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To Study and Analyze Economic Load Dispatch in Power System Using Genetic Algorithm

Umang Meshram[1], Sayali Morey[2], Santoshi Gawande[3]

Student, Department of Electrical Engineering, K.D.K. College of Engineering, Nagpur, India[1, 2]

Asst Professor, Department of Electrical Engineering, K.D.K College of Engineering, Nagpur, India[3]

Abstract: This paper presents the application of Genetic Algorithm to solve the economic load dispatch problem of the power system. Economic Load Dispatch is one of the major optimization problems dealing with the modern power system .The objective of Economic Load Dispatch is sharing the power demand among the online generators while keeping the minimum cost generation as constraint. The aim of this paper is to operate the economic load dispatch problems of power system while meeting the total load plus transmission line losses within generation limits .This work aims in modeling the economic load dispatch problem with transmission loss and is being applied to 3 generator and 6 generator system using MATLAB.

Keywords: Economic Load Dispatch (ELD), Genetic Algorithm (GA), Fuel cost.

I. INTRODUCTION

Electrical power systems are designed and operated to meet the continuous variation of power demand. In power system minimization of operation cost is very important. Economic load dispatch (ELD) is a method to schedule the power generator outputs with respect to load demands and to operate the power systems most economically. To solve ELD problem some conventional methods are used. The conventional methods include Newton-Raphson method, Lambda iteration method, Base point and participation method, Gradient method etc. However these classical dispatch algorithms require the incremental cost curves to be monotonically increasing or piece wise linear. The classical calculus based techniques fail in solving these types of problems. In this respect ,stochastic search algorithms like Genetic algorithm(GA), Evolutionary strategy(ES),Evolutionary Programming (EP), Practical Swarm Optimization (PSO),and Simulated Annealing (SA) may prove to be very efficient in solving highly non linear ELD problem without any restrictions on the shape of the cost curves .These methods generally provide a fast and reasonable solution.

Genetic algorithm (GA) technique is successfully applied to ELD case. Genetic algorithm technique is based on the theory of natural genetics and an advantage of GA is using stochastic instead of deterministic rules to search a extinction .GA has a large potential for application in power systems and can be applied to solve problem such as ELD , unit commitment ,reactive power control etc. Another attractive property of GA is that that it searches for many optimum points in parallel.

II. ECONOMIC LOAD DISPATCH

A. Economic Dispatch Load

The Economic Load Dispatch (ELD) can be defined as the process of allocating generation units, so that the system load is supplied entirely and most economically. The method of economic load dispatch for generating units at different loads must have total fuel cost at the minimum point. The economic load dispatch is used to define the production level of every plant so that the total cost of transmission and generation is minimum for a prescribed panel of load.

B. Generator operating cost

The running or operating cost of a unit consist of fuel cost, maintenance cost, labour cost. Out of which the maintenance cost and the labour cost are negligible in comparison with the fuel cost .Also they are difficult to find in practice .Therefore while studying the economic operation the operating cost of generator is assumed to be the fuel cost . Therefore the economic load dispatch problem is to minimize the fuel cost to supply the required load.

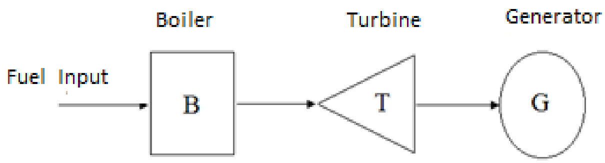

Fig1.Simple model of a fossil plant

Figure 1shows the simple model of a fossil plant dispatching process. The operating cost of a plant has the form figure 2.

