Artificial Intelligence Techniques For Optimum Allocation of Generating Units

Chinmaya Ranjan Pradhan, Soumya Ranjita Nayak

Abstract— Economic load dispatch (ELD) is a sub problem of the optimal power flow (OPF) having the objective of fuel cost minimization. The fuel cost equation of a thermal plant is generally expressed as continuous quadratic equation. In real situations the fuel cost equations can be discontinuous. Recent advancements in artificial intelligence especially in evolutionary algorithms have enabled much efficient way to solve the constrained optimization problems in various fields of engineering. In this paper we applied Particle Swarm optimization (PSO) technique to a 3-generator test system having continuous fuel cost equations. Results are compared to conventional quadratic programming method to show the superiority of the proposed computational intelligence technique.

Index Terms— Economic Load Dispatch, Fuel Cost, Particle Swarm Optimization (PSO), Quadratic Programming

1 Introduction

Economic load dispatch is defined as the process of allocating generation levels to the generating units in the mix, so that the system load is supplied entirely and most economically. Economic load dispatch (ELD) is a sub problem of the optimal power flow (OPF) having the objective of fuel cost minimization. The classical solutions for ELD problems have used equal incremental cost criterion for the loss-less system and use of penalty factors for considering the system losses. The lambda-iterative method has been used for ELD. Many other methods such as gradient methods, Newton's methods, linear and quadratic programming, etc have also been applied to the solution of ELD problems. However, all these methods are based on assumption of continuity and differentiability of cost functions. Hence, the cost functions have been approximated in the differentiable form, mostly in the quadratic form. Further, these methods also suffer on two main counts. One is their inability to provide global optimal solution and getting stuck at local optima. The second problem is handling the integer or discrete variables. In recent years, one of the most promising research fields has been "Evolutionary Techniques", an area utilizing analogies with nature or social systems. Evolutionary techniques are finding popularity within research community as design tools and problem solvers because of their versatility and ability to optimize in complex multimodal search spaces applied to non-differentiable objective functions. Several modern heuristic tools have evolved in the last two decades that facilitate solving optimization problems that were previously difficult or impossible to solve. These tools include evolutionary computation, simulated annealing, tabu search, particle swarm, etc.

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Recently, genetic algorithm (GA) and particle swarm optimization (PSO) techniques appeared as promising algorithms for handling the optimization problems. These techniques are finding popularity within research community as design tools and problem solvers because of their versatility and ability to optimize in complex multimodal search spaces applied to non-differentiable cost functions. Particle Swarm Optimization (PSO) is inspired by the ability of flocks of birds, schools of fish, and herds of animals to adapt to their environment, find rich sources of food, and avoid predators by implementing an information sharing approach. PSO technique was invented in the mid 1990s while attempting to simulate the choreographed, graceful motion of swarms of birds as part of a sociocognitive study investigating the notion of collective intelligence in biological populations. In PSO, a set of randomly generated solutions propagates in the design space towards the optimal solution over a number of iterations based on large amount of information about the design space that is assimilated and shared by all members of the swarm.

PROBLEM STATEMENT

The basic economic dispatch problem can described mathematically as a minimization of problem of minimizing the total fuel cost of all committed plants subject to the constraints.

$$\text{MinF}=\sum_{i=1}^{N}(F_i(P_i) \qquad (1)$$

Subject to the constraints

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

$$P_{imin} \le P_i \le P_{imax},\ i=1, 2...N \qquad (3)$$

Where
F = Total operating cost
N = Number of generating units
P_i = Power output of i th generating unit
F_i (P_i) = Fuel cost function of i th Generating unit
P_D = Total load demand
P_L = Total losses
$P_{i\,min}$ = Minimum out put power limit of i th generating unit

$P_{i\,max}$ = Maximum out put power limit of i th generating unit

The total fuel cost is to be minimized subject to the constraints. The transmission loss can be determined form B_{mn} coefficients. The conditions for optimality can be obtained by using Lagrangian multipliers method and Kuhn tucker conditions as follows:

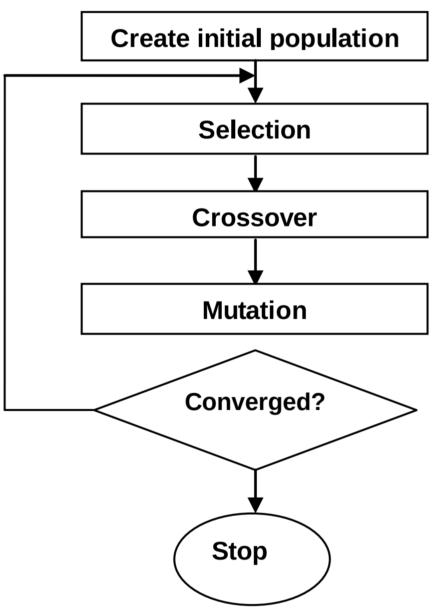
$$2a_iP_i+b_i=\lambda(1-2\sum_{J=1}^{N}(B_{ij}), i=1,2\ldots N \quad (4)$$

2. Genetic Algorithm

Genetic Algorithm (GA) was first introduced by john Holland of Michigan university in1970's.The GA is a stochastic global search method that mimics the metaphor of natural biological evolution such as selection, crossover, and mutation. The artificial principal is the Darwinians survival of fittest principal and genetic operation is abstracted from nature form a robust mechanism that is very effective at finding optimal solutions to complex real world problems.

