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OPTIMAL POWER SYSTEM USING PSO TECHNIQUE

Ram Kumar*, MdIrfan Ahmed & Rizwan Ahmed*****

* Assistant Professor, Department of Electrical Engineering, Sityog Institute of Technology, Aurangabad, Bihar, India

** Assistant Professor (HOD), Department of Electrical Engineering, Sityog Institute of Technology, Aurangabad, Bihar, India

*** Junior Engineer, Department of Electrical Engineering, Vinoba Bhave University, Hazaribagh, Jharkhand, India

Abstract:

Now days, the major issue all over the world is power crisis. The production is not so enough to fulfil the demands of power by consumers. Under this condition, the total generating cost is minimized by economic load dispatch (ELD). This work shows the optimal system operation using Particle Swarm Optimization (PSO) technique. Various optimization tools which include Genetic Algorithm (GA), lambda iteration have been used for achieving the optimal system operation. Here cost and Losses is minimized using PSO technique. This algorithm attempts to find most probable solution for minimization problems. This method is tested on 3 unit systems.

Index Terms: Economic Load Dispatch Programming (ELDP), Economic Load Dispatch (ELD), Particle Swarm Optimization (PSO) & Genetic Algorithm (GA)

1. Introduction:

In the present scenario, the standard of living in a society is measured by the amount of energy consumed. Also the sizes of electric power systems are increasing rapidly to fulfil the energy requirements. Optimal Power system is the base of power system analysis and design. Power systems need to be operated economically to make electrical energy cost-effective to the consumer in the face of constantly rising prices of fuel, wages, salaries, etc. With the development of the grid systems, it becomes necessary to operate the plant units most economically new generator- turbine units added to steam power plant operate more efficiently than other older units. In the operation of power systems, the contribution from each load and from each unit within a plant must be such that the cost of electrical energy produced is a minimum [6].

For optimal operation of system the main problem is to find the generation of different units so that the total cost is minimum. The term scheduling is the process of allocation of generation among different generation units. Economic scheduling of generators aims to guarantee at all times the optimum combination of generators connected to the system to supply the load demand. This can also be termed as an economic dispatch.

The main aim of the ELD is to reduce the cost of generation. A various types of optimization techniques have been used in order to reduce the cost of plants to get maximum output from the plant and considering less loss across the whole system. The various techniques to solving ELDP using the conventional method in order to reduce the cost like Lagrange method, steepest descent method, piecewise linear cost functions and many more. But the problem remain is that all the conventional methods are for the linear cost functions. Virtually the I/P and O/P characteristics of this ELDP are non-convex, non-smooth and also it is discrete in nature. Therefore it becomes difficult to solve these problems using the conventional methods. That's why new approach like PSO is used to solve these problems in a best way and frequently attain fast and close to global best possible solution. The PSO method can produce good superiority of solutions inside a shorter computation time and steady convergence characteristics. Here, PSO is projected as methodology for solving ELD Problems [7].

1.1 Objective of the Work:

The main aim of this paper is to find solution of economic load dispatch problem for optimal operation of system. With this scheduling, the total fuel cost is minimized while satisfying all the power generation limits using the optimization PSO technique.

2. Economic Load Dispatch:

The Economic Load Dispatch (ELD) is the process in which generating levels of generating unit is allocated so that the power is supplied most economically. It is necessary to reduce the cost for interconnected system. The production level of each plant is defined by Economic Load Dispatch so that the total price of generation and transmission is reduced for the schedule of load. The aim of Economic Load Dispatch is to minimize the generating cost [5]. These methods in generating unit also focus on minimizing the fuel cost.

There are various techniques to solve the ELDP using lambda iteration, neural network, GA but here we can solve by using PSO technique so the total cost is minimized using this technique. The optimization problem can be therefore be stated as

$$\text{Minimize:} \qquad F(P_{gi}) = \sum_{i=1}^{NG} F_i(P_{gi})$$

2.1 Equality Constraints:

The energy balance equation

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

2.2 Inequality Constraints:

The inequality constraints

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max} \qquad (i=1, 2,\ldots\ldots\ldots\ldots, NG)$$

Where

P_{gi} is the decision variable, i.e. real power generation at bus i

P_D is the real power demand

Ng is the number of generation plants

P_{gi}^{min} is the lower permissible limit of real power generation

P_{gi}^{max} is the upper permissible limit of real power generation

$F_i(P_{gi})$ is the operating fuel cost of the i^{th} plant and is given by the quadratic equation

