

Analysis and Comparison of Conventional Methods and Artificial Intelligence Techniques to Solve the Economic Load Dispatch Problem

S. Vairamuthu¹, K. Kaaviya Lakshmi², B. Jeevitha³

Assistant Professor, Department of EEE, University College of Engineering, Pattukkottai, Tamilnadu, India¹

U.G Student, Department of EEE, University College of Engineering, Pattukkottai, Tamilnadu, India^{2,3}

ABSTRACT: Economic Load Dispatch (ELD) problem is one of the most important ones in Power system operation and Planning. The main objective of the ELD problem is to determine the Optimal combination of power outputs of all generating units so as to meet the required demand at minimum cost while satisfying the Constraints. This project endeavours to tackle the ELD problem, whose Scheduling is done over a time period of hours with the sole purpose of minimizing the expecting cost of operation of power plants while providing Reliable and Robust power to consumer within given set of system and operational constraints. In this thesis, the three main Optimization techniques of both Conventional method and Artificial Intelligence techniques namely Analytical method, Lambda-Iteration method and Genetic Algorithm (GA) are analysed. And at the last the comparison between all the three methods have been presented with a conclusion of “The GA provides better Optimization than any other Conventional methods”.

KEYWORDS: Economic load dispatch, Fuel cost function, Constraints, Lambda-Iteration method, Genetic Algorithm.

I. INTRODUCTION

Economic Load Dispatch is a Constrained multi-objective Combinatorial problem that can be solved by both Mathematical optimization and Heuristic methods. Mathematical optimization techniques includes Analytical method, Lambda-Iteration method etc. and Heuristic techniques that have been adopted in solving ELD problem includes Genetic Algorithm, Particle SWARM optimization etc. [15]

Most Mathematical based algorithms can guarantee reaching Optimal solution while do not necessarily guarantee reaching a Global optimum. Global optimality may be only reached, checked or guaranteed for simple cases. On the other hand, many practical optimization problems do not fall in strict forms and assumptions of Mathematical based algorithms [1]. Moreover if the problem is highly complex we may not readily be able to solve them at all, through mathematical algorithms. Besides finding global optimum is of interest, as finding a local one would be a major drawback. These drawbacks are tackled by employing Heuristic techniques. The Objectives are to come up with a solution of Effectively and Efficiently solves the ELD problem. [14]

II. ECONOMIC LOAD DISPATCH

The definition of ELD is “The operation of generation facilities to provide energy at the lowest cost to reliably serve consumers, recognizing any operational limits of generation and transmission facilities”. The ELD can also be defined as the process of allocating generation levels to the generating units in a mix, so that the system load can be supplied entirely and most economically. For an interconnected system, it is necessary to minimize the expenses. The ELD 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.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

The objective of ELD is to minimize the overall cost of generation. The method of ELD for generating units at different loads must have total fuel cost at the minimum point. In a typical power system, multiple generators are implemented to provide enough total output to satisfy a given total consumer demand. Each of these generating stations can, and usually does, have a unique cost per hour characteristics for its output operating range. In the Load Dispatching, the operation of a modern power system has become very complex. It is necessary to maintain frequency and voltage within limits in addition to ensuring reliability of power supply and to match the generation of active and reactive power with the load demand. [2]

In a practical power system, the power plants are not located at the same distance from the centre of loads and the fuel costs are different. Also under normal operating, the generation capacity is more than the total demand and losses. Thus, there are many options for scheduling generation. In an interconnected power system, the objective is to find the real and reactive power scheduling of each power plant in such a way so as to minimize the operating cost. This means that the generators real and reactive powers are allowed to vary within certain limits so as to meet a particular load demand with minimum fuel cost. This is called the “ECONOMIC LOAD DISPATCH problem” [1] [3].

III. CONVENTIONAL METHODS

Electrical power systems are designed and operated to meet the continuous variation of power demand. With large interconnection of the electrical networks, the energy crisis in the world and continuous rise in prices, it is very essential to reduce the running cost of electrical energy. A saving in the operation of the power system brings about a significant reduction in the operating cost as well as in the quantity of fuel consumed. Now we can have a brief study on Analytical method and Lambda-Iteration method to solve the problem of ELD. The input-output curve of a generating unit specifies about the fuel cost per hour as the function of generating power output in fig1. [5]

