A Genetic Algorithm Approach for the Solution of Economic Load Dispatch Problem

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Abstract-This paper presents the application of Genetic algorithm (GA) to solve the economic load dispatch problem of the power system. The effectiveness of the proposed algorithm has been demonstrated on two different test systems considering the transmission losses. Test system-1 includes a three generator system and test system-2 includes an IEEE 30-bus system. The results of test system-1 are compared with a conventional method and found better. Short term thermal generation scheduling is done for IEEE 30-bus system.

Keywords-Economic load dispatch (ELD), genetic algorithm (GA), fuel cost

I. Introduction

Economic load dispatch (ELD) is one of the most important problems to be solved for the economic operation of a power system [1]. Economic load dispatch is to define the production level of each plant so that the cost of fuel is reduced for the prescribed schedule of load. The objective of economic load dispatch (ELD) is to allocate the generation among the committed units such that the cost of fuel is minimized, while satisfying the equality and inequality constraints [2].

Literature survey [1-15] shows that the fuel cost function is represented by a simple quadratic equation and problem is optimized by using different methods [2]. To solve ELD problem some conventional methods are used. Lagrangian multiplier method [2] was introduced to solve the ELD problem. Economic load dispatch (ELD) problem using classical method like Newton-Raphson Method, Approximate Newton-Raphson method, Efficient method were introduced [2,3]. In these methods assumption is made that the incremental cost curves of the generators is linear. However, in practical case, the cost curves of the units are highly non linear.

Dynamic programming is used but has dimensionality and local optimality problem [4]. Hierarchical structure method, which is a numerical method was proposed to solve ELD problem with piece-wise quadratic cost functions [5]. Then artificial intelligence techniques named Particle swarm optimization (PSO), Modified PSO (MPSO), Artificial neural network (ANN) were applied [2]. ANN technique suffer from stability problem [6,7].

Genetic algorithm (GA) technique is successfully applied to ELD problem. GA technique is based on the principle of natural genetics and natural selection [8,9]. One of the advantage of GA is using stochastic instead of deterministic rules to search a solution. Therefore global optimum of the problem can be approached with high probability [10] .In recent years,the interest in these algorithms is rising fast and provides robust and powerful adaptive search mechanisms. GA has an immense potential for applications in the power system and applied to solve problem such as ELD [11,12], unit commitment, reactive power control, hydrothermal scheduling and distribution system planning. Therefore, global optimum of the problem can be approached with high probability. Another attractive property of GA is it searches for many optimum points in parallel [2]. GA search through many points in the solution space at one time which is other important advantage of GA as compared to other techniques.

In this paper GA is applied to the ELD problem of two different test systems. GA is a potential heuristic tool for ELD Problem. Results of genetic algorithm approach applied on test system-1[14] are compared with Lambda iteration method (LIM). Further, GA is extended on Test system-2[15] and short term optimal generation scheduling is obtained for Test system-2 (IEEE 30-bus system) .

II. PROBLEM FORMULATION

The objective function of ELD problem is to find out the optimal combination of power generation that minimizes the total generation cost, while satisfying an equality and inequality constraints. We have to allocate the generation among the committed units economically.

The objective function [2] is taken as to minimize the summation of the fuel cost for all the thermal units over the dispatching interval. Mathematically the objective function or fuel cost function to be minimized is given as

$$F_i(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i \quad \text{Rs/h} \qquad (1)$$

Where

a_i, b_i, c_i are the cost coefficients of i_{th} generator

Subject to the following constraints

a) Equality Constraint (Energy balance equation):

Total generated power is equal to the total demand plus the transmission losses. Equality constraint [2] with transmission losses is given in equation (2)

$$\sum_{i=1}^{NG} P_{gi} = P_d + P_L \qquad (2)$$

Where,

P_L - total power transmission losses

P_d - total demand

This equation denotes that the total generation is equal to the total demand when transmission losses are considered.

b) Inequality constraints (Generating capacity limit constraints):

The generation output of each unit should be between its maximum and minimum limits. Inequality constraints [2] is given as

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \qquad (3)$$

Where,

P_{gi}^{min} - minimum power output of the i^{th} generating unit

P_{gi}^{max}- maximum power output of the i^{th} generating unit

To achieve true ELD transmission losses must be taken into account. Using B-coefficients method, the transmission losses are expressed using George's formula [2] as

$$P_{Loss} = \sum_{i-1}^{NG} P_{gi} \sum_{j=1}^{NG} Pgj\, B_{ij} \qquad (4)$$

Where,

B_{ij} are constant called B-coefficients or loss coefficients.