$F_i(P_{gi}) = a_iP_{gi}^2 + b_iP_{gi} + c_i$ Rs/hr

3. Particle Swarm Optimization:

PSO is a technique whose algorithm for the solution of the problem is based on population. This technique was used for the analysis of the behavior of biological species like birds and fishes for the action of their searching food. But now this technique is used for the analysis of practical problem related to the voltage stability, ELDP, bidding etc. In PSO, section of two things is very necessary. These are particles and fitness function. The position of the particles is chosen randomly. These particles attained the optimized position by taking the information from their neighborhood. They also use self-intelligence to approach the optimum position. The Optimum position corresponding to the minimized or maximized objective function is one of the solutions of the problem [3].

To understand the PSO approach, let us take an example. Suppose the following scenario: A flock of birds searching for the food which is located at a minimum distance from their home. The whole flocks of birds are divided into small number of groups and then starts searching. In the process of searching, all small groups share their knowledge to each other. Hence if there is any one of the group that is searching the best position of food then all the remaining groups starts moving towards the best position by its own intelligence and the intelligence of the neighbourhood. In such a manner after doing number of iterations they can achieve the optimum position of the food location [1].

4. Problem Formulation:

In PSO, after every iteration, particles are updated with the two best values that it has obtained. First value that it has attained so far it is called as the p-best value which is the best solution [4]. The second best value is called g-best value or the global best value after the PSO has attained in a proper population. The p-best value is also called as the local best value. The velocity and position update is done after finding the two best values are given in equations below:

$V_i^{(u+1)} = W * V_i^{(u)} + C_1 * rand() * (pbest_i - p_i^{(u)}) + C_2 * rand() * (gbest_i - p_i^{(u)})$

$P_i^{(u+1)} = p_i^{(u)} + V_i^{(u+1)}$

In the above equations,

The term $rand() * (pbest_i - p_i^{(u)})$ is called particle memory influence.

The term $rand() * (gbest_i - p_i^{(u)})$ is called swarm influence.

$V_i^{(u)}$ which is the velocity of i^{th} particle at iteration 'u' must lei in the range.

$V_{min} \leq V_i(u) \leq V_{max}$

- The term V_{max} determines the resolution, or fitness, with which regions are to be searched between the present position and the target position.
- If V_{max} is too high, particles may fly past good solutions. If V_{min} is too small, particles may not explore sufficiently beyond local solutions.
- In many experiences with PSO, V_{max} was often set at 10- 20% of the dynamic range on each dimension.
- The constants C_1 and C_2 pull each particle toward p-best and g-best positions.
- Low values allow particles to roar far from target regions before being tugged back. On the other hand, high values results in abrupt movement towards, or past, target regions.
- The acceleration constants C_1 and C_2 are often set to be 2.0 according to past experiences.
- Suitable selection of inertia weight 'w' provides a balance between global and local explorations, thus requiring less iteration on average to find a sufficiently optimal solution.
- In general, the inertia weight w is set according to the following equation,

$$W = W_{max} - \left[\frac{W_{max-} W_{min}}{ITER_{max}} \right] * ITER$$

Where,

W = inertia weighting factor

W_{max} = Maximum value of Weighting factor

W_{min} = Minimum value of Weighting factor

$ITER_{max}$ = Maximum number of iterations

ITER = Current number of iteration

4.1 ELD with Losses Using PSO:

When the losses are considered the optimization process becomes little bit complicated. Since the losses are dependent on the power generated of the each unit, in each generation the loss changes, the p- loss can be found out by using the equation

$$P_L = \sum_m \sum_n P_m B_{mn} P_n$$

Where, B_{mn} are the losses coefficients. The loss coefficients can be calculated from the load flow equations or it may be given in the problem. However in this work for simplicity the loss coefficient are given which are the approximate one. Some parts are neglected [2].