3.1 ANALYTICAL METHOD

The Analytical method of solving ELD is a simple process which involves finding of incremental fuel cost (λ) and the process continues with the execution of determined incremental fuel cost to find the power generation of the i th generators. The incremental fuel cost is nothing but the ratio of small change in input to the small change in output. Finally the fuel cost of each generators can be found with the help of generated power in each generators. [1] [3]

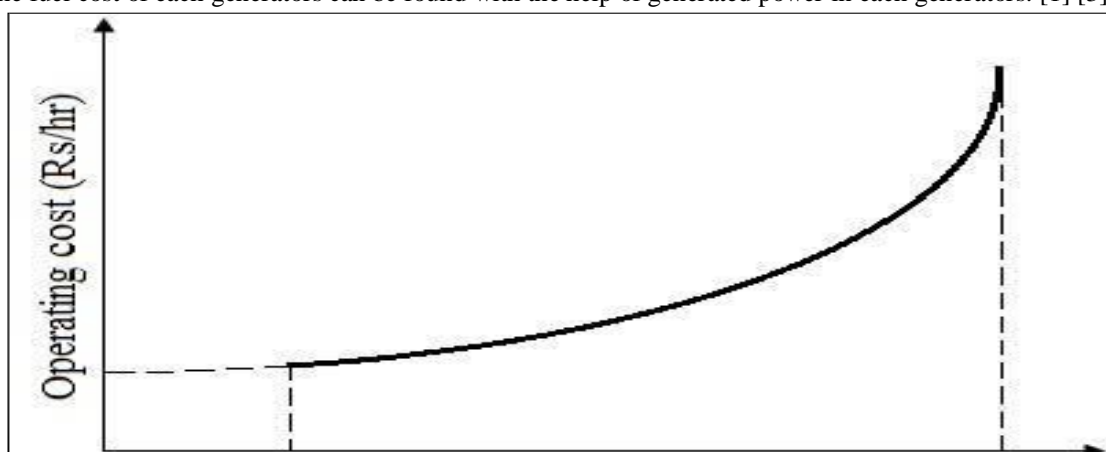


Fig 1 Input-output curve of the generating unit

3.1.1 ALGORITHM FOR ANALYTICAL METHOD

1. Read the given values of cost coefficients a_i , b_i , c_i , power demand P_d , maximum and minimum power of generators P_{max} , P_{min} .

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

2. Cost function $C = a_i P_{gi}^2 + b_i P_{gi} + C_i$
3. Calculate the value of incremental fuel cost (λ)
$$\lambda = [P_d + \sum (b_i/2a_i)] / [\sum (1/2a_i)]$$
4. Using the value of incremental fuel cost, calculate the values of the power generation of each generators
$$P_{gi} = [\lambda - b_i] / [2a_i]$$
5. Check the values of power generation with minimum and maximum constraints of the generator
$$P_{gi,min} \leq P_{gi} \leq P_{gi,max}$$
6. If P_{gi} violates the operating limits, then fix the generation at the respective limit
$$P_{gi} < P_{gi,min} \text{ , fix } P_{gi} = P_{gi,min}$$

$$P_{gi} > P_{gi,max} \text{ , fix } P_{gi} = P_{gi,max}$$
7. By P_{gi} values, calculate the values of fuel cost of each generators
8. Stop the program.

3.2 LAMBDA-ITERATION METHOD

The Lambda-Iteration method of solving the problem of ELD involves change in the value of the incremental fuel cost for each iterations to set a minimum fuel cost. This procedure involves iterative type of commutations. This procedure converges very rapidly for the optimization problem. The actual computational procedure is slightly more complex than the Analytical method because they are used to project the incremental cost value to drive the error between the computed and desired generation to zero.

3.2.1 ALGORITHM FOR ANALYTICAL METHOD

1. Read the given values of cost coefficients a_i , b_i , c_i , power demand P_d , maximum and minimum power of generators P_{max} , P_{min} .
2. Cost function $C = a_i P_{gi}^2 + b_i P_{gi} + C_i$
3. Calculate the value of incremental fuel cost (λ)
$$\lambda = [P_d + \sum (b_i/2a_i)] / [\sum (1/2a_i)]$$
4. Using the value of incremental fuel cost, calculate the values of the power generation of each generators
$$P_{gi} = [\lambda - b_i] / [2a_i]$$
5. Check the values of power generation with minimum and maximum constraints of the generator
$$P_{gi,min} \leq P_{gi} \leq P_{gi,max}$$
6. If P_{gi} violates the operating limits, then fix the generation at the respective limit
$$P_{gi} < P_{gi,min} \text{ , fix } P_{gi} = P_{gi,min}$$

