The International Journal Of Engineering And Science (IJES)
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805
Pages || 94-100 || 2014 ||

Particle Swarm Optimization to solve Economic Dispatch considering Generator Constraints

[1,]M Vijay Karthik , [2,]Dr A Srinivasula Reddy
[1,]Department of Electronics & Communication Engineering, CMR Engineering College
Email: mvk291085@gmail.com
[2,]Department of Electronics & Communication Engineering, CMR Engineering College
Email: svas_a@yahoo.com

--ABSTRACT--
As we know that electrical energy plays a major role in day to day human life. It is not possible to imagine human life without electrical energy. This is because of the storage problem i.e. the electrical energy cannot be strong but is generated from natural sources and delivered as demand arises. An electrical engineer always tries to generate, transmit, and distribute the electrical energy at affordable cost while satisfying the constraints. Economic Dispatch is the process of allocation of optimal load to each committed generators while satisfying the equality and inequality constraints. The objective is to minimize the fuel cost by maintaining the generation power in limits and to reduce the computational time. The Economic Dispatch(ED) has been frequently solved by using classical optimization methods. In this proposed method the ED problem is formulated and solved by Particle Swarm Optimization technique. Three case studies are carried out on 6-unit and 15-unit systems. The solution is developed using MATLAB. Cost Generation is taken as an objective function and it is compared with the results of Genetic Algorithm (GA).

KEYWORDS *:Cost Function, Economic Dispatch, Power Loss, Objective function, Particle Swarm Optimization, Constraints.*

I. INTRODUCTION

Power system operation and planning involves the study of several problems like load flows, Economic Dispatch, Unit Commitment, Reactive Power Control, Power System Stability and Relay Coordination. Among these problems ED and UC are broadly classified as optimization problems and are ranked high among the major tasks in power system operation and planning. Several researchers in the past have attempted to solve these problems by conventional optimization techniques such as Lambda iteration, Gradient method, Newton and Heuristic methods. The ED has been usually considered as the minimization of an objective function representing the generation cost. The constraints involved are physical laws governing the power generation – transmission systems and operating limitation of the equipment.

In the past to solve ED problems various mathematical programming methods and optimization techniques are employed. In this method for solution of ED problems an essential assumption is that the incremental cost curves of the units are monotonically increasing piece wise linear functions. Unfortunately this assumption may give rise these methods infeasible because of its non linear characteristics in practical systems. F.N. Lee [1] addresses the solution of ED using Dynamic Programming (DP) method. But it causes dimensions of the ED problem to become extremely large, thus requiring huge computational efforts. C.T. Su [2] gave solution of ED using Hopfield neural Networks, this method begins with piece wise quadratic fuel cost functions and prohibited zones constraint. However an unsuitable sigmoid cost function used in the Hopfield model may suffer from excessive numerical iterations resulting in huge calculations. P.H. Chen & H.C. Chang [3] explains the procedure to solve the ED using Genetic Algorithm. Due to its high potential for global optimization GA has received great attention in solving ED problems. Though GA methods have been employed successfully to solve complex optimization problems, recent research has identified some deficiencies in GA performance. This degradation in efficiency is apparent in applications with highly epistemic objective functions [4]. The crossover and mutation operations cannot ensure better fitness of offspring because chromosomes in the population have similar structures and their average fitness is high toward the end of the evolutionary process [5],[6]. Moreover the premature convergence of GA degrades its performance and reduces its search capability that leads to a higher probability toward obtaining a local optimum [7].

II. ECONOMIC OPERATION OF POWER SYSTEM

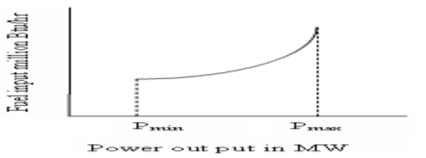
The ED formulation has a single objective function. The common objective functions are minimum cost of operation, minimum power transmission losses, minimum power transmission losses and minimum deviation from the specified point. The most common objective function to be minimized is the cost of operation, which will be our objective function as well. The objective function usually depends on variables with direct cost (power generation) and variables without direct cost (voltage magnitude). The minimum cost of generation objective function is a sum of the costs of the generators participating in the dispatch. A number of algorithms analysis programs and simulation software are available to the operators to aid their decision making process and make power system operations more economic and reliable. Depending on the relative accuracy and computational burden, these programs are used in dispatch or pre-dispatch stages. Various methods used early:

Base load method: where the next most efficient unit is loaded to its maximum capability, then the second most efficient unit is loaded and so on.

