3	118.6	82.1
4	119.5	82.2

It is observed that generating units P_1, P_2 converges to approximately same value after the 39 iteration.

$$P_1 = 118MW$$

$$P_2 = 82MW$$

Eq.(12) shows tolerance or convergence limit under genetic algorithm for different set of iteration level(k)

At 39th iteration , some better results is obtained as shown in Fig.5 and its tolerance or convergence limit.

$$\varepsilon^{39} = 0.00721$$

It is lying within the acceptable limit for

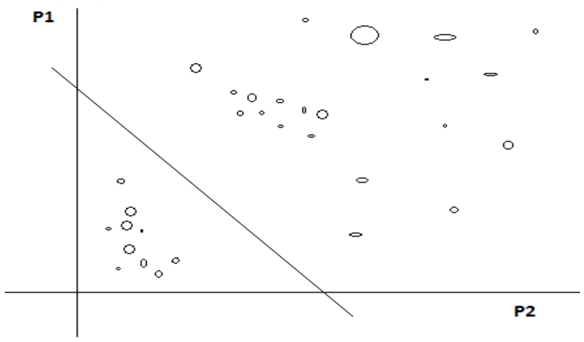

Fig.4. Regression Analysis for initial iteration

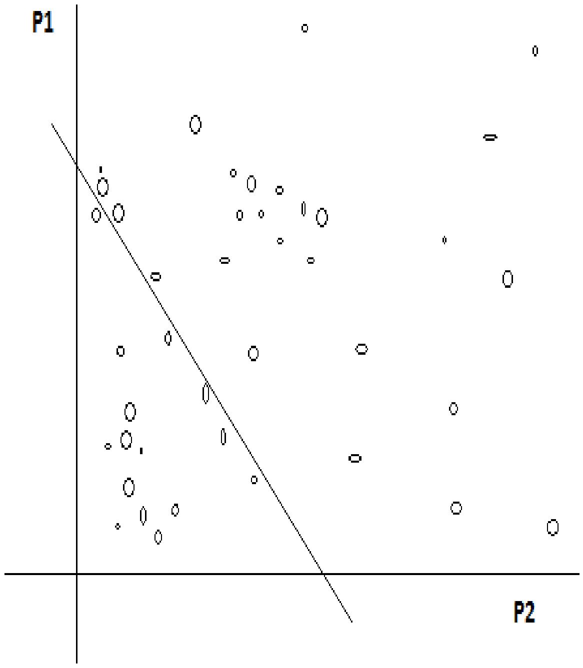

Fig.5. Regression Analysis for 12th iteration

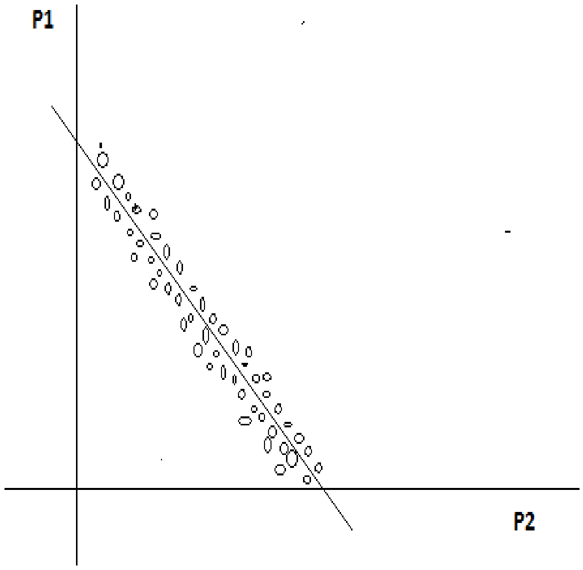

Fig.6. Regression Analysis for 39th iteration

Fig.4,5,6 shows the regression analysis of 2 generating units using PSO for checking the tolerance limit. It is observed that during iteration generating units are so much diverging in nature.

As iteration level increases generating units are approaching to each other towards regression line. But at the end of 39th iteration clustering of all generating units are very close to each other as shown in Fig.6 which shows the converging nature in acceptable range.

V. CONCLUSION

This paper shows the optimum load planning of two generating units feeding load of 200 MW using particle swarm optimization (PSO). Under process PSO system consisting of different generating units is converging after attaining the particular iteration. It is found that Thermal generating units gives the better output using PSO in comparison to conventional method in terms of better tolerance band. The Application of PSO makes the system more converging, reliable and efficient for selecting the different generating units to satisfy load demand of 200 MW

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