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Genetic Algorithm for Solving the Economic Load Dispatch

Satyendra Pratap Singh[1], Rachna Tyagi[2] and Anubhav Goel[3]

[1]*Research Scholar, Electrical Engineering Department, IIT (BHU) Varanasi, UP*
[2]*Asst. Prof. Electrical Engineering Department, AITM Varanasi, UP*
[3]*Lecturer, Electronics and Communication Engineering, JPIET Meerut, UP*
E-mail: [1]spsingh.rs.eee@iitbhu.ac.in, [2]er.rachnatyagi@gmail.com,
[3]anubhavgoel207@gmail.com

Abstract

In this paper, comparative study of two approaches, Genetic Algorithm (GA) and Lambda Iteration method (LIM) have been used to provide the solution of the economic load dispatch (ELD) problem. The ELD problem is defined as to minimize the total operating cost of a power system while meeting the total load plus transmission losses within generation limits. GA and LIM have been used individually for solving two cases, first is three generator test system and second is ten generator test system. The results are compared which reveals that GA can provide more accurate results with fast convergence characteristics and is superior to LIM.

Keywords: Economic load dispatch, genetic algorithm, lambda iteration method, generator systems.

1. 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].

ELD is the very huge topic and lots of research works have been done in this area. In [3], an arithmetic crossover GA has been proposed to solve the ELD problem. In

[4], a hybrid method which is the combination of GA and fuzzy logic is used to optimize the cost of generation.

2. Economic Load Dispatch

The minimization of objective function is the primary concern of an ELD problem. The objective function meets the demand of generation and satisfies all other constraints. Mathematically objective function of ELD problem with constrained optimization problem is

$$F_T = \sum_{i=1}^{N} F_i(P_i) \quad (1)$$

F_T is the total generation cost; N is the total number of generating units; F_i is the power generation cost function of the i_{th} unit. The total cost of operation includes the fuel cost, costs of labour, maintenance and supplies. Mostly, costs of labour, supplies and maintenance are fixed percentages of incoming fuel costs. Now assume that the variation of fuel cost of each generator with the active power output is given by a quadratic polynomial

$$F_i P_i = \sum_{i=1}^{NG} (a_i P_i^2 + b_i P_i + c_i) \quad \frac{Rs}{hr} \quad (2)$$

Where, P_i is power output of generator i; a_i, b_i, and c_i are cost coefficients.

The ELD problem is defined as to minimize the total operating cost of a power system while meeting the total load plus transmission losses within generator limits.

Subject to (1) the energy balance equation

$$\sum_{i=1}^{NG} P_i = P_D + P_L \quad (3)$$

(2) the inequality constraints

$$P_{i(min)} \leq P_i \leq P_{i(max)} \quad (4)$$

Where P_L is the power transmission loss.

3. LIM for the Solution of the ELD Problem

The LIM is the most popular method for the solution of the economic load dispatch problem. It gives a decentralized solution to the ELD problem by equating the marginal cost of generation of each thermal unit to the price of electricity, or, equivalently, the marginal revenue of each unit under perfect competition conditions, known as system lambda [5].The minimum and maximum lambda values are initially computed,

$$\lambda_{min} = min_{i=1,n} \left\{ \frac{dF_i(P_{i,min})}{dP_i} \right\} \quad (5)$$

$$\lambda_{max} = max_{i=1,n} \left\{ \frac{dF_i(P_{i,max})}{dP_i} \right\} \quad (6)$$

The initial value chosen for lambda is the mid-point of the interval (λ_{min},λ_{max}), i.e,

$$\lambda = \frac{\lambda_{min} + \lambda_{max}}{2} \quad (7)$$

4. Genetic Algorithm

The GA is a stochastic global search method that mimics the metaphor of natural biological evolution such as selection, crossover, and mutation [6-7]. GA's work on string structures where string is binary digits which represent a coding of control parameters for a given problem. All parameters of the given problem are coded with strings of bits. The individual bit is called 'gene' and the content of the each gene is called 'allele'. Typically, the genetic algorithms have three phases initialization, evaluation and genetic operation. The fitness function for the maximization problem is

$$f(x) = F(x) \tag{8}$$

and for the minimization problem is

$$f(x) = \frac{1}{(1+F(x))} \tag{9}$$

Where f(x) is fitness function and F(x) is objective function.

