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Economic Load Dispatch using Lambda Iteration, Particle Swarm Optimization & Genetic Algorithm

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Abstract: In economic load dispatch problem scheduling of loads is done in order to achieve reliable power supply with reduced costs. With the increase in load demand with each passing year energy crisis is increasing hence an area of study where fuel costs can be reduced was proposed. This can be achieved using various methods among which the methods discussed in this paper are Lambda Iteration, Particle Swarm Operation and Genetic Algorithm. Based on numerical results the best optimization technique can be figured out among the discussed methods.
Keywords: Lambda Iteration, PSO, GA, economic load dispatch, optimization solutions.

I. INTRODUCTION

Electrical power system is divided into sections of generation, transmission and distribution. The distribution companies or power companies then supply this power to end-users. With the increase in load demand the electrical power systems are increasing rapidly. However the rate of increase is not proportional to the demand thereby causing economic imbalances for the utilities. To operate the electrical power system economically, an area of study called economic load dispatch was proposed. In economic load dispatch the parameters that are considered include load demand, transmission power losses and generation cost coefficient. Costs such as fuel cost, maintenance, labour cost, salary of personnel, supplies etc. are considered out of which the main concern for economic operation is fuel cost. Generally, the labour cost, supplies and maintenance cost being difficult to approximate are assumed to vary in accordance with the fuel costs' fixed percentage. Traditionally the cost function in ELD problem has been approximated as a quadratic function [1].

For a particular power system the plants are present at different locations from the load centres' so their fuel cost will not be the same. Also if we consider normal operating conditions, the generating capability is less than the load demand and losses. As such scheduling of different generating units is done in accordance to the load demand in order to reduce the price of generation and supply a reliable power to end-users.

II. ECONOMIC LOAD DISPATCH

In ELD, the scheduling of loads is done between several generating units so as to reduce operating costs and increase the reliability and quality of power delivered considering the energy crisis of the current world. Economic load dispatch can be considered as an optimization problem where the main purpose is the allocation of load to generating units in order to reduce the operating costs keeping in mind the equality and inequality constraints.

The drafting of ELD problem can be done as follows:

A. *Objective Function*

The fuel cost curve of generating unit is a quadratic function in terms of real power output and can be represented as;

$$F(P_{gi}) = \sum_{i=0}^{Ng} F_i\ (P_{gi})$$

$$F(P_{gi}) = \sum_{i=0}^{Ng}(a_i P_{gi}^2 + b_i P_{gi} + c_i) \qquad (1)$$

Where,

a, b and c = generator coefficients

P_{gi} = active power output of i^{th} generator

$F_i\ (P_{gi})$ = fuel cost of i^{th} generator

Ng = number of generators

B. System Constraint

1) *Equality constraint*: According to this constraint real power of all generating units must be equal to the total real power demand on the system including losses.

$$\sum_{i=0}^{Ng} P_{gi} = P_L + P_D \qquad (2)$$

Where,

P_{gi} = active power output of i^{th} generator

P_L = Power transmission loss

P_D = total real power demand

The transmission losses can be represented by Loss coefficient method as;

$$\sum_{i=0}^{Ng} \sum_{j=0}^{Ng} P_{gi} B_{ji} P_{gj} \qquad (3)$$

Where,

P_{gi} , P_{gj} = Real power generated at i^{th} and j^{th}buses

$B_{ji} = B_{ij}$ = Loss coefficients

2) *Generator Constraint:* Generator constraint or inequality constraint can be written as;

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max} \qquad (4)$$

Where,

P_{gi}^{min} & P_{gi}^{max} are minimum and maximum power generation limits. The output power of generators should be within these limits.

III. LAMBDA ITERATION

The most common method of solving ELD problems is by using the lambda iteration method where the procedure converges rapidly. Here the best fuel cost is determined along with optimal generator outputs. The detailed algorithm is given below;

1) Read the given data.
2) Choose initial value of λ & $\Delta\lambda$.
3) Determine P_{gi} corresponding to incremental fuel cost.
4) For each unit check the generation limits.

   If $P_{gi} > P_{gi}^{max}$ set $P_{gi} = P_{gi}^{max}$
   If $P_{gi} < P_{gi}^{min}$ set $P_{gi} = P_{gi}^{min}$

5) The difference in power at all generator bus between consecutive iterations should be less then prescribed value. If not, go back to step 3.
6) After all P_{gi} values are calculated, find out the loss using equation (3). Calculate mismatch between generator power and demand including losses.

$$\Delta P = \sum_{i=0}^{Ng} P_{gi} - P_D$$

7) If the value of ΔP is less than some specified value ε stop calculation and calculate cost of generation with these values of power. Otherwise go to step 8.
8) Increase the value of λ & $\Delta\lambda$; if $\Delta P < 0$ or
   Decrease the value of λ & $\Delta\lambda$; if $\Delta P > 0$
   And repeat from step 4.