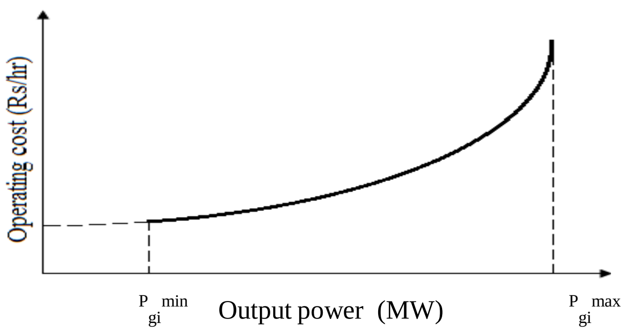

Fig2. Operating cost of fossil fired generator

The cost is usually approximated by one or more quadratic segments. The fuel cost curve may have number of discontinuities. Within the continuity range the incremental fuel cost may be expressed by a number of short line segments or piece wise linearization.

The P_{gi}^{min} is the minimum loading limit below which operating the unit proves to be uneconomical and P_{gi}^{max} is the maximum output limit.

III. PROBLEM FORMULATION

A. Objective Function

The objective of the economic dispatch problem is to minimize the total fuel cost of thermal power units subjected to the equality and inequality constraints of power system. The simplified cost function of every generator can be represented as a quadratic function as given (2)

$$F(P_{gi}) = \min \sum_{i=1}^{NG} F_i(P_{gi}) \quad (1)$$

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

Where a_i, b_i, c_i are cost coefficients for i^{th} unit , $F_i(P_{gi})$ is the total cost of generation , P_{gi} is the generation of i^{th} plant ,NG signifies the number of generators.

B .Equality and Inequality constraints

a .Active power balance equation

For power balance an equality constraint should be acquiescent. The total generated power should be the same as total load demand plus the total transmission line loss.

$$\sum_{i=1}^{NG} P_{gi} = P_D + P_{loss} \quad (3)$$

Where P_D is the total demand and P_{loss} is the total line loss.

b. Minimum and maximum power limits

Generation output of each generator should lie between minimum and maximum limits .The compatible inequality constraints for each generator are

$$P_i^{min} \le P_i \le P_i^{max} \ (i=1,2,3,\ldots\ldots,NG) \quad (4)$$

Where P_{gi}^{min} is the lower permissible limit of real power generation, P_{gi}^{max} the upper permissible limit of real power generation.

IV. GENETIC ALGORITHM

Genetic algorithms are categorized as global search heuristics. Genetic algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems .Genetic algorithms are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection and crossover.

Genetic algorithms are implemented in a computer simulation in which a population of abstract representations (called chromosomes or the genotype of the genome)of candidate solutions (called individuals, creatures, phenotypes) to an optimization problem evolves towards the better solutions .Traditionally ,solutions are represented in binary as string of 0s and 1s,but other encodings are also possible .The evolution usually starts from a population of randomly generated individuals and happens in generations .In each generation the , fitness of every individual in population is evaluated ,multiple individuals are stochastically selected from the current population (based on their fitness) and modified to form a new population .The new population is then used in the next iteration of algorithm. Commonly , the algorithm terminates when either a maximum number of generations have been produced ,or a satisfactory fitness level has been reached for the population .If the algorithm has terminated due to a maximum number of generations ,a satisfactory solution may or may not have reached .Once we have the genetic representation and the fitness function defined ,GA proceeds to initialize a population of solutions randomly, and then improve it through repetitive application of mutation, crossover, inversion and selection operators .

a. Representation

In GA, the design variables or features that characterize an individual are represented in an ordered list called a string .Genetic algorithms are derived from the study of biological method .In biological method evolution takes place on organic devices used to encode the structure of living beings. Each design variable corresponds to a gene and the string of genes corresponds to a chromosome. Chromosomes are built of discrete units known as genes .Natural selection is the link between the chromosomes and the performance of their decoded structures .These organic devices are known as chromosomes .A living being is only a decoded fabrication of chromosomes.

b. Encoding

This requires a mapping mechanism between the solution space and the chromosomes. This mapping is known as an encoding. Normally, a chromosome corresponds to unique solution x in the solution space .The application of genetic algorithm to problem starts with encoding. In fact, GA works on the encoding of a problem, not on the problem itself .The encoding specifies a mapping that transforms a possible solution to a problem into a structure containing a collection of decision variables that are relevant to a problem into a structure containing a collection of decision variables that are relevant to the problem.

