Economic Load Dispatch Using Particle Swarm Optimization

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Abstract — Economic load dispatch (ELD) plays a very important role in the power system. Its main aim is to calculate the power generated by different generating units in a power plant such that the cost of fuel is minimum along with that the losses are also minimized. In economic dispatch of load, the sum of losses and the total power demand must me numerically equal to the total power generation. Many traditional or conventional methods like lambda iteration method, gradient method, Newton's method and intelligence methods such as particle swarm optimization, ant colony optimization, genetic algorithm are applied to find the solution having combination of output power of all generating units for meeting the desired demand within consideration of generator constraint and the solution is optimal. The Lambda iteration method and Particle Swarm optimization method have been used in this paper for solving the ELD problem for IEEE 30 bus system including transmission losses.

Index Terms —Economic Load dispatch (ELD), Fuel Cost, Lambda Iteration Method, Particle Swarm Optimization Method.

I. Introduction

Economic load dispatch [1] is an important task and necessity in power system for the allocation of optimal generation of power among the generator units at lowest possible cost such that they satisfy the system constraints and the losses are minimized. The main objective of economic dispatch of load is to minimize the cost and losses and to attain minimum disbursement of power generating station [2]. System constraint decides the generation cost which denotes that the generation cost is not fixed for a particular load demand but is dependent to the operating constraint of different sources [3-4].

Different types of optimization methods or techniques are used for solving of ELD problem, which can be classified as conventional and artificial intelligence techniques[5].Conventional or traditional[6] method includes Lambda iteration method[7],Newton's Method[8] etc. and Intelligence techniques includes Genetic Algorithm[9],Particle Swarm Optimization[10-15], Ant Colony optimization[16] and many other optimization techniques[17].

There is a comparison of Lambda iteration method and Particle Swarm optimization in this paper.

II. Formulation of ELD problem

The main task of ELD is to minimise the objective function which is cost function in this paper. Cost function is considered here as the objective function and the formulation of ELD problem is done under specific constraints.

A. Objective Function

The cost function C_i is considered as the objective function to find the of real generated power cost for each plant is given by the equation:

$$C_t = \sum_{i=1}^{ng} C_i = \sum_{i=1}^{n} \alpha_i + \beta_i P_i + \gamma_i {P_i}^2 \$/\text{hr}$$

When the power is transmitted through long and very large distances there is a huge loss of power due to different factors during transmission. These losses are termed as transmission losses. The effect due to transmission loss is also included and the total transmission loss is represented as a function of the generator power outputs. The quadratic form is given by-

$$P_l = \sum_{i=1}^{ng}\sum_{j=1}^{ng} P_i B_{ij} P_j$$

Where,

B_{ij} is loss coefficients or B-coefficient.

The allocation of loads in ELD is based upon constraints. There are two types of constraints, Equality constraints and Inequality constraints.
Both are discussed as follows-

B. Inequality Constraints

Generator constraints:

$$P_{min} \le P \le P_{max}$$

C. Equality Constraints

Equality constraints are very important for ELD.
They are very crucial for determination of the cost. The equality constraint can be given by the following equation-

$$P_d + P_l = \sum_{i=1}^{ng} P_i$$

Where
- P_i is the real power generation of i^{th} generating unit.
- P_d is the total real power demand.
- P_l is power loss in transmission.
- ng is number of generating units.

III. Optimization

The act of minimizing or maximizing a function related to any set, having a variety of choices available in any arbitrary or certain condition, is called optimization .Through comparison we can easily find out the best out of the given range or variety of choices. Some of the

applications of optimization are minimal cost, maximal profit, minimal error, optimal design and optimal management etc. Optimization can be applied to various fields.
In Electrical System it can be used to find optimal power, reduce losses, minimum cost of transmission etc.

IV. Methods of optimization

There are two methods for the optimization of our ELD problem i.e. traditional or conventional method and another method is Intelligence method. Both the methods can be used for the optimization of the system but the results differ for different algorithms.