The sequential steps to find the optimum solution are

1. The power of each unit, velocity of particles, is randomly generated which must be in the maximum and minimum limit. These initial individuals must be feasible candidate solutions that satisfy the practical operation constraints.
2. Each set of solution in the space should satisfy the following equation

$$\sum_{i=1}^{N} P_i = P_D + P_L$$

P_L is calculated by using the above equation. Then equality constraints are checked. If any combination doesn't satisfy then they are set according to power balance equation.

$$P_d = P_D + P_L - \sum_{\substack{i=1 \\ i \neq d}}^{N} P_i$$

3. The evaluation function of each individual P_{gi} is calculated in the population using the evaluation function F. Here F is

$$F = a\,(P_i)^2 + b\,(P_i) + c$$

Where a, b, c are constants. The present value is set as the p-best value.

4. Two of the best p-best values are compared among themselves and the best one is given as the g-best value.
5. The member velocity v of each individual P_g is modified according to the velocity update equation

$$V_{id}^{(u+1)} = W * V_{id}^{(u)} + C_1 * \text{rand}(\,) * (pbest_{id} - p_{id}^{(u)}) + C_2 * \text{rand}(\,) * (gbest_{id} - p_{id}^{(u)})$$

Where, u denotes the no. of iterations.

6. The velocity components constraints occurring in the limits from the following conditions are checked

$$V_d^{min} = -0.5 * P_{min}$$
$$V_d^{max} = +0.5 * P_{max}$$

7. The position of each individual P_i is modified according to the position update equation

$$P_{id}^{(u+1)} = P_{id}^{(u)} + V_{id}^{(u+1)}$$

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 g-best, the value is set to be g-best.
9. Go to step 10, if the number of iterations reaches maximum else go to step 2
10. The individual that generates the latest g-best is the optimal power of each unit with the minimum total generation cost.

4.2 Flow Chart of PSO:

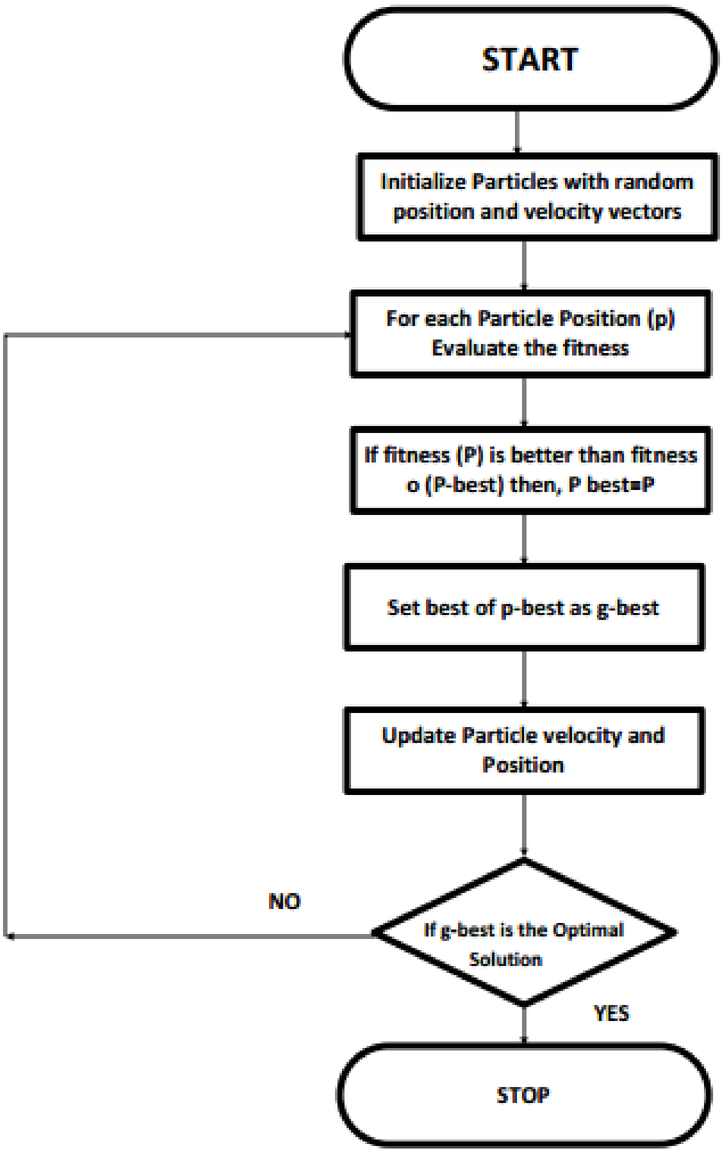

Figure 1: Flow Chart of PSO

5. Results:

The Optimal Generation at each node is formulated by using the ELD. In first stage determine the Optimal Generation at each unit using Lambda-Iteration and PSO technique and in the next stage losses and total generation cost is determined using Lambda-Iteration and PSO technique. This method is tested on 3 unit system.