$$P_{gi} > P_{gi,max} \text{ , fix } P_{gi} = P_{gi,max}$$
7. Redistribute the remaining system load P_d
$$P_{d,new} = P_{d,old} - \text{sum of the fixed generations to the remaining units}$$
8. Compute λ new using $P_{d,new}$ and compute the remaining generations using
$$P_{gi,new} = [\lambda_{new} - b_i] / [2a_i]$$
9. Check whether the optimality condition is satisfied i.e.,
$$\frac{dF_i(P_{gi})}{dP_{gi}} = \lambda_{new} \text{ for } P_{gi,min} \leq P_{gi} \leq P_{gi,max}$$

$$\frac{dF_i(P_{gi})}{dP_{gi}} \leq \lambda_{new} \text{ for } P_{gi} = P_{gi,max}$$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

$$\frac{dFi(Pgi)}{dPgi} \leq \lambda_{\text{new}} \text{ for } Pgi = Pgi, \text{min}$$

10. If the condition is satisfied, then stop. Otherwise release the generation schedule fixed at Pgi,min or Pgi,max of those units not satisfying optimality condition. Include these units in the remaining units and modify the new power demand (Pd new)

Pd new1 = Pd new + sum of the fixed generators not satisfying optimality condition

and go to step (8).

IV. ARTIFICIAL INTELLIGENCE TECHNIQUES

The Artificial Intelligence techniques are also called as Heuristic methods which are employed to tackle the problem of ELD. The brief study of Genetic Algorithm and the comparison of Conventional methods and Artificial Intelligence techniques are also presented to demonstrate that Genetic Algorithm provides better optimization technique than any other Conventional methods. [7]

Genetic Algorithm (GA) is based on conjunction of natural selection (survival of the fittest) and genetics. GA was developed by John Holland in 1960s. The decision variables to be found are in the form of string of genes. This string is called problem chromosome, selected from the set of population. The objective function calculated for this chromosome is called problem fitness function. Next population (off-springs) are generated from initial chromosomes (parents). This regeneration results in chromosomes with a better fitness value. [8] [11]

GA depends on selection, crossover and mutation. Population of chromosomes is initially generated. Then two chromosomes are considered as parents based on the fitness value. Crossover is used to generate off-springs from the two parents by interchanging the value of genes at specific positions. Mutation curbs the drawback of the value of a given gene not changing during crossover. Mutation operator tries to alter the value of a gene randomly. A summary of GA approach is made below. [2] [9]

1. Randomly **generate an initial solution** population
2. **Evaluate** these solutions for fitness
3. If iteration/time constraints are **not yet satisfied**
4. **Select parents** (best solution so far)
5. **Recombine parents** using portions of initial solutions (crossover)
6. **Add possible** random solutions (mutation)
7. **Evaluate new solution** for fitness then return to step 3

In recent times, GA has become the most popular algorithm for solving ELD. GA has the following advantages: ease of coding, inherent parallelism, the use of genotype instead of phenotype moves the search from local minima. However, GA requires intensive computational time making the optimization process slow. GA is suited for optimization of multi-modal functions in highly complex and nonlinear landscape, especially when the function does not have an analytic description and is noisy and discontinuous and such is the nature of ELD problem. [4] [12]

4.1 ALGORITHM FOR GENETIC ALGORITHM

The step-wise procedure is outlined below

1. Read data, namely cost coefficients ai, bi, ci, number of iterations, length of the string, population size, probability of crossover and mutations, power demand, Pmin and Pmax
2. Create the initial population randomly in the binary form
3. Decode the string, or obtain the decimal integer from the binary string

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

4. Calculate the power generated from the decoded population

$$P_i^j = P_i^{\min} + \frac{P_{\max} - P_{\min}}{2l - 1} Y_i^j \quad (i=1,2,\dots,NG) \quad (j=1,2,\dots,L)$$

Where L is the number of strings or population size, Y_i^j is the binary coded value of the i th substring