The exact value of the system losses can only be determined by power flow solution. Kron's formula is used to find the losses and appropriates the losses as a function of the output level of the system generators. Transmission losses using Kron's formula [2] is expressed as

$$P_{Loss} = \sum_{i=1}^{NG} P_{gi} \sum_{j=1}^{NG} P_{gj}\, B_{ij} + \sum_{i=1}^{NG} Pgi\, B_{i0} + B_{00} \qquad (5)$$

III. GENETIC ALGORITHM APPROACH: AN OVERVIEW

Genetic algorithm (GA) has emerged as a candidate due to its flexibility and efficiency for many optimization applications [2]. GA was developed by John Holland and finally popularized by one of his student, David Goldberg. GA is a stochastic searching algorithm. It is a genetics search algorithm based on the principles of natural selection and natural genetics [2].

Movement in GA is accomplished using three primary operators: reproduction, crossover, and mutation. Reproduction operator [2] selects a string from the previous generation based on the string's fitness and its probability of propagation to the next generation. Crossover operator [2] selects a locus position with in two parent strings and swaps the gene information from that position to the end of string. The mutation operator changes random allele values during the reproduction-crossover phase to increase the diversity of the sample space. Initial population is generated using a random number generator.

3.1 Fitness function and parent selection

Implementation of power dispatch problem in GA is realized with the fitness function [2]. Since the proposed approach uses the equal incremental cost criterion as its basic the constraint equation (2) can be written as

$$\varepsilon^{j} = \left| \sum_{i=1}^{NG} P_{gi} - (P_d + P_L) \right| \quad (6)$$

Then the convergence rule is when error (ε) decreases with in a particular value. For the purpose of emphasizing the best chromosome and speed up convergence of the iteration procedure, fitness is normalized between 0 and 1[12]. The fitness function used is:

$$f^{j} = 1/1+\alpha(\varepsilon^{j}/P_d) \qquad (j=1, 2.......L) \quad (7)$$

In the discrete genetic algorithm, resulting point is a binary string of 0 and 1called chromosome and number of bits called gene. A simple solution with 8-bits and two variables (x,y) is given

1 0 0 1} gene1(x)
0 0 1 1} gene2(y)

The bits are decoded as below:

{x→1*2^3+0 +0 +1*2^0 = 9
{y→0*2^3+0+1*2^2+1*2^0= 5

The equivalent decimal integer of binary string λ is obtained as

$$y^{j} = \sum_{i=1}^{l} 2^{i-1} b_i^{j} \,(j=1,2,........L) \quad (8)$$

The continuous variable λ can be obtained to represent a point in the search space according to a fixed mapping rule, i.e

$$\lambda^{j}= \lambda^{min}+(\lambda^{max}-\lambda^{min}) * y^{j}/2^{l}-1 \quad (9)$$

The GA begins with a collection of chromosome known as the population. The population has L chromosome called population size.

IV. STEPS OF ECONOMIC LOAD DISPATCH USING GENETIC ALGORITHM

The step-wise procedure [2] is outlined below.

1.Read data, namely cost coefficients, B-coefficients, convergence tolerance, error, Step size, maximum allowed iterations, ITMAX,L population size, probability of crossover and mutation,λ^{min} and λ^{max}.
2. Generate an array of random numbers. Generate the population λ^{j}(j=1,2....L) by flipping the coin .The bit is set according to the coin flip as
b_{ij} = 1 if p=1or random 0≤p
= 0 Otherwise
Where p is the probability (0.5)
3. Set generation counter, k=0, f^{min} =1and f^{min}=0.
4. Increment the generation counter, k=k+1 and set the population counter, j=0.
5. Increment population counter, j=j+1
6. Decode the string.
7. Using Gauss elimination method, find P_l^{J}
8. Calculate transmission losses.
9. Find ε^{j} and check if ε^{j}<BIG, then set BIG = ε^{j}
10. Find fitness from eq. (7)
If (f^{j}>f^{j}) then f^{j}=f^{j} and if f^{j}<f^{j} then set f^{j}=f^{j}
11. If (j<L) then go to step 5 and repeated
12. If (BIG<error) then go to step 17.

