International Journal of Current Trends in Engineering & Technology
Volume: I, Issue: VII (Nov. - Dec. 2015)

ECONOMIC LOAD DISPATCH USING PARTICLE SWARM OPTIMIZATION

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Abstract: The efficient optimal economic operation and planning of electric power generating system has always occupied an important position in the electric power industry. With large interconnection of the electric networks, energy crisis in the world, continuous rise in fossil fuel and tariff structure necessitates the optimal operation of committed power generating units. A small saving in the operation of generating system results a significant reduction in operating cost as well as in the quantities of fuel consumed. The classic problem is the economic load dispatch of generating systems to achieve minimum operating cost. In this work PSO is applied to find out the minimum cost for different power demand which is finally compared with the results. Data was taken from the published work in which loss coefficients are also given with the max-min power limit and cost function. The technique will be implemented in MATLAB software. Results obtained are better as compared to the previous work in the literature.

Key Words: ELD (Economic Load Dispatch), PSO (particle swarm optimization), Constraints.

1. INTRODUCTION

The need of power is increasing day by day, and to fulfill its demand many various kind of power generation and efficient techniques are implemented. Currently the power industry is facing the challenges and much striation for operation as its constraints. Due to energy crises the price of energy is rising so the main concerned for the power engineers is the cost of products and its services, the planning and operation of electric power generation. The economic load dispatch (ELD) is one of the most important problems in the operation and planning of power system just as functions like unit commitment, Load Forecasting, Available Transfer Capability (ATC) calculation, Security Analysis, Scheduling of fuel purchase etc. the main objective of ELD is to determine the optimal combination of power output of all generating units so that the required load demand should be fulfill in minimum cost as well as satisfying all equality and inequality constraints. A bibliographical inspection on Economic Load Dispatch methods reveals that number of numerical optimization techniques have been employed to approach the ELD problem. A bibliographical inspection on Economic Load Dispatch methods reveals that number of numerical optimization techniques have been employed to approach the ELD problem. The equation of cost function of each generator is approximately represented by a single quadratic function and it is traditionally solved by using mathematical programming based on optimization techniques such as lambda iteration, gradient method and so on. However many mathematical assumptions such as convex, differential and constraints are required to simplify the problem. Economic load dispatch with piecewise linear cost functions is a highly heuristic, approximate and extremely fast form of economic dispatch. Recently a wide variety of optimization techniques are implemented for solving ELD. Some of the techniques are based on classical optimization methods, while others are based on artificial intelligence methods. The classical optimization methods are highly sensitive to staring points and often converge to local optimum or diverge altogether. The dynamic programming has no limitations on the mature of curves. It can generate global solutions even for the nonlinear and discrete cost curves of generation units. However the later have a drawback of curse of dimensionality that worsens for large scale problems, resulting to extremely high computation time.

Later on, Stochastic techniques such as evolutionary programming (EP) (Yang, Yang & Huang,1996), genetic algorithms (GA) (Walter & Sheble, 1993), improved tabu search (Lin, Cheng, & Tsay, 2002), Clonal algorithm (Panigrahi, Yadav, Agarwal & Tiwari,2007) are being used to find global solution or near to global solution.

B. Mohammadi Ivatloo et.al presents a novel heuristic algorithm for solving economic dispatch (ED) problems, by employing iteration particle swarm optimization with time varying acceleration coefficients (IPSO-TVAC) method, Including valve-points and prohibited operation zones (POZs) in the generating units cost functions. G. Baskar et. al proposed a new technique is proposed known as Improved Particle Swarm Optimization (IPSO) on IEEE 14 bus system and 66 bus Indian Utility system have been considered, in which a new velocity strategy equation is formulated for a large scale system and the features of constriction factor approach (CFA) is also incorporated. Chengfu Sun et. al presented a modified quantum behaved particle swarm optimization for short-term combined economic emission hydro & thermal scheduling, which is modeled as a bi-objective problem: (i) minimizing fuel cost and (ii) minimizing emission cost. Immanuel Selvakumara et. al presented a new optimization strategy, civilized swarm optimization (CSO), by integrating society-civilization algorithm (SCA) with particle swarm optimization (PSO). Jong Bae Park et. al suggests a modified PSO (MPSO) mechanism is suggested to deal with the equality and inequality constraints in the ED problem. Also a dynamic search space reduction strategy is devised to accelerate the optimization process. K.T. Chaturvedi et. al Explained that Economic dispatch (ED) is one of the key functions of the modern energy management system. The Conventional gradient based methods can be used to solve Economic Dispatch problem effectively only if the fuel cost curves of generating units are assumed to be linear, monotonically increasing in nature, otherwise these methods are likely to meet suboptimal or infeasible solutions. K. Vaisakh et. al presented a heuristic optimization methodology, namely, Bacterial foraging algorithm by integrating Bacterial Foraging Optimization Algorithm technique (BFOA), Particle Swarm Optimization (PSO) and Differential Evolution (DE) were used for solving non-smooth non-convex Dynamic Economic Dispatch problem.