5. Check P_i^j
 - If $P_i^j > P_{\max}$, then set $P_i^j = P_{\max}$
 - If $P_i^j < P_{\min}$, then set $P_i^j = P_{\min}$
6. Find the fitness or cost function
 - If $F_j < F_{\min}$, then set $F_j = F_{\min}$
7. Find population with maximum fitness and average fitness of the population.
8. Perform the Reproduction Process, which includes the following steps:
 - 8(a). Set selection rate and number of mating in a pool.
 - 8(b). Define total fitness as sum of values obtained by using above step for all chromosomes which are selected.
 - 8(c). Select percentage of each chromosome which is equal to the ratio of its fitness value to the total fitness value, i.e. find probability which can be written as,

$$\text{Probability} = \text{fitness} / \sum \text{Fitness's.}$$
 - 8(d). Calculate cumulative sum (CS) to normalize the values between 0.0 and 1.0.
9. Perform Crossover Process:
 - 9(a). Choose a pair of random numbers between 0 and 1 to select one mother and one father chromosome, so as to produce new offspring.
 - 9(b). Pairing the chromosomes from different location, for different locations, crossover point has to be selected which can be selected randomly. Generate offspring by applying crossover.
10. Perform mutation by randomly selecting the mutation points from the total number of bits in the population matrix.
11. Update the population.
12. If the number of iterations reaches the maximum, then go to step 13.
Otherwise, go to step 6.
13. The fitness that generates the minimum total generation cost is the solution of the problem.

V. RESULTS AND DISCUSSION

In this session, the scheduling is done for a set of SIX generators with a power demand of 700MW without considering the losses. The analysis is done in all the three methods by using MATLAB 7.6.0 and the given data is shown in table 1.

Generators	Pmin	Pmax	A	B	C
1	100	500	0.007	7	240
2	50	200	0.0095	10	200
3	80	300	0.009	8.5	300
4	50	150	0.009	11	150
5	50	200	0.008	10.5	200
6	50	120	0.0075	12	120

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

Analytical	Lambda-Iteration	Genetic Algorithm
------------	------------------	-------------------

Table 1 Specifications for a six generator test system

Generator	Pgi (MW)	Fgi (Rs/hr)	Pgi (MW)	Fgi (Rs/hr)	Pgi (MW)	Fgi (Rs/hr)
1	103.9140	1042.985	236.7831	2289.945	311.6196	3101.085
2	124.6893	1594.594	95.5244	1241.931	69.5837	941.835
3	113.3573	1299.186	142.4980	1613.984	157.7193	1784.492
4	124.6868	1711.476	73.0535	1051.620	52.7237	804.979
5	113.3527	1512.994	97.8102	1323.542	55.7516	830.258
6	120.0000	1668.000	54.3309	794.110	53.1872	779.463
Total	700	8829.235	700	8315.132	700.585	8242.112

Table 2 Outputs of Analytical, Lambda-Iteration and Genetic Algorithm methods

The programmed outputs of all the three methods are presented in the table 2. From the outputs, it is clear that on comparing the results of Analytical method and Lambda-Iteration method the better optimization is done with the Lambda-Iteration method and a profitable cost of Rs.514.103/hr is saved. On comparing the results of Analytical method and GA, the better optimization is done with the GA method with a profitable cost of Rs.587.123/hr. On comparing the outputs of Lambda-Iteration methods and GA, the better optimization is done with the GA method with a profitable cost of Rs.73.020/hr. Hence we can conclude that the better optimization is done in Genetic Algorithm on comparing with any other conventional method. The simulated output of GA is shown in the figure 2. The graphical representation of the outputs are in figure 3.