A. Conventional Method

Conventional methods are also called traditional methods. They are Lambda Iteration Method, Newton's Method and Gradient Method .In this, we will be using one of these conventional methods as our base and that is the lambda iteration method. The advantages of traditional or conventional methods are easy implementation, simplicity etc.
But there are any drawbacks of traditional methods like-

1. The initially chosen solution determines the convergence of the problem.
2. Many of the algorithms get trapped in a sub-optimal solution.
3. These algorithms are not efficient in solving those problems which have discrete search space.

a. Lambda iteration method

Lambda iteration method is one of the traditional techniques for solving the ELD problem for minimizing the cost of generating unit. In this method only the computational process is complex but it converges very fast.
Initially assume a λ value. Then we will find out the generation from each plant using the equation

$$P_i^{(k)} = \frac{\lambda^{(k)} - \beta_i}{2(\gamma_i + B_{ii}\,\lambda^{(k)})}$$

We will calculate the power mismatch

$$\Delta P^{(k)} = P_d + P_l^{(k)} - \sum_{i=1}^{ng} P_i^{(k)}$$

Where $P_l = \sum_{i=1}^{ng} B_{ii} P_i^{2}$

Then we will calculate

$$\Delta\lambda^{(k)} = \frac{\Delta P^{((k)}}{\Sigma\left(\frac{dP_i}{d\lambda}\right)^{(k)}}$$

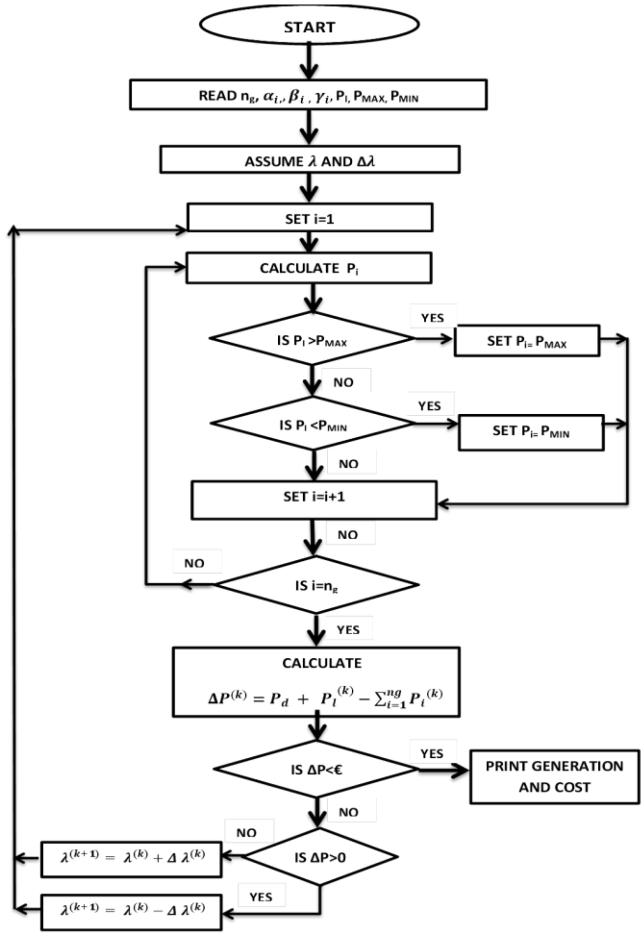
Where i=1,2,3…………ng

Then we will further update the value of λ

$$\lambda^{(k+1)} = \lambda^{(k)} + \Delta\lambda^{(k)}$$

We will repeat the procedure with new value of λ until the power mismatch is within the limit.

Flow chart for Lambda iteration method is given below-



The algorithm of lambda iteration method for ELD problem is given below:

1. Note provided data, i.e. cost coefficients (α_i, β_i, γ_i) , power limits, B-coefficients and power demand.
2. Select the starting value of Δλ and λ
3. Calculate power generated P_i for each unit.
4. Check generation limit for each unit.
5. If P_i>P_{max}, set P_i=P_{max}
6. Calculate total generated power.
7. Calculate mismatch in power which is given by following equation
   ΔP=sum(P_i)-P_d-P_l
8. If P_i<P_{min}, set P_i=P_{min}
9. If ΔP<e, then stop calculation and calculate the generation cost. Otherwise go next step.
10. If ΔP>0, then λ=λ - Δλ
11. If ΔP<0, then λ=λ +Δλ
12. Repeat the procedure from step 3.

