© September 2018 | IJIRT | Volume 5 Issue 4 | ISSN: 2349-6002

Economic Load Dispatch Using Genetic Algorithm

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***Abstract*- This paper presents an application of Genetic Algorithm (GA) to solve Economic Load Dispatch problem which aims to determine minimum cost .Test system is chosen as IEEE-30 bus system which includes 6 generators with necessary values given for ease of simulation. Several cases of Economic Load Dispatch with different load demands considering and non-considering line losses are simulated, and these verified results are compared with previous research results.**

Index Terms- Economic load dispatch, genetic algorithm, lambda iteration method, generator systems.

I. INTRODUCTION

Economic Load Dispatch is the very important issues in the area of Power System. Load demands are increasing day by day. With the development of integrated power system, it becomes necessary to operate the plant units economically. An important objective in the operation of such a power system is to generate and transmit power to meet the system load demand at minimum fuel cost by an optimal mix of various types of plants [1]. Thus ELD occupies an important position in the electric power system. For any specified load condition, ELD determines the power output of each plant (and each generating unit within the plant) which will minimize the overall cost of fuel needed to serve the system load taking in consideration all practical constraints [2].

The use of renewable energy for electricity generation will increase in the future. Doherty [6] identifies two scenarios for dispatching wind turbines in the power system. The first is the fuel saver scenario that does not consider wind forecast power in the load dispatch. In real time operation, when output is present, conventional generators will reduce their output in merit order to accommodate wind power. If wind power output increases such that it cannot be accommodated by reducing conventional generation, then wind production will be curtailed. There will be wasted wind output. The second scenario is the forecasted approach. In this scenario, wind power forecasts are included in the ELD calculation. The forecasted approach should consider the increase of reserve on the system due to wind forecast error. Therefore, reserve constraints in the ELD of high wind power will need to become more complex. will be an important part of the ELD problem. Consequently, a more flexible and powerful method that can cope with constraints caused by wind penetration should be used to solve the ELD problem. Recent GA methods have been reported as an effective method for solving various cases of the ELD problem in power systems with a variety of characteristics [9-12]. Another advantage of GAs is that they can be deployed to overcome problems such as no smoothness, or discontinuity of system functions [12]. The paper will investigate a GA based method for solving the ELD problem to maximise profit for generators in power systems that contain renewable energy.

II. ECONOMIC LOAD DISPATCH

a. a.The Economic Dispatch can be defined as the process of allocating generation levels to the generating units, so that the system load is supplied entirely and most economically. For an interconnected system, it is necessary to minimize the expenses. The economic load dispatch is used to define the production level of each plant, so that the total cost of generation and transmission is minimum for a prescribed schedule of load. The objective of economic load dispatch is to minimise the overall cost of generation
b. The total cost of operation includes the fuel cost, cost of labour, supplies and maintenance. Generally, costs of labour, supplies and maintenance are fixed percentages of incoming

fuel costs. The power output of fossil plants is increased sequentially by opening a set of valves to its steam turbine at the inlet. The throttling losses are large when a valve is just opened and small when it is fully opened.

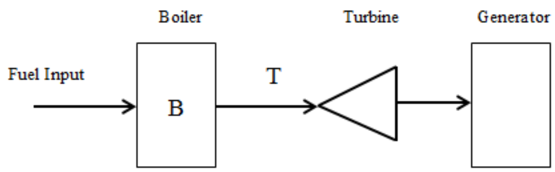
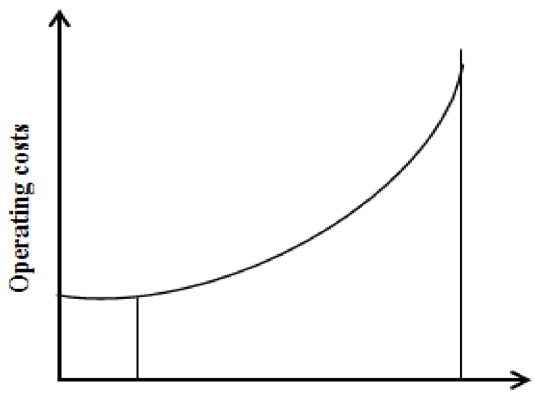