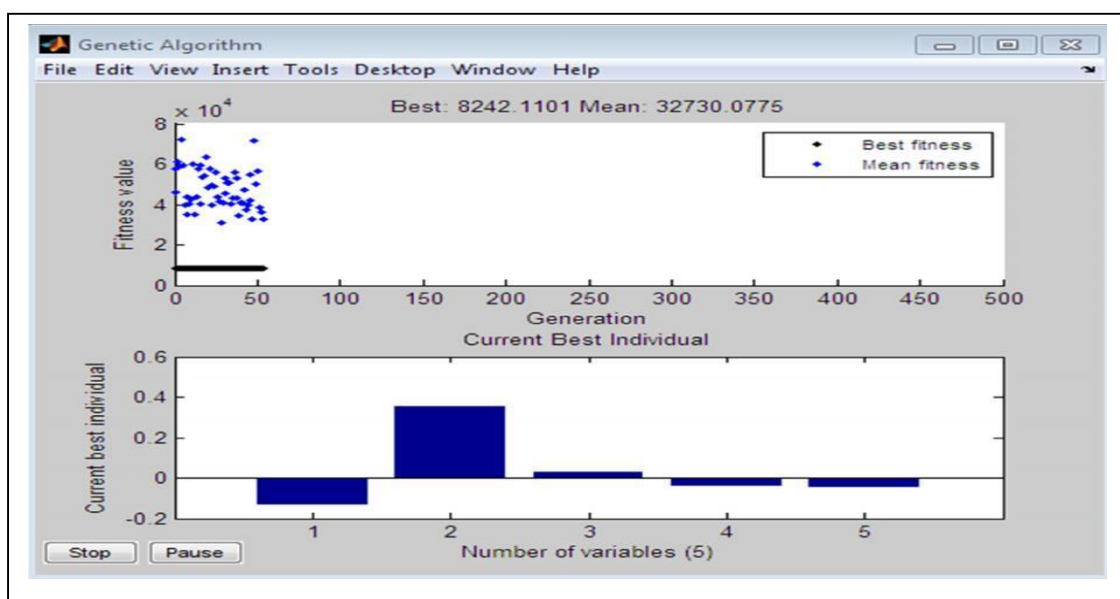


Figure 2 Output of Genetic Algorithm

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

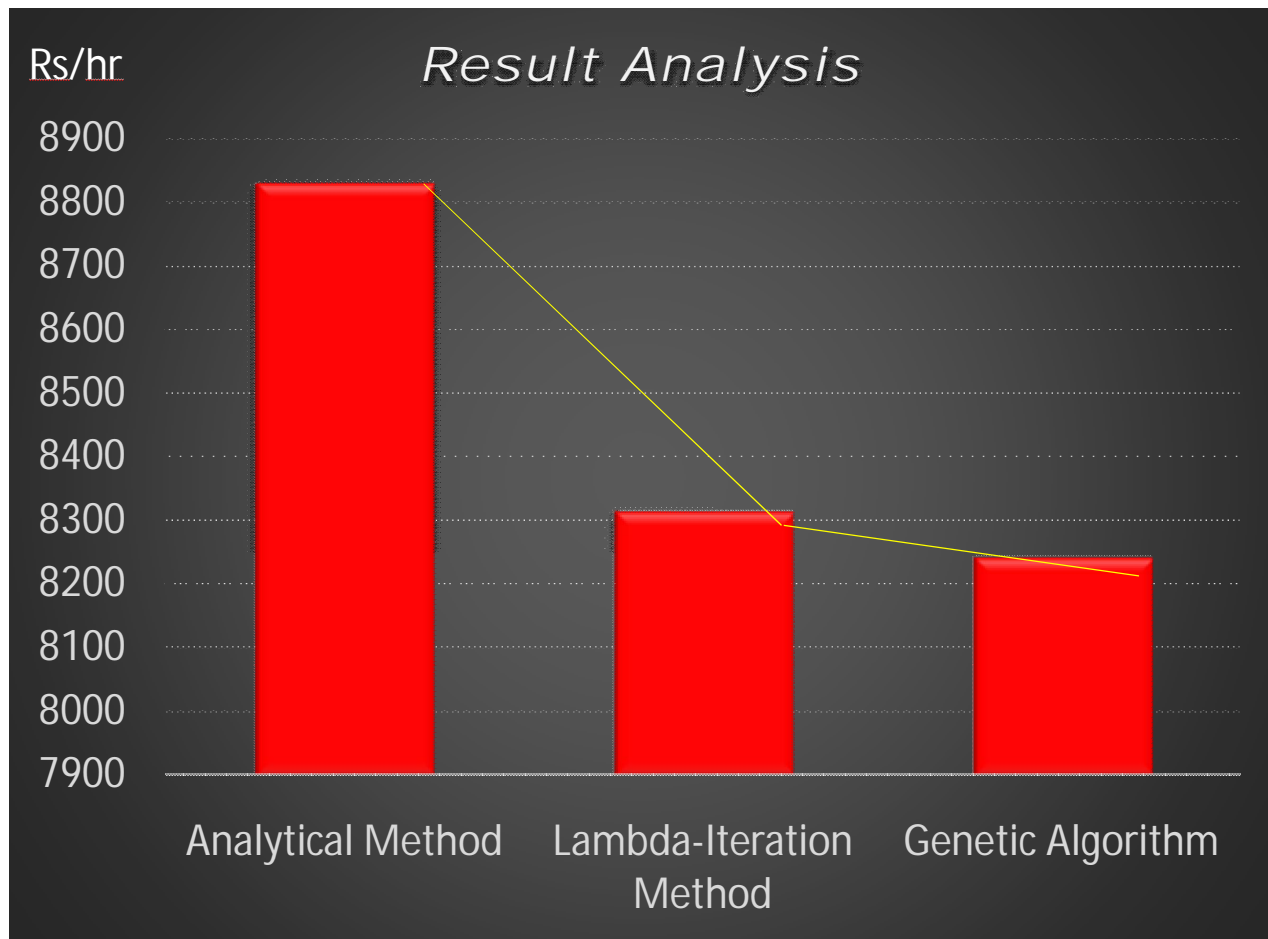


Figure 3 Graphical Representation of the three outputs

VI. CONCLUSION

In this thesis, the formulation and implementation of solution methods to obtain the optimum solution of Economic Load Dispatch problem using Genetic Algorithm, Lambda iteration method and Analytical method is carried out. From the programmed outputs of all the three methods using MATLAB 7.6.0, we can conclude that **“Genetic algorithms are a powerful and robust optimization technique than any other conventional methods”**

REFERENCES

- [1] 1.Allen J. wood and Wollenberg B.F., “Power generation, operation and control” published by John wiley and sons, Newyork, 1984.
- [2] 2.Sivanandam S.N. and Deepa S.N., “Introduction to genetic algorithms” published by Springer berlin Heidelberg, Newyork, ISBN-978-3-540-73189-4.
- [3] 3.Malla reddy N., Ramana N.V., Ramesh reddy N., “Detailed literature survey on different methodologies of Unit commitment” published in International journal of theoretical and applied information technology(IJTAIT),ISSN-1992-8645.
- [4] 4.Lily chopra, Raghuwinder kaur, “Economic load dispatch using simple and refined Genetic algorithm” published in International journal of advances in engineering and technology(IJAET),ISSN-2231-1963.
- [5] 5.Mohammed Asif Iqbal, “Analysis and comparison of Lambda-iteration method, Genetic algorithm and Particle swarm optimization to solve economic load dispatch problem” published in International journal of software and web services(IJSWS),ISSN-2279-0063.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

- [6] 6.Devendra bisen, Hari mohan dubey, Manjaree pandit, Panigrahi B.K., "solution of large scale economic load dispatch problem using Quadratic programming and GAMS: a comparative analysis" published by International journal of information and computer science(IJICS),England,UK,ISSN-1746-7659.