B. Intelligence method

Many intelligent methods are used for the optimization of our ELD Problem and they are: Genetic Algorithm, Particle Swarm Optimization, and Ant Colony Optimization etc.
In this paper Particle Swarm Optimization technique is applied to solve the ELD problem for IEEE 30 bus system.

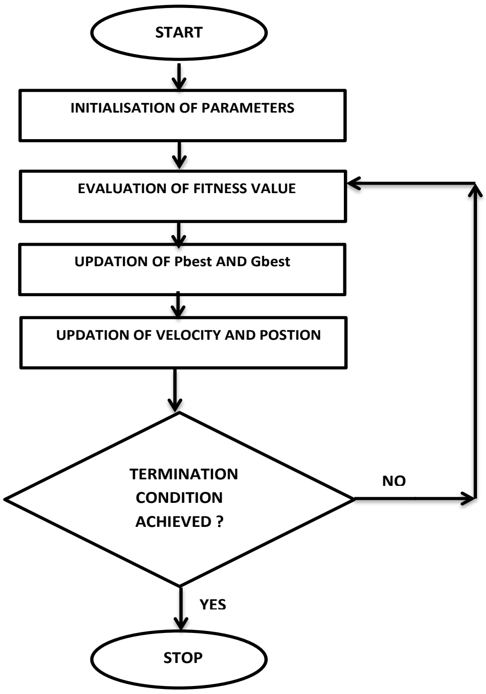
a. Particle Swarm optimization

James Kennedy and Russell C. Eberhart [9-10] first described the Particle Swarm optimization algorithm in 1995 by observing the social behavior of fish schooling or bird flocking. PSO comes under the category of artificial intelligence technique. It can be used to find the solution of highly complex and difficult minimization and maximization problems. Due to its simplicity, PSO algorithm requires comparatively less memory. In particle swarm optimization the technique, there is initialization of a population of random solutions which is called as swarm, where the particle denotes a potential solution. Information is collected by this swarm from each other from an array which is created by their position by making use of the velocity. Updation in position of the particles and the velocities of the particles take place with the help of particle's own experience and neighbour's experience. Particle moves through a search space which is multidimensional to determine the position which is best in that space. PSO is a very simple algorithm. Implementation of PSO is also easy and adjustment of a very few parameters is required.

Advantages of the basic particle swarm optimization algorithm:

1. It can be used for scientific as well as engineering purposes.
2. As PSO has no chances of overlapping and no concept of mutation so the speed becomes faster.
3. In PSO, the calculation is very simple and it can be completed easily.

Flow chart for PSO algorithm is shown below-



b. Computational Procedure of PSO

In Particle Swarm optimization, initially, a group of random particles (solutions) are initialized and then optimal solution is searched by generation up gradation. After each time interval, the particles are evaluated as per some fitness criterion. During each iteration, there is updation of each particle by two solutions. First is the best solution or best fitness achieved by the particle so far. This best value is known as Pbest i.e. Personal best. And the second one is the best value that is achieved by any particle in the population so far. This best value is called global best or Gbest.

In PSO, the particle updates its velocity and position which is given by following equations-

Velocity update equation is given by-

$$V_i^{(j+1)} = \omega * V_i^{(j)} + C1 * R1 * (Pbest_i - P_i^{(j)}) + C2 * R2 * (Gbest_i - P_i^{(j)})$$

Position update equation is given by-

$$P_i^{(j+1)} = P_i^{(j)} + V_i^{(j+1)}$$

Where,

$V_i^{(j)}$ is the velocity of individual i at iteration j,
ω is the weight parameter,
C1, C2 are the acceleration constants,
R1, R2 are random numbers between 0 and 1,
$P_i^{(j)}$ is the position of individual i at iteration j,
$Pbest_i$ is the best position of individual i
$Gbest_i$ is the best position of the group