2. ECONOMIC LOAD DISPATCH

The Economic Load dispatch (ELD) is defined as the process of allocating generation level to the generating unit, so that the system load is supplied fully and economically. In a typical power system, multiple generators are implemented to provide sufficient total output to suit a given total consumer demand. Each of the generating stations has a unique cost / hr characteristic for its output operating range. The station has incremental operating costs for fuel and maintenance and fixed costs associated with the station. In practical power system the power plants are not located at the equal distance from the loads and there fuel costs are also different. Under normal operating the generation operating is more than the total load demand and losses. Then it is necessary to maintain the real and reactive power programming of every station in such a way so as to minimize the operating cost.

A. Economic Load Dispatch without Losses

In this case the economic load dispatch problem is that when transmission losses are neglected. Thus the total demand is equal to the sum of generation. And the cost function of each plant is known. The problem is to find the real power generated with satisfying that the cost of generation should be minimum and the generation should be within minimum and maximum limit. The simplified economic load dispatch problem can be represented by quadratic function as mentioned in given equation

Minimize $$F_T=\sum_{i=1}^{n} Fi(Pi) \quad (1)$$

Where $$F_i(P_i) = a_i + b_iP_i + c_iP_i^2 \quad (2)$$

F_T: total generating cost; F_i: cost function of i^{th} generation unit; a_i, b_i, c_i,: cost coefficient of generator i; P_i: power of generator i; n: number of generator.

B. Constraints

There are mainly two types of constraints

i) Equality constraints

ii) Inequality constraints

The inequality constraints on real power generation P1 for each generator is

$$P_i^{min} \leq P_i \leq P_i^{max} \quad (3)$$

Where P_i^{min} and P_i^{max} are the minimum and the maximum value of real power allowed at generator i .

And the total power generated should exactly match with the load demand and losses which is mathematically represented by the equation

$$\sum_{i=1}^{N} Pi = P_D + P_L \quad (4)$$

P_i is the total generated power of N units, P_D is the total load demand, P_L and are the total transmission losses.

3. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is an evolutionary computation technique developed by Kennedy and Eberhart in 1995 Particle Swarm Optimization (PSO) could be a machine intelligence technique for solving global optimization problems. The Particle Swarm Optimization was originally proposed by J. Kennedy as an emulation of the behavior of birds' swarms and fish school while searching for food. It was introduced as an optimization method. Through cooperation and competition among the population, population-based optimization approaches often can get really good results efficiently and efficaciously. In many of the population primarily based search approaches are driven by evolution as seen in nature. Four well-known examples are genetic algorithms, biological process programming, biological process methods and genetic programming. Particle swarm optimization (PSO), on the opposite hand, is driven from the simulation of social behavior. Nevertheless, they all work in the same way that is, change the population of people by applying some kinds of operators according to the fitness information obtained from the atmosphere in order that the people of the population can be expected to move towards better solution areas. Particle swarm optimization has roots in two main component methodologies. Perhaps more obvious are its links to artificial life (A-life) in general, and to fish schooling, birds flocking, and swarming theory in particular. The PSO is also related, however, to evolutionary Computation, and has ties to both genetic algorithms and evolution strategies. Particle swarm optimization comprises a real simple concept, and prototypes are implemented in a few lines of computer code. Conjointly PSO needs solely primitive mathematical operators, and is computationally cheap in terms of each memory necessities and speed. Early testing has found the implementation to be effective with many sorts of issues.

STEPS OF PSO

Understanding the conceptual basis of the PSO, the task then becomes to develop the algorithmic tools needed to implement the optimization.