13. Find population with maximum and average fitness of the population.
14. Select the parents for crossover and perform crossover
15. Perform mutations
16. If (k<ITMAX) then go to step 4 and repeat.
17 stop

V. TEST SYSTEM AND RESULTS

The power system economic load dispatch problem based on genetic algorithm has been tested on two different test systems. Two different test systems are taken to study the ELD problem, First test system [14] and second test system (IEEE 30-bus system) [15] are taken for study. Genetic algorithm parameters used are

Population size = 50
Generation = 500
Crossover probability = .7
Mutation probability = .01

5.1 Results of test system-1

Results of test system-1 are shown in the Table-1. Power demand is taken 300MW. Losses are determined using equation (4). Results obtained with GA are compared with LIM and given in Table-1. The transmission losses are 10.5401MW with fuel cost of 3615.1033Rs/hour

Table-1: Results of test system-1

Generator Output	LIM	GA
P1(MW)	202.49	202.4506
P2(MW)	81.0267	80.9589
P3(MW)	27.0149	27.1307
Transmission Losses(MW)	10.5311	10.5401
Fuel cost (Rs/hour)	3615.11	3615.1033

5.2 Results of Test System-2

Test system-2 is considered for ELD and short term optimal generation scheduling is obtained. Power Demand is taken as 2.834 pu at 100 MVA base. Results for test system-2 are shown in Table 2. Table-3 shows the short term optimal generation scheduling [13] with corresponding load profile as shown in figure 1.The transmission losses are determined using equation (5). The transmission losses calculated are .0287 pu MW and optimal fuel cost obtained is 608.48 Rs/hour. The power demand, allocation and losses are given in Table-2 and Table-3 and taken in pu MW.

Table-2(Results of Test system-2)

P1(pu MW)	0.1100
P2(pu MW)	0.3104
P3(pu MW)	0.6373
P4(pu MW)	0.9517
P5(pu MW)	0.5177
P6(pu MW)	0.3413
Demand(p.u MW)	2.834
Power losses(pu)	0.0287
Fuel Cost(Rs/hour)	608.48