c. Decoding

The decoded feature values are used to compute the problem characteristics like the fitness values, constraint violation, objective function, and system statistical characteristics like standard deviation variance and rate of convergence .The stages of crossover, selection, mutation etc. are repeated till some termination condition is reached .Decoding is the process of conversion of binary structure of chromosome into decimal equivalents of the feature values. Usually this process is done after decatination of the entire chromosome to individual chromosomes. The equivalent decimal integer of binary string λ is obtained as

$$y^j = \sum_{i=1}^{l} 2^{i-1} b_i^j \quad (j=1,2,\ldots,L) \tag{5}$$

Where b_i^j is the i^{th} binary digit of the j^{th} string, I is the length of the string, L is the number of strings or population size.
The continuous variable λ can be obtained to represent a point in the search space according to a fixed mapping rule, i.e.

$$\lambda^j = \lambda^{min} + \frac{\lambda^{max} - \lambda^{min}}{2^l - 1} y^j \quad (1,2,\ldots\ldots,L) \tag{6}$$

Where λ^{min} is the minimum number of variable, λ^{max} is the maximum value of variable, y^j is the binary coded value of the string.

d. Initialization
Many individual solutions are randomly generated form an initial population. Occasionally, the solutions may be "seeded" in the area where optimal solutions are likely to be found .Traditionally, covering the entire range of possible solutions, population is generated randomly.The population size depends on nature of case, however typically contains several hundreds or thousands of possible solutions.

e. Evaluation
The evaluation function is a procedure for establishing the fitness of each chromosome in population and is application oriented .This function is derived from the objective function and used in successive genetic operation. Suitability of the solution is determined from the initial set of solution of the problem .For this suitability allocation we use a function called fitness function .In the case of command interpreter routines ,the fitness is the value of objective function to be optimized .Penalty function can also be inclusive in the objective function ,in order to achieve a constrained problem, since Genetic algorithms proceed in the direction of evolving the fittest chromosomes and the performance is highly sensitive to the fitness values.

f. Fitness function
Fitness value f(x) is derived from the objective function and is used in successive genetic operations .Minimization problems are usually transferred into maximization problems using some suitable transformations .The Genetic algorithm is based on Darwin's principle that "The candidates, which can survive, will live, others would die ''This principle is used to find fitness value of the process for solving maximization problems. The fitness function for maximization problem can be used same as the objective function F(x). The fitness function for the maximization problem is:

$$F(x) = F(X) \tag{7}$$

For minimization problems, the fitness function is an equivalent maximization problem chosen such that the optimal point appears stationary. The following fitness function is often used in minimization problems

$$F(X) = \frac{1}{1 + f(x)} \tag{8}$$

Here f(x) is fitness function and F(X) is objective function

g. Selection
Individual solutions are selected through a fitness –based process, where fitter solutions are more likely to be chosen. Certain selection methods rate the fitness of each solution and preferentially select the best extrication .Other methods rate only a random sample of population, as this process may be very time consuming .During every continuous generation, a proportion of existing population is forced to breed a new generation.
This helps to keep the diversity of population, preventing premature convergence on beggarly solutions.

h. Reproduction
The further step is to generate a second generation population of solutions from those selected through genetic operators: crossover, and / or mutation.
By producing a "Child" solution using above methods of crossover and mutation, a new solution is generated which typically shares many of the characteristics of its "Parents". For each new solution to be produced, a pair of "parent '' solution is selected for breeding from the pool selected previously. New parents are selected for every new child ,and the procedure continues until a new population of solutions of appropriate size is created .Although reproduction methods that are based on the use of two parents are more "biology inspired", some research suggests more than two "parents '' are better to be used to reproduce a good quality chromosome. Generally average fitness will have increased by this procedure for the population. These processes result in next generation population of chromosomes that is different from initial generation.

i. Termination
This generational process is repeated until a termination condition has been attained. The complete process of Genetic Algorithm can be evaluated using flowchart given in fig 3.