Best point loading: where units are successively loaded to their lowest heat rate point, beginning with the most efficient unit and working down to the least unit.

III. ECONOMIC DISPATCH

Economic Dispatch is the process of allocating generation levels to the generating units in mix, so that system load is supplied entirely and most economically. It is one of the important optimization problems in power system operation. The problem is a multimodal, discontinuous and highly non-linear problem due to the valve point loading, ramp limits and prohibited operating zones. Fuel cost function of generating unit is generally represented by a quadratic in terms of output power. But input and output characteristics of modern generating units are highly non-linear because of value point loading. Further they may generate multiple local minimum points in the fuel cost function. The economic dispatch problem with valve point loading is represented as a non smooth optimization problem with equality and inequality constraints, classical dispatch algorithms require these characteristics be approximated. Each generating unit consumes fuel at a specific rate in million of Btu per hour (M Btu/hr) to generate power in million of watt (MW). This rate characteristic of generating unit can be plotted as an input-output or heat power curve.



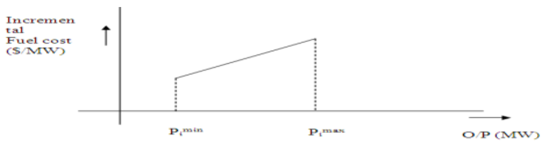


Fig1. A typical input-output curve of generating unit. Fig2. Incremental fuel cost v/s output power of generating unit.

IV. PROBLEM FORMULATION

The ED problem is a non-linear programming optimization problem. Main objective of this problem is to minimize the total fuel cost at thermal plants subjected to the operating constraints of power system. Considering fuel cost function as a quadratic function of real power generation, the ED problem can be formulated as follows:

$$F_i(P_i) = \alpha_i + \beta_i P_i + \gamma_i P_i^2 .....\$/hr \qquad (1)$$

It may be noted that in online operation of generating unit, the objective function of the ED problem has non-differential points due to valve point loading. Therefore, the objective function is composed of a set of non-smooth fuel cost functions. The fuel cost function of generating unit with valve point loading is given as:

$$F_i(P_i) = \alpha_i + \beta_i P_i + \gamma_i P_i^2 + \left| l_i \sin\left[f_i(P_i^{\min} - P_i) \right] \right| ...\$/hr \qquad (2)$$

The objective function is

$$\min F_T = \sum_{i=1}^{n_g} F_i(P_i) \qquad (3)$$

Objective Function: Main objective of the economic dispatch problem is to determine the optimal schedule of online generating units so as to meet the power demand at minimum operating cost under various system and operating constraints. The individual costs of each generating unit are assumed to be function only of active power generation and are represented by quadratic curves of second order. The objective function is given in equation (4).

$$\min F_T = \sum_{i=1}^{n_g} F_i(P_i) = \alpha_i + \beta_i P_i + \gamma_i P_i^2 \ldots\$/hr \qquad (4)$$

Constraints: The set of constraints can be divided into equality constraints and inequality constraints.
Equality Constraints: While minimizing cost function, it's necessary to make sure that the generation still supplies load demand plus losses in transmission lines. Usually power flow equations are used as equality constraints.
Pi – PD – PL = 0; PL = Active Load
Qi – QD – QL = Ni = 0: QL = Reactive Load
Where Pi, Qi are real and reactive powers at scheduled generation.
PD, QD are real and reactive powers at respective load demands.
Mi, Ni are power residuals.

$$P_L = P_P = |V_p| \sum_{i=1}^{n} |Y_{pq}| |V_q| \cos(\delta_q - \delta_p + \theta_{pq}) \qquad (5)$$

$$Q_L = Q_P = -|V_p| \sum_{i=1}^{n} |Y_{pq}| |V_q| \sin(\delta_q - \delta_p + \theta_{pq}) \qquad (6)$$

Inequality Constraints: These constraints arise due to physical and operational limitations of respective units and components.
a) Generator Constraints: The KVA loading on a generator is given by $(P_i^2 + Q_i^2)^{1/2}$ and this should not exceed a pre specified value Ci because of the temperature rise condition i.e:

$$P_i^2 + Q_i^2 \leq C_i^2 \qquad (7)$$

If output power of a generator for optimum operation of the system is less than a pre specified value P_i^{min} the unit is not put on the bus bar because it is not possible to generate that low value of power from that unit. Hence the generator powers Pi cannot be outside the range stated by inequality i.e:

$$P_i^{min} \leq P_i \leq P_i^{max} \qquad (8) \qquad\qquad Q_i^{min} \leq Q_i \leq Q_i^{max} \qquad (9)$$

i) Ramp rate limits: The operational decision at the present hour may affect the operational decision at later hour due to ramp rate limits. Inequality constraints due to ramp rate limits of generating units are given as:

1. When generation increases

$$P_i - P_i^o \leq UR_i \qquad (10)$$

When generation decreases

$$P_i^o - P_i \leq DR_i \qquad (11)$$

Finally the generator constraints are modified as:

$$\max(P_i^{\min}, P_i^0 - DR_i) \leq P_i \leq \min(P_i^{\max}, P_i^0 + UR_i) \qquad (12)$$

ii) Prohibited operating zones: Prohibited operating zones in the fuel cost either due to vibrations in the shaft bearing caused by steam valve or due to the associated auxiliary equipment such as boiler and feed pumps. The best economy is achieved by avoiding operation of generating units in these areas.
b) Voltage constraints: It is essential that the voltage magnitudes and phase angles at various nodes should vary within certain limits. The normal operating angle of transmission line lies between 30 to 45 degrees for transient stability reasons.

V. PARTICLE SWARM OPTIMIZATON

Particle Swarm Optimization (PSO) is a population based stochastic algorithm for solving various problems. It is a kind of swarm intelligence that is based on social psychological principles and provides insight into social behavior. In PSO, the potential solutions called particles fly through the problem space by following current optimum particles. The swarm is typically modeled by particles in multi dimensional space that have a position and velocity. Each particle represents a candidate solution to the problem and particles change their positions by flying around in a multi dimensional search space until computational limitations are exceeded. During the flight each particle adjusts its position according to its own experience and the neighboring particles, making use of the best position encountered by it and its neighbors. In a minimization optimization problem valve is become best particle. Members of a swarm communicate good positions to each other and adjust their own position and velocity based on these good positions.Velocity of a particle is influenced by three components, namely inertial, cognitive and social. The inertial component simulates the inertial behavior of the bird to fly in the previous direction. The cognitive component models the memory of the bud about its previous best position and the social component models the memory of the bird about the best position among the particles (interaction inside the swarm). The particles move around the multi dimensional search until they find the food (optimal solution).

VI. ALGORITHM OF PSO FOR SOLVING ECONOMIC DISPATCH PROBLEM

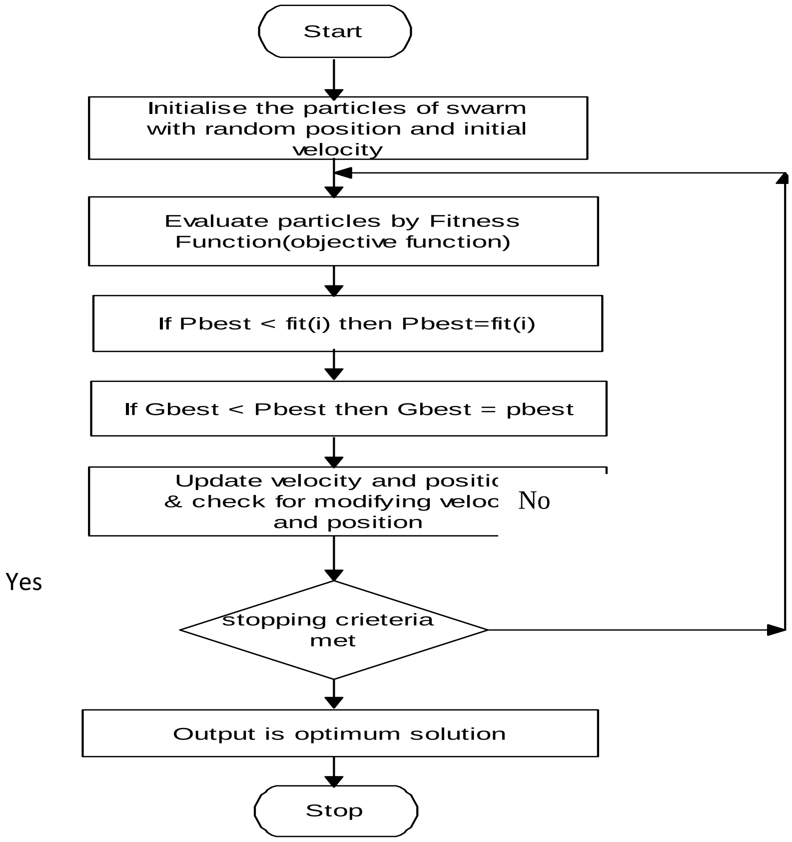


Fig3: Flowchart of PSO for ED problem.