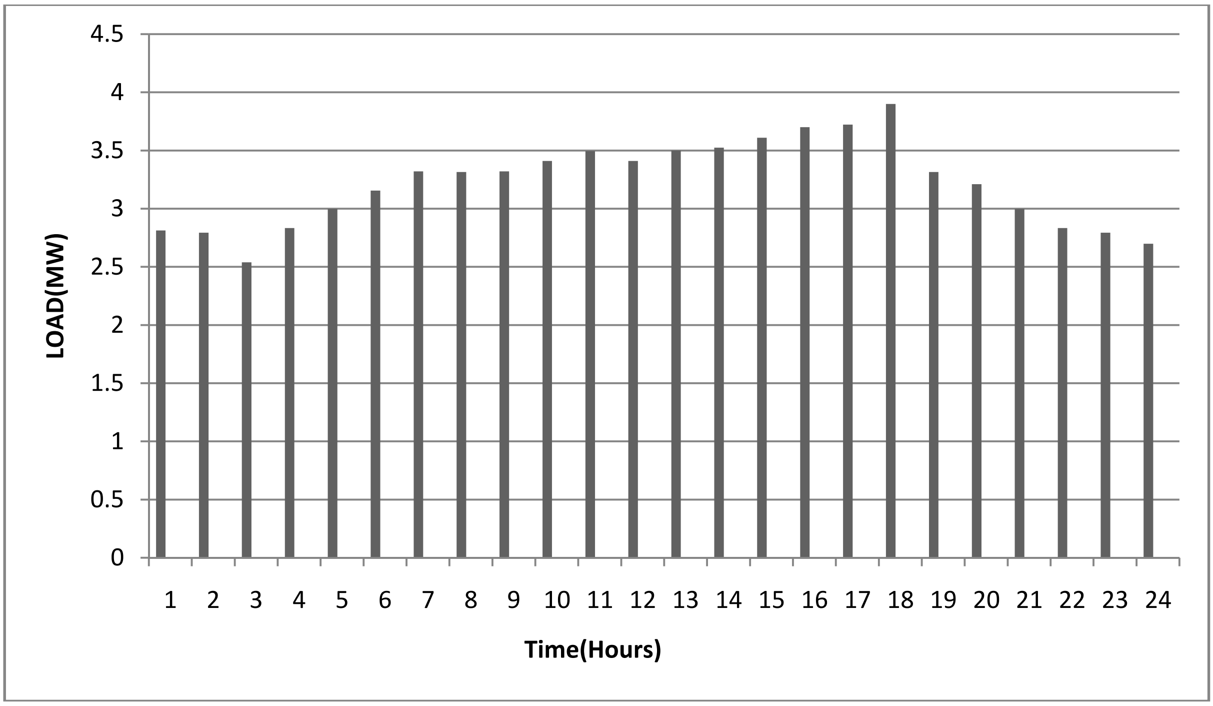

Figure-1 Load curve of a day

Table-3: Short term optimal generation scheduling

Time interval	Demand(MW)	Unit-1	Unit-2	Unit-3	Unit-4	Unit-5	Unit-6	Losses	Fuel cost(Rs/h)
1	2.813	.1138	.3019	.6262	.9588	.5027	.3439	.0285	603.73
2	2.794	.1110	.2980	.6201	.9516	.4979	.3492	.0282	599.45
3	2.539	.0859	.2742	.5506	.9142	.4342	.3105	.0250	542.78
4	2.834	.1125	.3025	.6346	.9572	.5163	.3453	.0287	608.47
5	2.999	.1318	.3170	.6785	.9798	.5562	.3724	.0309	646.08
6	3.155	.1466	.3328	.7297	1.0105	.5940	.3803	.0330	682.21
7	3.320	.1679	.3455	.7993	1.0343	.6366	.3976	.0353	721.03
8	3.315	.1661	.3457	.7705	1.0407	.6337	.4000	.0357	719.84
9	3.320	.1679	.3455	.7993	1.0343	.6366	.3976	.0353	721.03
10	3.410	.1750	.3576	.7908	1.0602	.6601	.4100	.0376	742.46
11	3.495	.1807	.3587	.8248	1.0671	69.45	.4135.	.0384	762.88
12	3.410	.1750	.3576	.7908	1.0602	.6601	.4100	.0376	742.46
13	3.500	.1860	.3680	.8207	1.0668	.6828	.4202	.0386	764.08
14	3.525	.1853	.3642	.8406	1.0690	.6909	.4195	.0385	770.08
15	3.610	.1947	.3756	.8539	1.0872	.7139	.4314	.0404	790.75
16	3.700	.2064	.3827	.8723	1.1065	.7420	.4387	.0424	812.79
17	3.723	.2136	.3843	.8777	1.1009	.7467	.4486	.0425	818.46
18	3.315	.1661	.3457	.7705	1.0407	.6337	.4000	.0357	719.84
19	3.900	.2224	.3949	.9414	1.1323	.7974	.4632	.0453	862.42
20	3.211	.1517	.3372	.7281	1.0421	.6068	.3863	.0352	695.35
21	2.999	.1318	.3170	.6785	.9798	.5562	.3724	.0309	646.08
22	2.834	.1125	.3025	.6346	.9572	.5163	.3453	.0287	608.47
23	2.794	.1110	.2980	.6201	.9516	.4979	.3492	.0282	599.45
24	2.699	.1015	.2942	.5885	.9298	.4812	.3364	.0270	578.16

V. CONCLUSION

In this paper, genetic algorithm is applied to solve the economic load dispatch problem. An extensive analysis is made by applying the GA on two different test systems. The results of the test system -1 using GA are compared with Lambda iteration method (LIM) which shows better results than LIM method and satisfy ELD requirenents. A short term optimal generation scheduling for the test system-2 has been obtained. GA is better than the conventional methods from computational point of view.

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