The process of GA follows this pattern:

1) An initial population of a random solution is created.
2) Each member of the population is assigned a fitness value based on its evaluation against the current problem.
3) Solution with highest fitness value is most likely to parent new solutions during reproduction.
4) The new solution set replaces the old, a generation is completed and the process Continues at step (2).



[**GA FLOW CHART]**

3. Particle Swarm Optimization

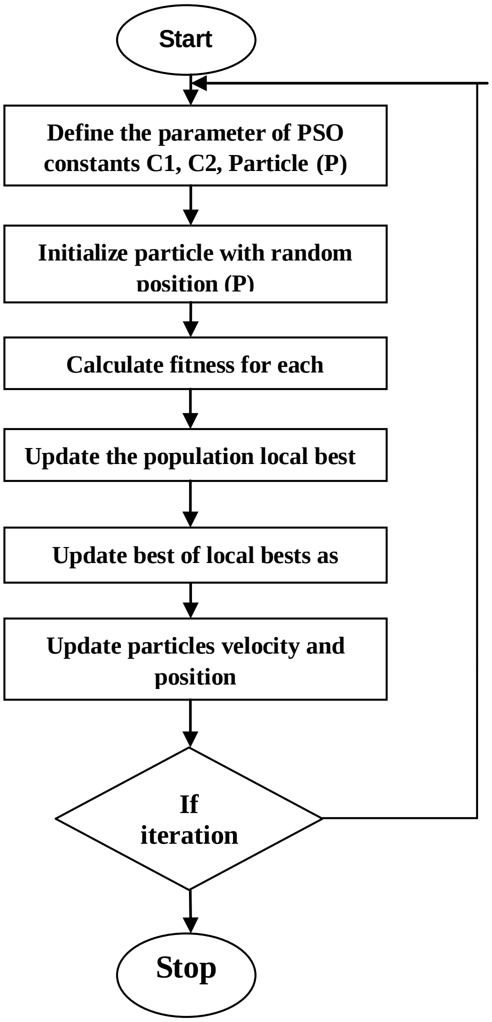
The PSO method is a member of wide category of swarm intelligence methods for solving the optimization problems. It is a population based search algorithm where each individual is referred to as particle and represents a candidate solution. Each particle in PSO flies through the search space with an adaptable velocity that is dynamically modified according to its own flying experience and also to the flying experience of the other particles. In PSO each particles strive to improve themselves by imitating traits from their successful peers. Further, each particle has a memory and hence it is capable of remembering the best position in the search space ever visited by it. The position corresponding to the best fitness is known as *pbest* and the overall best out of all the particles in the population is called *gbest.* The modified velocity and position of each particle can be calculated using the current velocity and the distances from the *pbestj,g* to *gbestg.*.

ALGORITHM FOR ECONOMIC LOAD DISPATCH USING PSO

The search procedure for calculating the optimal generation quantity of each unit is follows:

1. In the ELD problems the number of online generating units is the 'dimension' of this problem. The particles are randomly generated between the maximum and the minimum operating limits of the generators.
2. To each individual of the population calculate the dependent unit output from power balance.
3. Calculate the evaluation value of each particle p_{gi} in the population using the evaluation function.
4. Compare each particle's evaluation value with its pbest. The best evaluation value among them pbest is identified as gbest.
5. Modify the velocity of each particle.
6. Check the velocity constraint of the members of each particle from the following

   If $V_{ij}^{r+1} > V_j^{max}$, then $V_{ij}^{r+1} = V_j^{max}$
   If $V_{ij}^{r+1} < V_j^{min}$, then $V_j^{r+1} = V_j^{min}$
7. Modify the position of each particle.Pij^{r+1} must satisfy the constraint, namely the generating limits. If p_{ij}^{r+1} violate the constraints, then p_{ij}^{r+1} must be modified towards the nearest margin of feasible solution.
8. If the evaluation value of each particle is better than previous pbest, the current value is set to be pbest. If the current value is set to be pbest. If the best pbest is better than gbest, the best pbest is set to be gbest.
9. If the number of iterations reaches the maximum, then go to step 10.Otherwise, go to step2.
10. The individual that generates the latest gbest is the optimal generation power of each unit with the minimum total generation cost.



[PSO FLOW CHART]

4. Result and Discussion

CASE STUDY: 3 GENERATOR TEST SYSTEMS

The coefficient of fuel cost and maximum and minimum power limits are given in table1.The power demand is to be 850(MW).The results corresponding to GA and PSO are detailed in section 2 and 3 respectively and the comparison of results of both methods shown in table 4.

Table 1 Specification for three generator system

Unit no.	a_i	b_i	C_i	P_i^{min}	P_i^{max}
1	0.001562	7.92	561	150	600
2	0.00194	7.85	310	100	400
3	0.00482	7.97	78	50	200

Table 2: Optimal results of GA

P_1(MW)	393.0103
P_2(MW)	319.2256
P_3(MW)	137.7642
Total power	850.00
Total cost	8195.9790

Table 3: Optimal results of PSO

P_1(MW)	387.9446
P_2(MW)	340.52180
P_3(MW)	121.5336
Total power	850.0
Total cost	8194.45

Table 4: Comparison of GA and PSO

Technique	Total Cost
GA	8195.9790
PSO	8194.45

5. Conclusion

Genetic algorithm and particle swarm optimization have been successfully introduced to obtain the optimum solution of Economic Load Dispatch. Power system has large variation in load from time to time and it is not possible to have the load dispatch for every possible load demand as there is no general procedure for finding out optimum solution of economic load dispatch. This is where PSO plays an important role to find out optimum solution in a fraction of second.

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