VII. RESULTS

15 unit system: The system contains 15 thermal units. The load demand of the system is 2630MW.

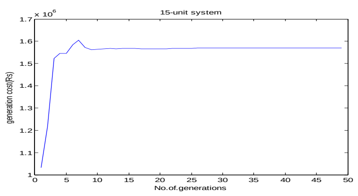


Figure4: Generation cost curve for generators 15 unit system.

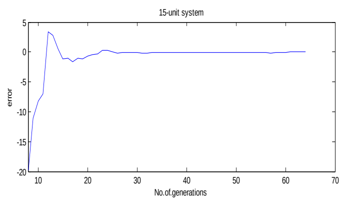


Figure 5: Error curve of a 15 unit system.

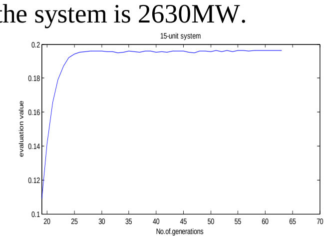
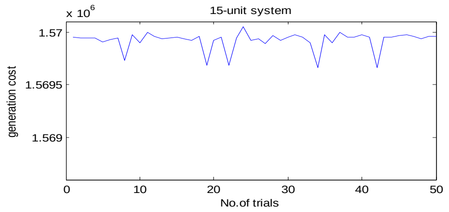


Figure 6 Evaluation Vs no. of Of a 15 unit system.



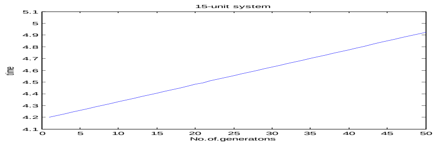


Figure 7: Generation cost curve for

Figure 8: Computation timecurve 15 unit system for 50 trials

6-unit system: The system contains 6 thermal units. The load demand of system is 1263MW.

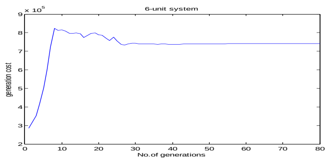


Figure 9: Generation cost curve no. of 6-unit system.

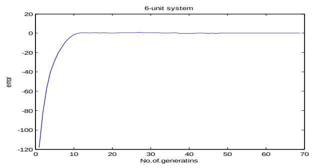


Figure 10: Error curve of 6-unit system.

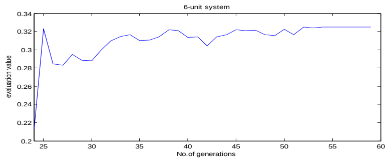


Figure 11: Evaluation value Vs generations for 6-unit system.

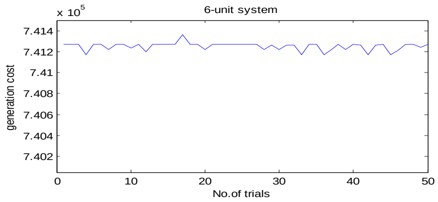


Figure12: Generation cost curve of a 6-unit system

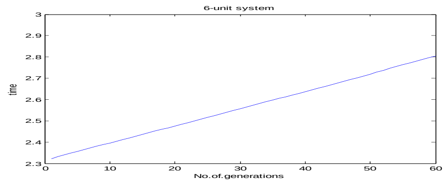


Figure 13: Computation curve of 6-unit system.

PARAMETER	WITH PSO	WITH GA
Total Generation Cost (Rs/hr)	15,69,945	15,89,424
Total Power losses (MW)	29.3761	38.2782
Execution Time (sec)	4.982	9.186

Table 1: Total Generation cost and execution

Unit	P_i^{min}	P_i^{max}	$\alpha_i(\$)$	$\beta_i(\$/MW)$	$\gamma_i(\$/MW^2)$
1	150	455	671	10.1	0.000299
2	150	455	574	10.2	0.000183
3	20	130	374	8.8	0.001126
4	20	130	374	8.8	0.001126
5	150	470	461	10.4	0.000205
6	135	460	630	10.1	0.000301
7	135	465	548	9.8	0.000364
8	60	300	227	11.2	0.000338
9	25	162	173	11.2	0.000807
10	25	160	175	10.7	0.001203
11	20	80	186	10.2	0.003586
12	20	80	230	9.9	0.005513
13	25	85	225	13.1	0.000371
14	15	55	309	12.1	0.001929
15	15	55	323	12.4	0.004447

Table 2: Total generation cost, power losses and execution time for 15-unit system.