- [7] 7.Bishnu sahu, Avipsa lall, Soumya das, Manoj patra, "Economic load dispatch in Power system using Genetic algorithm" published in International journal of computer applications(IJCA),ISSN-0975-8887.
- [8] 8.Naveen kumar, Singh parmar K.P., Surender dahiya, "A Genetic algorithm approach for the solution of economic load dispatch problem" published in Inter-national journal on computer science(IJCS),ISSN-0975-3397.
- [9] 9.Arunpreet kaur, harinder pal singh, Abhishek Bhardwaj, "Analysis of economic load dispatch using Genetic algorithm" published in International journal of application or innovation in engineering and management(IJAIEM),ISSN-2319-4847.
- [10] 10.Patel F.M., Panchal N.B., "The MATLAB solution of mathematic equation using Genetic algorithm for optimum result" published in International global journal for research analysis(IGJRA), ISSN-2277-8160.
- [11] 11.Satyendra pratap singh, Rachna tyagi, Anubhay goel, "Genetic algorithm for solving economic load dispatch" published in International journal of electrical and electronics engineering(IJEEE),ISSN-0974-2174.
- [12] 12.Anuj gargeya M., Sai premnath pabba, "Economic load dispatch using Genetic algorithm and pattern search methods" published in International journal of advanced research in electrical,electronics and instrumentation engineering (IJAREEIE),ISSN-2320-3765.
- [13] 13.Chiragkumar K.patel,Prof.Mihir B., "Economic load dispatch using Genetic algorithm" published in Indian journal of applied research(IJAR),ISSN-2249-555X.
- [14] 14.Chowdhury B.H. Salfur Rahman, "A review of recent advances in economic dispatch" published in IEEE transactions of power system volume5,no.4,nov1990.
- [15] 15.Jagabondhu hazra, Avinash Sinha, "Applications of soft computing methods for economic dispatch in power system" published in International journal of electrical and electronics engineering(IJEEE).
- [16] 16.Purohit G.N., Arun mohan sherry, Manish saraswat, "Optimization of function by using a new MATLAB based genetic algorithm procedure" published in International journal of computer applications,ISSN-0975-8887.