Fig. 1 Simple model of a fossil plant

Figure 1.shows the simple model of a fossil plant dispatching purposes. The cost is usually approximated by one or more quadratic segments. The operating cost of the plant has the form shown in Figure2



P_{gi}^{min} Output Power (MW) P_{gi}^{max}

Fig. 2 Operating costs of a fossil fired generator The fuel cost curve may have a number of discontinuities. The discontinuities occur when the output power is extended by using additional boilers, steam condensers, or other equipment. They may also appear if the cost represents the operation of an entire power station, and hence cost has discontinuities on paralleling of generators. Within the continuity range the incremental fuel cost may be expressed by a number of short line segments or piece-wise linearization. The min P_{gi} is the minimum loading limit below which, operating the unit proves to be uneconomical (or may be technically infeasible) and max P_{gi} is the maximum output limit. [1]

III. FORMULATION OF ELD PROBLEM

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 a power system. The simplified cost function of each generator can be represented as a quadratic function as given in (2)

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

$$F(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i \; Rs/hr \; (2)$$

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

b. Equality and Inequality Constraints 3.1.1 Active power balance equation For power balance, an equality constraint should be satisfied. The total generated power should be the same as total load demand plus the total transmission line loss.

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

Where, P_D is the total load demand and is the total line loss.

Minimum and maximum power limits Generation output of each generator should be lie between maximum and minimum limits. The corresponding inequality constraints for each generator are

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \text{ ----------- } (5)$$

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

IV.GENETIC ALGORITHM

A Genetic Algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics. Genetic algorithms are a particular class of Evolutionary Algorithms (EA) 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, or phenotypes) to an optimization problem evolves toward better solutions. Traditionally, solutions are represented in binary as strings 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 the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has 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 been 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. [6]

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

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

c. Decoding Decoding is the process of conversion of the binary structure of the chromosomes into decimal equivalents of the feature values. Usually this process is done after de-catenation of the entire chromosome to individual chromosomes. The decoded feature values are used to compute the problem characteristics like the objective function, fitness values, constraint violation and system statistical characteristics like variance, standard deviation and rate of convergence. The stages of selection, crossover, mutation etc are repeated till some termination condition is reached. The equivalent decimal integer of binary string λ is obtained as : [7] – [9]

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

Where b_i^j is the i^{th} binary digit of the j^{th} string, l 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.

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

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

d. Initialization Initially many individual solutions are randomly generated to form an initial population. The population size depends on the nature of the problem, but typically contains several hundreds or thousands of possible solutions.

e. Fitness Function The Genetic algorithm is based on Darwin's principle that "The candidates, which can survive, will live, others would die". This principal is used to find fitness value of the process for solving maximization problems. Minimization problems are usually transferred into maximization problems using some suitable transformations.

f. Selection During each successive generation, a proportion of the existing population is selected to breed a new generation. Individual solutions are selected through a fitness-based process, where fitter solutions (as measured by a fitness function) are typically more likely to be selected.

g. Termination This generational process is repeated until a termination condition has been reached. Common terminating conditions are: 1.) A solution is found that satisfies minimum criteria 2.) Fixed number of generations reached 3.) Allocated budget (computation time/money) reached 4.) The highest ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results 5.) Manual inspection 6.) Combinations of the above.[10]