PSO parameters that have been used here to solve the problems of three generating units are as follow:

Epochs between updating display = 100
Maximum no. of iterations = 100000
Population size = 100
Acceleration constant, C1=2
Acceleration constant, C2=2
Initial inertia weight = 0.9
Final inertia weight = 0.4

Epoch when inertia weight at final value = 1500
Error gradient = 1e - 6
Cost Functions of three generating units are given below: -
$F_1 = 200 + 7.0P_1 + 0.008P_1^2$ $/Hour
$F_2 = 180 + 6.3P_2 + 0.009P_2^2$ $/Hour
$F_3 = 140 + 6.8P_3 + 0.007P_3^2$ $/Hour
Generator coefficients are
$10 \text{ MW} \le P_1 \le 85\text{MW}$
$10 \text{ MW} \le P_2 \le 80 \text{ MW}$
$10 \text{ MW} \le P_3 \le 70\text{MW}$
The transmission loss coefficient matrix is:

$$B_{ij} = 10^{-4} * \begin{bmatrix} 2.18 & 0.93 & 0.28 \\ 0.93 & 2.28 & 0.17 \\ 0.28 & 0.17 & 1.79 \end{bmatrix}$$

Output Power generation for a load demand of 150 MW with all the two methods for each generator is given below in the Table I

TABLE I. OUTPUT POWER GENRATION

UNITS	Lambda-Iteration	PSO
P_1	35.0908	36.9586
P_2	64.1319	65.0228
P_3	52.4768	54.2606

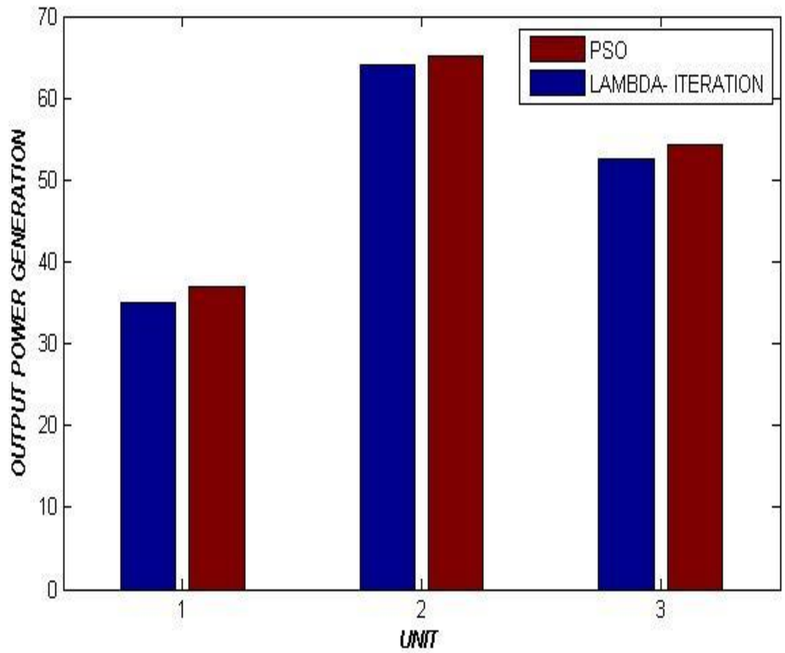

Figure 2: Output Power Generation of 3 units

Demand(P_d)	Losses (MW)		Cost($/Hour)	
	LAMBDA-ITERATION	PSO	LAMBDA-ITERATION	PSO
150 MW	2.3376	2.3008	1598.7	1597.13

TABLE II. COMPARISON RESULTS OF VARIOUS METHOD

6. Conclusions:

The Optimal Generation at each node is formulated by using the ELD. In first stage determine the Optimal Generation at each unit using Lambda-Iteration and PSO technique and in the next stage losses and total generation cost is determined using Lambda-Iteration and PSO technique. This method is tested on 3 unit system. Hence output power generation is more in PSO technique in comparison to Lambda-iteration technique. While Losses is reduced more in PSO in comparison to Lambda-iteration also, cost is reduced more in PSO.

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