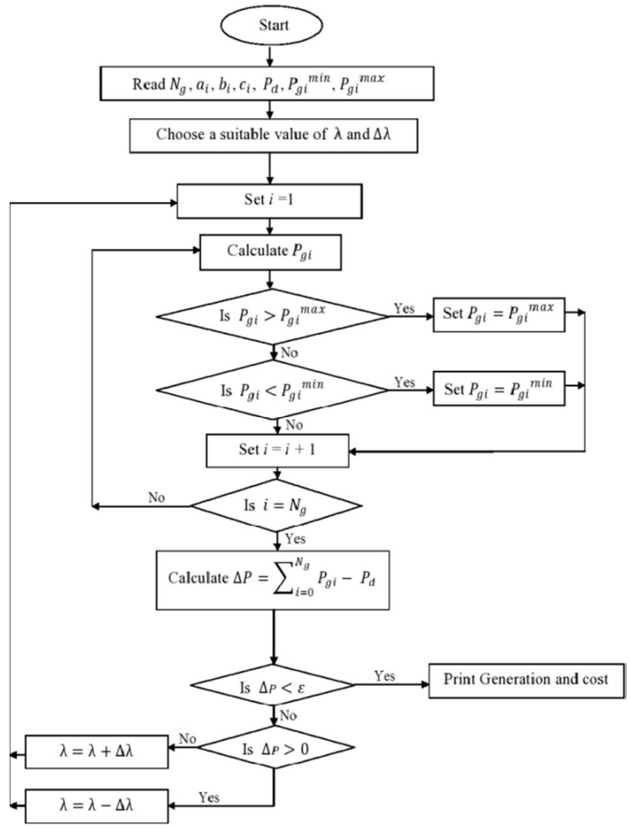

Fig. 1 Flow chart for Lambda Iteration

IV. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization (PSO) is one of the modern heuristic algorithms, which can be effectively used to solve nonlinear and non-continuous optimization problems [2]. It is a population-based search algorithm and searches in parallel using a group of particles similar to other Al-based optimization techniques. Eberhart and Kennedy in 1995 introduced it where the stochastic optimization technique based on movement and intelligence of swarms is used.

In PSO swarms of n particles communicate either directly or indirectly with one another using gradients or search directions on the search space to find a global solution. The best position achieved by the particle during its flight in search space is called $Pbest$ or personal best of the particle. The best among all $Pbest$ is termed as $Gbest$ or global best. The equation of the PSO velocity and position of particle is shown below;

$$V_i^{k+1} = w \times V_i^k + c_1 \times r_1 \times \left(Pbest_i^k - X_i^k\right) + c_2 \times r_2 \times \left(Gbest_i^k - X_i^k\right) \tag{5}$$

Where,

k= iteration count=1, 2, 3…k_{max}

i=particle number=1, 2, 3…N_p

N_p = number of particles

w = inertia weight factor

c_1, c_2 = acceleration coefficients

r_1, r_2 = random numbers between 0 and 1

V_i^k = velocity of particle i at k^{th}iteration

X_i^k = position of particle i at k^{th}iteration

$Pbest_i^k$ = best position of particle i until k^{th}iteration

$Gbest_i^k$ = best position of group until k^{th}iteration

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Each particle updates its position after moving from current position to the next position and can be given by;

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

Inertia weight also plays an important role in controlling speed of particle and is given by;

$$w = w_{max} - \left(\frac{w_{max} - w_{min}}{iteration_{max}}\right) \times iteration_k \quad (7)$$

The corresponding algorithm for PSO is as under;

1) Specify the suitable value of various parameters of PSO.
2) Initialize particles with random velocity with position in the search space.
3) Evaluate the fitness of each particle.
4) Compare the fitness with $Pbest$.
5) Identify the best among $Pbest$ and then set as $Gbest$.
6) Update the velocity and positions.
7) Until convergence repeat step 3 to step 6.