The weight parameter is given by the following equation-

$$\omega = \omega max - \frac{\omega max}{itermax} - \frac{\omega min}{itermax} \times iter$$

Where,

ωmax is final weight
ωmin is initial weight
Itermax is maximum iteration number
Iter is current iteration number

Table 1. Parameters of PSO

Parameter	C1	C2	ωmax	ωmin	Itermax
Value	2	2	0.9	0.4	2000

V. Problem Considered

Cost Characteristics for IEEE 30 bus system-

$C_1 = 50 P_1$^2 + 245 P_1 + 105 \$/hr
$C_2 = 50 P_2$^2 + 351 P_2 + 44.4 \$/hr
C_3= 50 P_3^2 + 389 P_3 + 40.6 \$/hr

Table 2. Parameters of given ELD problem

Generating Unit	**A**	**β**	**γ**
1	0.0050	2.45	105
2	0.0050	3.51	44.4
3	0.0050	3.89	40.6

B-Coefficients Calculated are as-

B_{11} = 0.0307
B_{12} = 0.0129
B_{13} = 0.0002
B_{21} = 0.0129
B_{22} = 0.0152
B_{23} = - 0.0011
B_{31} = 0.0002
B_{32} = -0.0011
B_{33} = 0.0190

Power Demand, P_d =283.4 MW

Table 3. Generator constraints

Generating Unit	**P_{max} (MW)**	**P_{min}(MW)**
1	250	50
2	100	30

3	100	30

The above problem has been solved using both the methods i.e. Using Lambda iteration method (Traditional method) and Particle swarm optimization method (Intelligence Method).

C. Algorithm for PSO

1. Initialization of particle with any random number for each particle.
2. Calculation of the fitness value for each particle,.
3. If fitness value is better than (Pbest) in history.
   Set the current value as the new Pbest.
4. Selection of Gbest i.e. the particle with the best fitness value among all the particles.
5. Calculation of particle velocities as per velocity update equation for each particle.
6. Updation of particle position as per position update equation.
7. Iterate again ,if stopping condition is not achieved.

VI. Results and Discussion

Economic load dispatch using traditional method and the Particle swarm optimization methods are applied to IEEE 30 bus system
Table 3 and Table 4 represent the results of ELD problem using Lambda iteration method and Particle swarm optimization method (PSO) respectively.

Table 3. Result of ELD using Lambda iteration method

S.NO.	Parameter	Value
1.	Lambda(λ)	4.228
2.	P_1	158.78 MW
3.	P_2	67.46 MW
4.	P_3	50.82 MW
5.	P_L	9.64 MW
6.	C_t	1154.42 $/hr

Table 4. Result of ELD using PSO

S.NO.	Parameter	Value
1.	P_1	158.98 MW
2.	P_2	52.39 MW
3.	P_3	30.50 MW
4.	P_L	9.45 MW
5.	C_t	1152.67 $/hr

When we compare the results of optimization by Lambda iteration method and PSO, we find that the losses are reduced in case of PSO and the total cost of the system is also reduced, which proves PSO to be better than traditional method.

Particle swarm optimization provides the results with reduced cost and reduced losses thus the objective function is minimised.

VII. Conclusion

After going through the result, we can conclude that PSO is quite better optimization technique as compared to traditional method. The losses are reduced by 2 percent (approximately), and the cost is also reduced, which is a matter of benefit to the system.

Economic load dispatch is very necessary and important aspect as the requirements of power and energy is increasing day by day. So, ELD helps us to minimize the losses and reduce the cost thus making the system optimal. This paper provides the overview of economic load dispatch problems and various solution techniques. The implementation is done using MATLAB programming and results are tabulated.

Though conventional techniques like lambda iteration method get converged rapidly but as the system size is increased, complexities are also increased and there is a requirement in lambda method that the method to find the output power of a generator must be known. Trapping up in local optimal solution, does not occur in PSO. Also the results are improved in PSO as compared to Lambda iteration method i.e. losses and cost are also reduced.

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