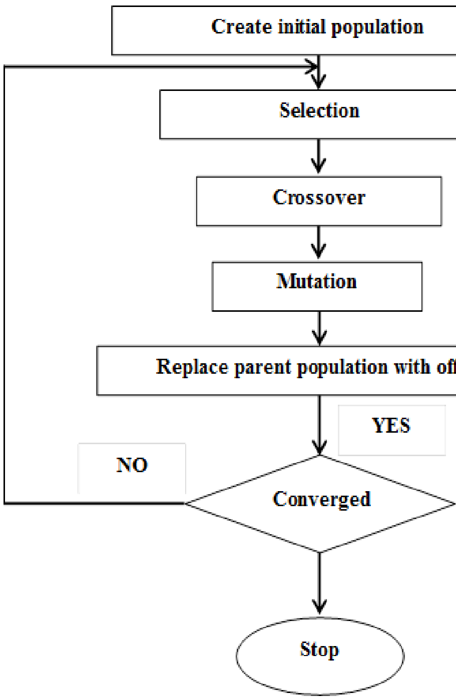


Fig. 3 Flow Chart of Genetic Algorithm

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 and 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 Eq. (5)
4. Calculate the power in MW generated from the decoded population by using Eq. (9)

   $P_i^j = P_i^{min} + \frac{P_i^{max} - P_i^{min}}{2^l - 1} y_i^j \quad (i = 1,2, \dots \dots . L)$ (7)

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

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

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

   , then set $P_i^j = P_i^{min}$
6. Find fitness if $(f_j > f_{max})$ then $f_{max} > f_j$ 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 the 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.

V. NUMERICAL RESULTS AND DISCUSSION

The result of ELD after the implementation of proposed GA method is discussed. The programs are implemented in MATLAB 13 The performance is evaluated without considering losses using 6 generator.