These steps are represented in the flow chart of Fig. 2

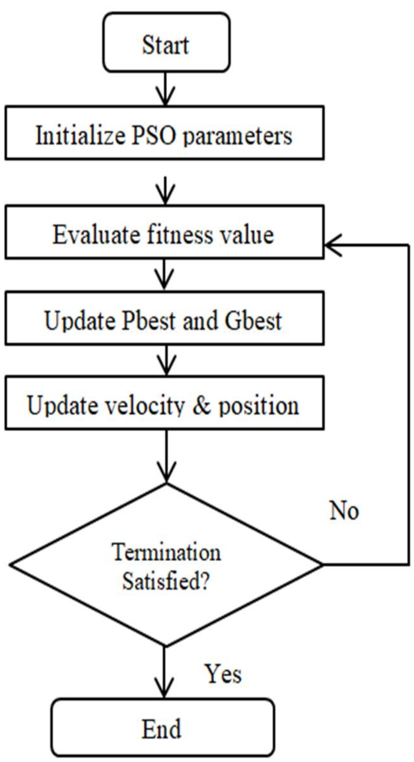

Fig. 2 Flow chart for PSO

V. GENETIC ALGORITHM.

G.A. is a method of deriving a new population from the older one. It maintains a set of candidate solutions called population and repeatedly modifies them. This is achieved by using natural selection to approximate the solution for a given population. It includes the steps of crossover, mutation and inversion [3]. Each specimen in the population has a genome (bits) that encodes our solution. The selection operator chooses those chromosomes that are allowed to reproduce considering the fitness factor. In crossover subparts are swapped to produce new solutions for the next generation. In mutation bits are changed randomly to discover new solutions that weren't otherwise possible with the gene pool. Inversion reverses the order of continuous selection of chromosomes.

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The flow chart for G.A. is as under:

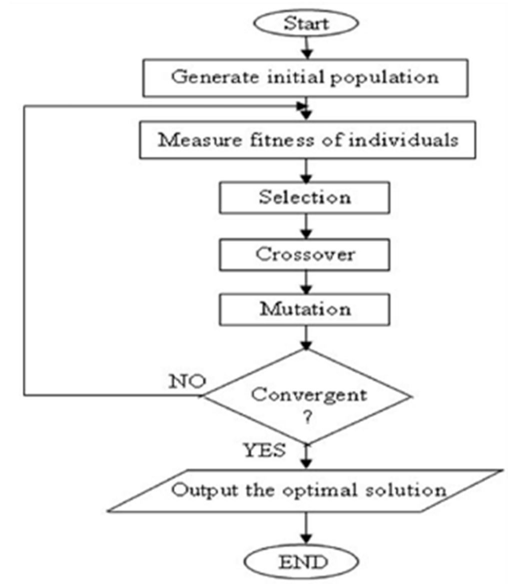

Fig. 3 Flow chart for GA

VI. RESULTS AND DISCUSSION

To find out the best optimization technique three methods are discussed in this paper viz. LI, PSO & GA. The results obtained are then compared with LI. The ELD problem discussed in this paper is solved by considering transmission losses on IEEE 30 test bus systems with 6 generating units. Programmes of respective methods were run to obtain required results. All the calculations and programming has been done using the MATLAB environment.

The cost coefficients and generator power limits are shown by table 1 [4].

Table I
Generating Unit Capacity And Cost Coefficients

Units	P_{gi}^{max}	P_{gi}^{min}	a_i	b_i	c_i
1	500	100	240	7.00	0.0070
2	200	50	200	10.0	0.0095
3	300	80	220	8.50	0.0090
4	150	50	200	11.0	0.0090
5	200	50	220	10.5	0.0080
6	120	50	190	12.0	0.0075

The loss coefficients of the system is given as
B = [0.000017 0.000012 0.000007 -0.000001 -0.000005 0.000002
0.000012 0.000014 0.000009 0.000001 -0.000006 -0.000001
0.000007 -0.000001 -0.000005 -0.000002 0.000009 0.000001
-0.000006 -0.000001 0.000031 0.000000 -0.000010 -0.000006
0.000000 0.000024 -0.000006 -0.000008 -0.000010 -0.000006
-0.000006 -0.000008 0.000129 -0.000002 -0.000002 0.000150]
The values are calculated at different MW ratings of 600 MW and 1263MW.

Table II
Results Using Lambda Iteration

Load demand (MW)	P_{g1} (MW)	P_{g2} (MW)	P_{g3} (MW)	P_{g4} (MW)	P_{g5} (MW)	P_{g6} (MW)	P_L (MW)	Fuel cost ($/hr)
600	273.5	50	129.6	50	50	50	2.989	7220
1263	447.12	173.22	263.96	140	165.61	86.65	12.42	15446.1

Table III
Results Using PSO

Load demand (MW)	P_{g1} (MW)	P_{g2} (MW)	P_{g3} (MW)	P_{g4} (MW)	P_{g5} (MW)	P_{g6} (MW)	P_L (MW)	Fuel Cost ($/hr)
600	273.1	50	129.8	50	50	50	2.988	7219.67
1263	452.26	182.65	267.5	136.17	155.9	80.80	12.41	15445.2