Unit power output	**WITH PSO**	**WITH GA**
P1(MW)	455.0000	415.3108
P2(MW)	380.0000	359.7206
P3(MW)	130.0000	104.4250
P4(MW)	130.0000	74.9853
P5(MW)	170.0000	380.2844
P6(MW)	460.0000	426.7902
P7(MW)	430.0000	341.3164
P8(MW)	60.0000	124.7867
P9(MW)	56.1657	133.1445
P10(MW)	160.0000	89.2567
P11(MW)	80.0000	60.0572
P12(MW)	80.0000	49.9998
P13(MW)	25.0000	38.7713
P14(MW)	15.0000	41.9425
P15(MW)	27.8125	22.6445
Total(MW)	2659.3	2668.4

Table 3 Total generator power and generated powers of each unit of 15-unit system

Method	Generation cost (Rs)			Evaluation Value			Avg CPU time (sec)
	Max	Min	Avg	Max	Min	Avg	
PSO	15,70,075	15,69,683	15,69,915	0.1964	0.1932	0.1928	4.982
GA	16,00,176	15,89,424	15,94,944	0.4738	0.4089	0.4325	9.856

Table 4: Results of PSO running after 50 trials for 15 unit system.

PARAMETER	**WITH PSO**	**WITH GA**
Total Generation Cost (Rs/hr)	7,41,267	7,42,032
Total Power losses (MW)	12.449	13.0217
Execution Time (sec)	2.806	5.325

Table 5: Total generated power and individual generated powers of each unit in 6-unit system

Unit	P_i^{min}	P_i^{max}	$\alpha_i(\$)$	$\beta_i(\$/MW)$	$\gamma_i(\$/MW^2)$
1	100	500	240	7.0	0.0070
2	50	200	200	10.0	0.0095
3	80	300	220	8.5	0.0090
4	50	150	200	11.0	0.0090
5	50	200	220	10.5	0.0080
6	50	120	190	12.0	0.0075

Table 6: Generator power limits and cost parameters 6-unit system.

Unit power output	WITH PSO	WITH GA
P1(MW)	447.3990	474.8066
P2(MW)	173.2408	178.6363
P3(MW)	263.3815	262.2089
P4(MW)	138.9796	134.2826
P5(MW)	165.3917	151.9039
P6(MW)	87.0515	74.1812
Total(MW)	1275.444	1276.03

Table7: Total generated power and individual generated powers of 6-unit system

Method	Generation cost (Rs)			Evaluation Value			Avg CPU Time (sec)
	Max	Min	Avg	Max	Min	Avg	
PSO	7,41,302	7,41,168	7,41,170	0.3251	0.3233	0.3248	2.806
GA	7,45,152	7,42,032	7,42,512	0.3609	0.1602	0.248	5.325

Table 8: Results of PSO running after 5 trials on 6-unit system.

VII. RESULTS

In this work, ED has been solved by using PSO method. The effectiveness of the proposed method has been explained with 15-unit and 6-unit systems. Many non-linear characteristics of generator are considered for practical generator operation in the proposed method. and the results are compared with GA. From the case studies, it has been observed that there is a reduction in Total generation cost, total real power loss and execution time for proposed method compared to GA. Here PSO shows better solution quality, better convergence characteristics and better computation efficiency than GA.

REFERENCES

[1] F.N. Lee and A.M. Breipohl, "reserve constrained economic dispatch with prohibited operating zones", IEEE transactions on Power Systems, vol. 8 pp 246-254, Feb 1993.

[2] C.T. Su and G.J Chiou, " A fast computation Hopfield method to economic dispatch of power systems". IEEE transactions, Power System vol. 12, pp 1759-1764, Nov 1997.

[3] T. Yalcinoz and M.J. Short, "Neural Networks approach for solving economic dispatch problem with transmission capacity constraints:, IEEE transaction Power Systems, vol.13 pp. 307-313, May 1998.

[4] B.H. Choudary and saifur rehaman " A review of recent advances in economic dispatch" IEEE transactions, power system, vol 5, pp 1248-1259, Nov 1990.

[5] D.B. Chen and H.C.Cheng "Large scale economic dispatch by geneti algorithm", IEEE transaction, power system, Vol 10, pp 1919-1926, Nov 1995.

[6] R.C Elbert and Y.Shi "Comparision between genetic algorithm and PSO", IEEE conference, Evol,Comput, pp 611-616,May 1998.

[7] T.yalcionoz, H. Altun and M. Uzam "Economic dispatch solution using genetic algorithm based on arithmetic crossover", in Proc IEEE oroto power technology, conference,Proto, Portuugal, Sept 2001.