- Define the Solution Space: The first step toward implementation of the PSO is to pick the parameters that need to be optimized and give them a reasonable range in which to search for the optimal solution. This requires specification of a minimum and maximum value for each dimension in an N-dimensional optimization. This is referred to as Xmin and Xmax respectively, where ranges from 1 to N. Define a Fitness Function: This important step provides the link between the optimization algorithm and the physical world. It is critical that a good function be chosen that accurately represents, in a single number, the goodness of the solution. The fitness function should exhibit a functional dependence that is relative to the importance of each characteristic being optimized. The fitness function and the solution space must be specifically developed for each optimization; the rest of the implementation, however, is independent of the physical system being optimized.
- Initialize Random Swarm Location and Velocities: To begin searching for the optimal position in the solution space, each particle begins at its own random location with a velocity that is random both in its direction and magnitude. Since its initial position is the only location encountered by each particle at the runs start, this position becomes each particle's respective P_{best}. The first G_{best}, is then selected from among these initial positions.
- Systematically Fly the Particles through the Solution Space: Each particle must then be moved through the solution space as if it were a bee in a swarm. The algorithm acts on each particle one by one, moving it by a small amount and cycling through the entire swarm.
- Evaluate the Particle's Fitness, Compare to P_{best}. G_{best}, the fitness function, using the coordinates of the particle in solution space, returns a fitness value to be assigned to the current place. Let the value is greater than the value at the respective P_{best} for that particle, or the global G_{best}, then the appropriate locations are replaced with the current location.
- Update the Particle's Velocity: The manipulation of a particle's velocity is the centre component of the entire optimization. Careful understanding of the equation used to specify the velocity is the key to understanding the optimization as a whole. The particle velocity is changed according to the relative locations of P_{best} and G_{best}. It is accelerated in the directions of these locations of greatest fitness according to the following equation:

$$V_i^{K+1} = w\, V_i^K + c_1 r_1 \left(P_{best\,i}^K - X_i^K\right) + c_2 r_2 \left(G_{best\,i}^K - X_i^K\right) \qquad (5)$$

- Move the Particle: Once the velocity has been determined it is simple to move the particle to its next location. The velocity is applied for a given time-step usually chosen to be one and new coordinate is computed for each of the dimensions according the following equation:

$$X_i^{k+1} = V_i^k + V_i^{k+1} \qquad (6)$$

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} * iter \qquad (7)$$

- The particle is then moved to the location calculated by Equation 6. The composite nature of this algorithm composed of several independent agents makes it especially conducive to implementation on parallel processors.

5. RESULT AND DISCUSSION

PSO technique has been successfully applied to determine the optimal economic load dispatch of six units generating system. The technical details of the test system are mentioned in table I. Here a total load demand of 1263 MW has been considered. The economic load dispatch program for different trials is coded in MATLAB 7.10.

Experimental setting

PSO is population based stochastic evolutionary optimization algorithm, hence results are taken at different population sizes i.e. 5, 70, 200, 300, 500 with 50 trails for each population size. Other PSO parameters adopted in present work are given below. C1= C2 = 0.01.

Table 1: Optimal cost of 6 unit test system by PSO at different trials

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
P_{g1} (MW)	499.8231	503.49	474.3905	463.733	405.6287	522.585
P_{g2} (MW)	158.4582	80.371	164.4688	154.065	148.0258	127.071
P_{g3} (MW)	262.7565	289.664	223.5395	294.18	325.2677	216.585
P_{g4} (MW)	131.74	97.1929	111.0717	111.14	107.3649	130.894
P_{g5} (MW)	83.6157	203.279	183.3942	181.55	149.1303	118.552
P_{g6} (MW)	66.9574	87.2537	94.1495	107.277	92.7211	87.2432
Total Cost ($/hr)	14571.7	15374.6	15141.34	15944.32	14872.21	14582.2

From the table1 above it has been clearly observed that population size 100 is giving minimum value i.e.14571.79 $/h Fig 6.1 to fig 6.2 shows the convergence v/s iteration for the population size of 100 and number of iterations 100.