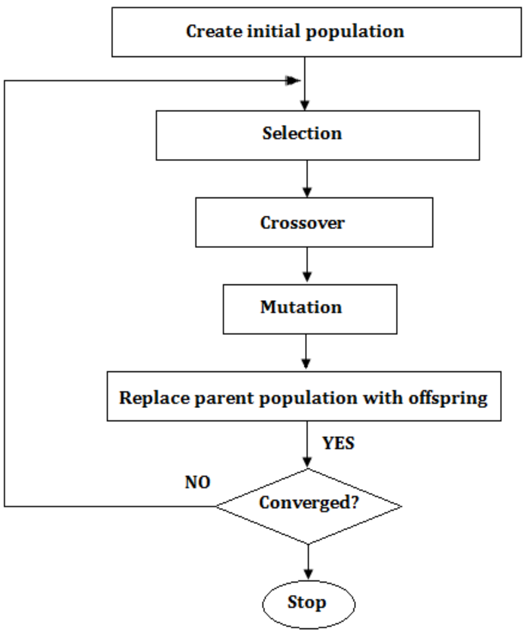

Fig 3 .Flow chart of Genetic Algorithm

Common terminating conditions are:
1) A solution is found that satisfies minimal criteria.
2) Fixed number of generations reached
3) Allocated budget (computation time/money) reached.
4) The higher ranking solutions' fitness is reaching or has reached a plateau such that successive iterations no longer produce better results.
5) Manual inspection
6) Combinations of above

V. PROPOSED ALGORITHM

The step-wise procedure is outlined below:
1. Read data, namely cost coefficients, a_i ,b_i , c_i , no. of iterations, length of string, population size, probability of crossover and mutations, power demand, P^{min} and P^{max}.
2. Create the initial population randomly in the binary form.
3. Decode the string, or obtain the decimal integer from the binary string using equation (5)
4. Calculate the power in MW generated from decoded population by using equation shown below

$$P_i^j = P_i^{min} + \frac{P_i^{max} - P_i^{min}}{2^l - 1} y_i^j \quad (i=1,2,\ldots.NG ,j=1,2,\ldots.L) \quad (9)$$

Where L is the number of string size or population Size , y_i^j is the binary coded value of i^{th} substring
5. Check P_i^j

If $P_i^j > P_i^{max}$, then set $P_i^j = P_i^{max}$
If $P_i^j < P_i^{min}$, then set $P_i^j = P_i^{min}$

6. Find fitness if ($f_j > f_{max}$) then set $f_{max}=f_j$ and If $f_j < f_{min}$ then set $f_{min} = f_j$
7 Find population with maximum fitness and average Fitness of the population.
8. Select the parents for crossover using stochastic Remainder roulette wheel selection method.
9. Perform single point crossover for the selected parents.
10. Perform mutation
11. If number of iterations reaches the maximum, then go To step 12, otherwise go to step 2.
12. The fitness that generates the minimum total Generation cost is the solution of the problem.

VI. NUMERICAL RESULTS AND DISCUSSION

The result of ELD after the implementation of proposed GA method is given by fig.4 and fig 5. The work has been done with the help of MATLAB 7.60 software .The performance is evaluated considering the losses using 3 generators and 6 generator test system.

The coefficients of fuel cost and maximum and minimum power limits for 3 generator system are given in Table 1 and their loss coefficients are given in Table2 .The power demand is considered to be 150 MW for 3 generator system. Figure 4 shows fuel cost test system for 3 generator system. The coefficients of fuel cost and maximum and minimum power limits for 6 generator system are given in Table 4 and their loss coefficients are given in Table 5 .The power demand is considered to be 450 MW for 6 generator system .Figure5 shows fuel cost test system for 6 generator system .