Table IV
Results Using GA

Load demand (MW)	P_{g1} (MW)	P_{g2} (MW)	P_{g3} (MW)	P_{g4} (MW)	P_{g5} (MW)	P_{g6} (MW)	P_L (MW)	Fuel Cost($/hr)
600	253.42	50.78	110.65	51.03	86.48	50.48	2.652	7217.69
1263	436.38	163.66	257.03	136.48	200	79.33	9.906	15376.5

VII. CONCLUSION

In this paper the ELD problem was solved using three optimization methods and the respective results at different load demands were calculated considering losses. On successful operation of the said programs it can be seen from the results that the best solution for optimization is genetic algorithm rather than the traditional techniques.

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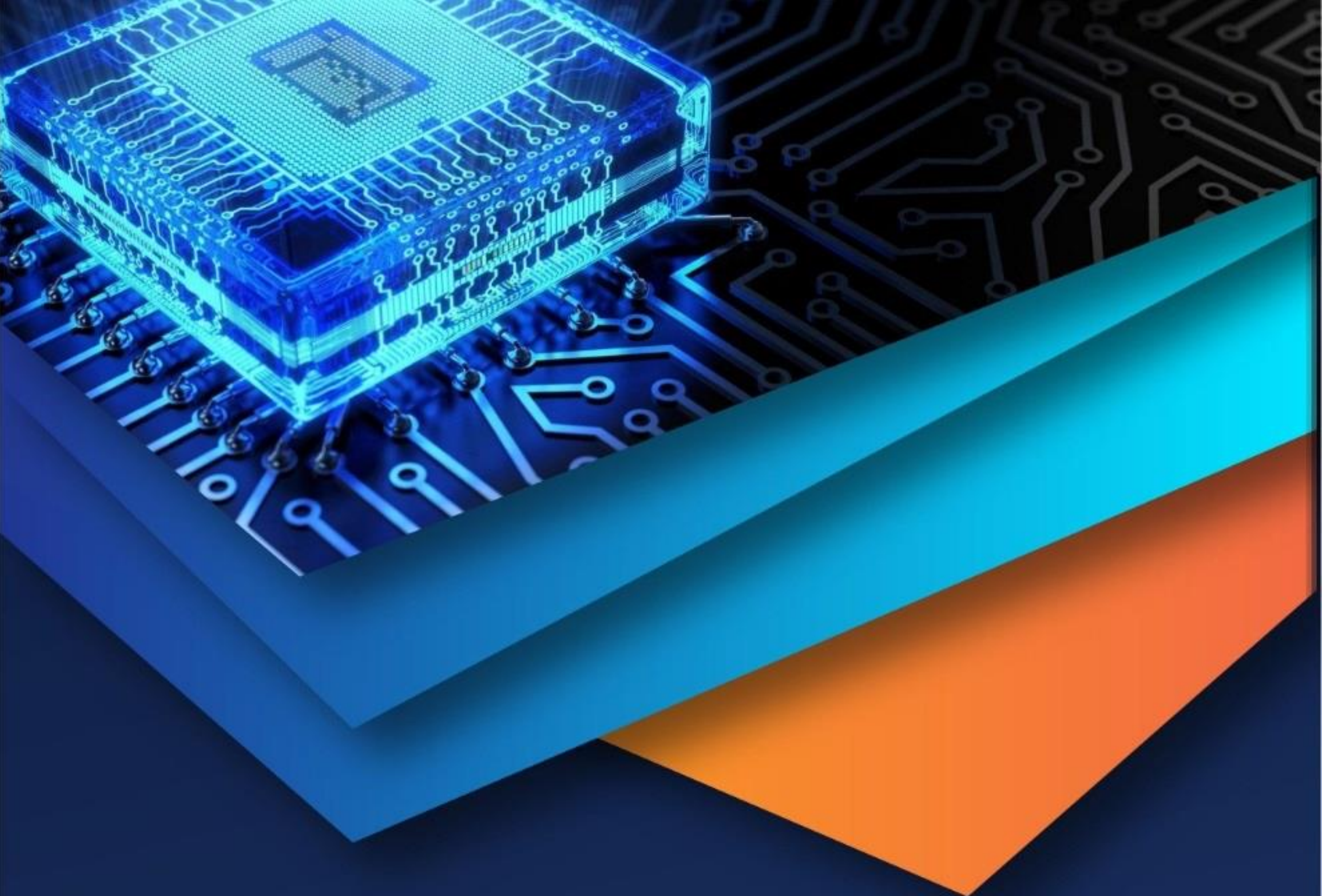

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