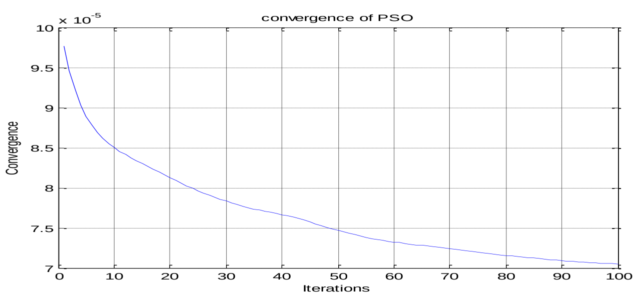

Fig.1 Convergence characteristic of PSO during trial no.1

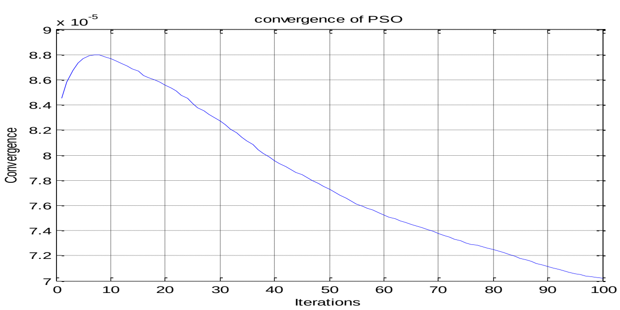

Fig.2 Convergence characteristic of PSO during trial no.2

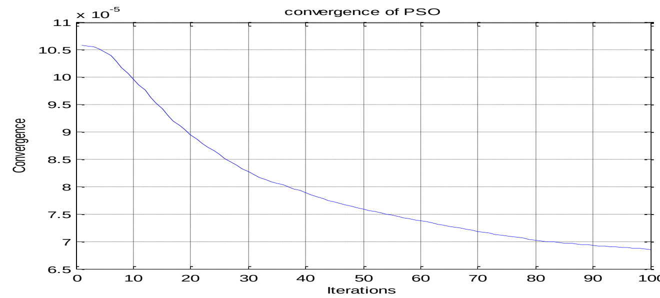

Fig.3 Convergence characteristic of PSO during trial no.3

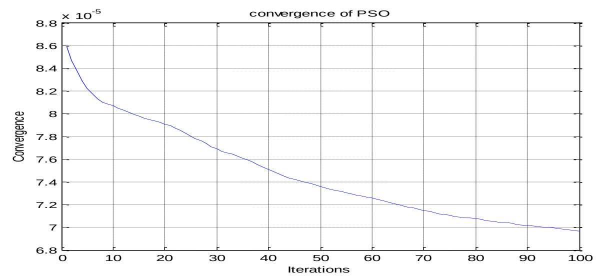

Fig.4 Convergence characteristic of PSO during trial no.4

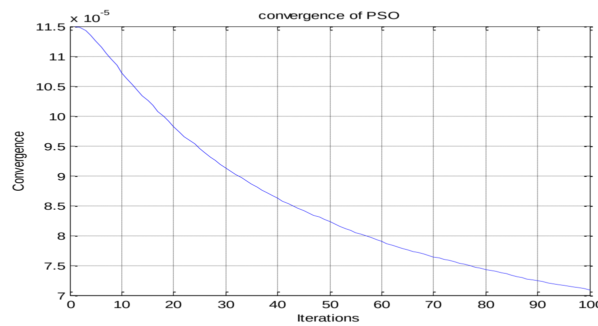

Fig.5 Convergence characteristic of PSO during trial no.5

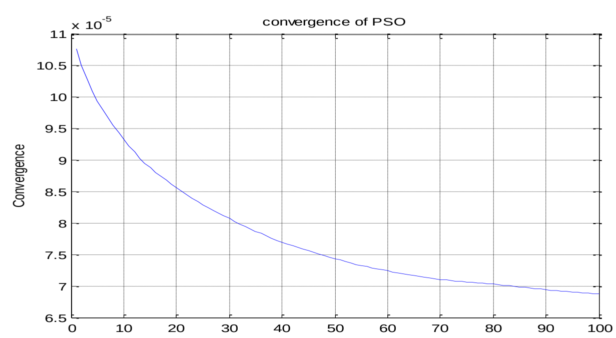

Fig.6.Convergence characteristic of PSO during trial no.6

W_{min} = 0.7, Itermax = 100. Results are simulated on MATLAB 7.10 language on Intel(R) Core(TM) i3-3110M CPU @2.40 GHz, 4.00 GB RAM.

Optimal Solution(MW)	Result Reported [39]	PSO
P_{G1}[MW]	499.9170	499.8231
P_{G2}[MW]	199.5572	158.4582
P_{G3}[MW]	299.950	262.7565
P_{G4}[MW]	162.5222	131.74
P_{G5}[MW]	199.3994	83.6157
P_{G6}[MW]	119.9644	66.9574
Total Generation[MW]	1561.8092	1203.351
Generation Cost($/hr)	15269	14571.79

6. CONCLUSION

The ELD problem assumes that the amount of power to be supplied by a given set of units is constants for a given interval of time and attempts to minimize cost of supplying this energy subject to constraints of the generating units. Therefore it is concerned with the minimization of total cost incurred in the system and constraints over the entire dispatch period. Here the economic load dispatch problem was solved for six units generating station for a total load demand of 1263 MW without considering complexity, ramp rate units and prohibited operating zones and without losses. The problem was solved by Natural exponent inertia weight strategy i.e. e1-PSO and e2-PSO with MATLAB 7.10 environment above mentioned two strategies has been successfully applied to determine the optimal generation schedule of the six unit test system. Detailed conclusions of the results are given below:

PSO is population based evolutionary optimization algorithm, hence results are taken at various population sizes i.e. 5, 70, 200, 300, 500 & it has been observed that 500 population size is giving optimal value of objective function i.e. 15275.56 $/h and 15275.55$/h for e1-PSO & e2-PSO respectively.

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