TABLE I FUEL COST COEFFICIENT FOR 3 GENERATOR SYSTEM

Sr .no	a_i	b_i	c_i	P_i^{min}	P_i^{max}
1	0.008	7.0	200	10	85
2	0.009	6.3	180	10	80
3	0.007	6.8	140	10	70

TABLE II LOSS COEFFICIENTS P_L FOR 3 GENERATOR SYSTEM

0.0218	0.0093	0.0028
0.0093	0.0228	0.0017
0.0028	0.0017	0.0015

TABLE III OPTIMAL RESULT OF GA BY USING 3 GENERATORS

P_1	34.489 MW
P_2	64.0299 MW
P_3	54.153 MW
Total Generation	152.67 MW
Total Cost (Rrs/Mwhr)	95999.0916 Rs/Mwhr

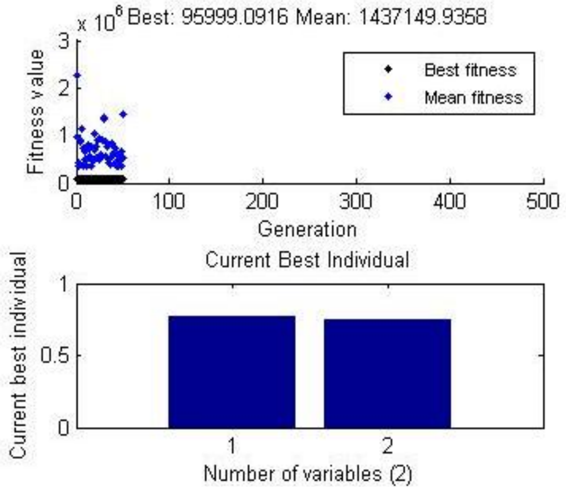

Fig4. Fuel Cost test system for 3 generators

TABLE IV FUEL COST COEFFICIENT FOR 6 GENERATOR SYSTEM

Sr No	a_i	b_i	c_i	P_i^{max}	P_i^{min}
1	0.005	2	100	10	85
2	0.010	2	200	10	80
3	0.020	2	300	10	70
4	0.003	1.95	80	50	250
5	0.015	1.45	100	5	150
6	0.010	0.95	120	15	100

TABLE V LOSS COEFFICIENTS P_L FOR 6 GENERATOR SYSTEM*10^{-4}

0.14	0.17	0.15	0.19	0.26	0.22
0.17	0.06	0.13	0.16	0.15	0.02
0.15	0.13	0.65	0.17	0.24	0.19
0.19	0.16	0.17	0.71	0.03	0.25
0.26	0.15	0.24	0.03	0.69	0.32
0.22	0.02	0.19	0.25	0.32	0.85

TABLE VI OPTIMAL RESULT OF GA USING 6 GENERATORS

P1	84.8916
P2	54.9674
P3	26.0439
P4	140.47
P5	49.96
P6	100.00
Total Generation	456.33
Total cost(Rs/MWhr)	116926.4949 Rs/MWhr

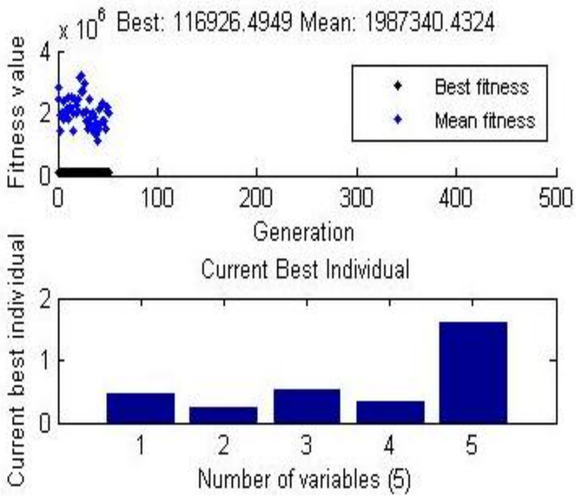

Fig 5 .Fuel Cost test system for 6 generators

VII. CONCLUSION

Genetic Algorithm is successfully implemented for 3 generator test system as well as 6 generator IEEE 30 bus system to minimize the fuel cost of the generators. It has been observed that genetic algorithm is capable of optimizing any kind of problems irrespective of load demand. The results discussed above are obtained after significant reduction in the fuel cost of generators and satisfies each and every constraint.

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