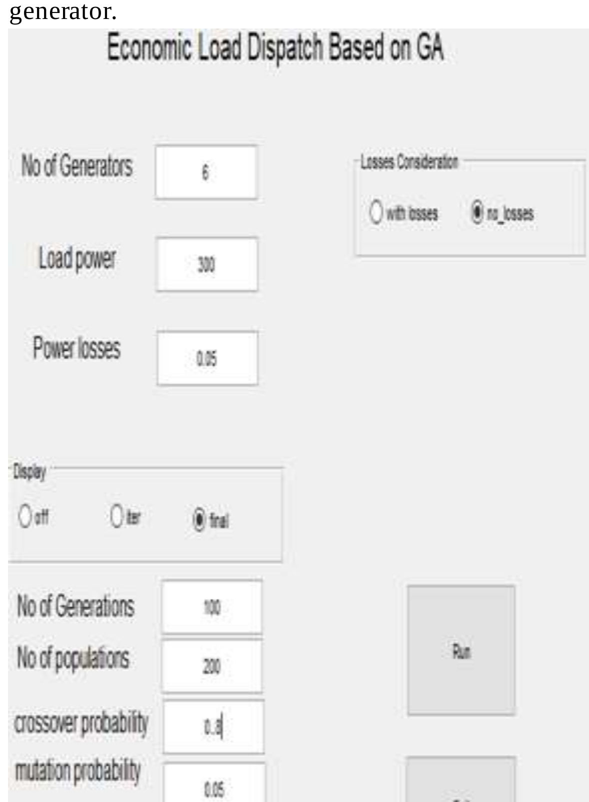


Fig. 3 Simulation of Economic Load Dispatch of the Power System using GA

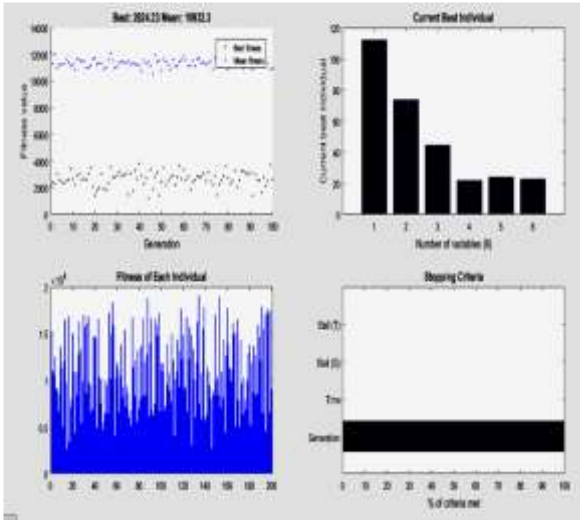


Fig. 4 Simulation of the GA showing Fitness Value, best cost and convergence

unit	a	b	c	d	e	f	Pmin	Pmax
1	0.00375	2	0	0.0126	1.1	22.983	50	200
2	0.0175	1.75	0	0.02	0.1	22.313	20	80
3	0.0625	1	0	0.027	0.1	25.505	15	50
4	0.00834	3.25	0	0.0291	0.005	24.9	10	35
5	0.025	3	0	0.029	0.04	24.7	10	30
6	0.025	3	0	0.0271	0.0055	25.3	12	40

Table 1. Generalized cost coefficients and Generator Limits for IEEE 30 Bus system

P_d MW	P_1 MW	P_2 MW	P_3 MW	P_4 MW	P_5 MW	P_6 MW	P_{loss} MW	Cost $/h
300	130.5825	68.56663	29.79104	25.41387	21.91182	23.7342	5.40191	863.6406
250	166.1875	23.28808	18.40897	13.19173	13.50654	15.417	6.429	667.376
200	113.0432	24.04951	18.618	14.35935	13.60948	16.3201	3.2221	337.9754

Table 2. The Results of Economic Load dispatch with loss

P_d MW	P_1 MW	P_2 MW	P_3 MW	P_4 MW	P_5 MW	P_6 MW	Cost $/h
300	85.8496	77.0393	45.8262	31.0261	24.3243	35.9838	952.0482
250	153.3677	24.96342	20.00968	17.42255	16.68156	17	668.9483
200	117.6158	22.7334	18.25042	12.79933	13.52502	15.12	514.1901

Table 3 The Results of Economic Load dispatch without loss

B_{ij} =

0.000218	0.000103	0.000009	-0.00001	0.000002	0.000027
0.000103	0.000181	0.000004	-0.000015	0.000002	0.00003
0.000009	0.000004	0.000417	-0.000131	-0.000153	-0.000107
-0.00001	-0.000015	-0.000131	0.000221	0.000094	0.00005
0.000002	0.000002	-0.000153	0.000094	0.000243	0
0.000027	0.00003	-0.000107	0.00005	0	0.000358

B_{0i}	-0.000003	0.000021	-0.000056	0.000034	0.000015	0.000078

B_{00}	0.000014

Table 4 Generalized loss coefficients of IEEE 30 Bus System

Demand Power MW	Fuel Cost $/h (previous work)	Fuel Cost $/h (proposed work)
300	884.66	863.64
250	699.32	667.376
200	523.93	514.1901

Table 5. The cost comparison for the previous research and the proposed Genetic Algorithm (with loss)

VI. CONCLUSION

One can clearly see the comparative results between the previous research work and our proposed work based on the genetic algorithm. Load dispatch problems aim to minimize the cost . A power system should be optimized periodically depending on its algorithm and on its frequency of demand power changes to have best results in long term. In this study, economic load dispatch including and neglecting line losses are simulated and solved on IEEE 30 Bus System by using GA. According to generator limits of the power system, three different situations in which demand power is 200 MW, 250 MW and 300 MW are considered in order to obtain realistic results.

Genetic algorithm is preferred for this study. Algorithm does not search for a solution from a certain point and has a low chance to cause fault optimization by sticking to a local maximum or minimum on a wide solution set. Algorithm is used with binary encoding, elitist selection, single-point crossover and bit string mutation. However as seen in comparisons of results obtained from this study and previous researches, genetic algorithm with value encoding which is more complicated gives better results compared to the algorithm with binary encoding.

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