In genetic operation phase, we generate a new population from the previous population using genetic operators. They are reproduction, crossover and mutation. Reproduction is the operator used to copy the old chromosome into matting pool according to its fittest value. Higher the fitness of the chromosome more is number of the copies in the next generation chromosome.

The various methods of selecting chromosomes for parents to crossover are roulette-wheel selection, boltzmann selection, tournament selection, rank selection, steady state selection etc. The commonly used reproduction operator is the roulette-wheel selection method where a string is selected from the mating pool with a probability proportional to the fitness [10]. The roulette-wheel mechanism is expected to make f_i / fit_{avg} copies of i_{th} string of the mating pool. The average fitness is

$$fit_{avg} = \sum_{j=1}^{n} \frac{\bar{f}_j}{n} \tag{10}$$

The basic operator for producing new chromosome is crossover. In this operator, information is exchanged among strings of matting pool to create new strings. The final genetic operator in the algorithm is mutation. In general evolution, mutation is a random process where one allele of a gene is replaced by another to produce a new genetic structure. Mutation is an important operation, because newly created individuals have no new inheritance information and the number of alleles is constantly decreasing.

5. Results and Discussions

The GA and classical method (lambda iteration) are used to solve ELD problems and results are discussed and compared. The algorithms are implemented in MATLAB to solve ELD problem. The main objective is to minimize the cost of generation of thermal plants using GA and classical Lambda Iteration Method. The performance is evaluated with losses for two set generator data, which are referred as Problem I and Problem II.

Problem I: Three generator test systems [9]

Problem II: Ten generator test systems [8]

For GA problem assume the length of the string, l is 16, population of string, *pop* is 20, crossover probability, p_c is 0.8 and mutation probability, p_m is 0.01.

6. Problem I: Three generator test systems

The coefficients of fuel cost are given below in Table 1. The power demand is considered to be 300MW. The results corresponding to LIM and GA for problem I are detailed in Table 2.

Table 1: Coefficients of Fuel Cost for Three generator test systems

Unit No.	a_i	b_i	c_i
1	0.00525	8.66	328.13
2	0.00609	10.040	136.91
3	0.00592	9.760	59.16

Table 2: Three Generator Test Results (P_D = 300 MW)

	LIM	GA
P_1	202.49	202.464
P_2	81.0267	80.9787
P_3	27.0149	27.0799
Fitness	-	0.999957
Losses	10.5311	10.5354
Error	0.000652	0.0129291
Total cost	3615.11	3614.95

Developed program returns the generated power, total cost, total losses and error.

7. Problem II: Ten generator test systems

Again the proposed technique has been performed on a sample system which consists of ten generator system. The power demand is considered to be 1440MW. Transmission loss coefficients are given in Table 3 [8]. The results corresponding to LIM and GA for problem II is detailed in table 4.

Table 3: Coefficients of Fuel Cost for Ten generator test systems.

Unit no.	a_i	b_i	c_i
1	0.001220	7.92	630
2	0.004700	7.91	190
3	0.001320	7.93	625
4	0.001153	7.92	723
5	0.001154	7.93	717
6	0.001562	7.92	561
7	0.001153	7.92	723
8	0.001321	7.91	618
9	0.001319	7.00	561
10	0.001530	7.00	561

Table 4: Ten Generator Test Results (P_D = 1440 MW).

	LIM	GA
P_1	160	160
P_2	65	65
P_3	150	150
P_4	170	170
P_5	160	160
P_6	130	130
P_7	170	170
P_8	145	145
P_9	140	140
P_{10}	163.926	163.981
Fitness	-	0.999976
Losses	13.9357	13.9261
Error	0.026341	0.0345486
Total cost	17608.4	17607.7

8. Conclusion

In this paper, Genetic Algorithm and Lambda Iteration method have been successfully implemented to obtain the optimum solution of ELD. Due to the large variation in load from time to time and it is not possible to have the load dispatch for every possible load demand. Since there is no general procedure for find out the optimum solution of economic load dispatches. This is where GA plays an important role to find out the optimum solution in a fraction of second.

For the testing of GA and LIM, three generators and ten generators test systems are used. The results obtained from both methods are compared with each other. It is found that GA is giving better results than LIM. i.e. GA proves itself as fast algorithm and yields true optimum generations of both operating costs and transmission line losses of the power system.

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