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Optimal solution for Economic Load Dispatch using Genetic Algorithms

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ABSTRACT

In a practical power system, the power plants are not located at the same distance from the center of loads and their fuel costs are different. Also, under normal operating conditions, the generation capacity is more than the total load demand and losses. Thus, there are many options for scheduling generation.In this paper, Economic Load Dispatch (ELD) of real power generation is considered. Economic Load Dispatch (ELD) is the scheduling of generators to minimize total operating cost of generator units subjected to equality constraint of power balance within the minimum and maximum operating limits of the generating units. In this paper, genetic algorithms are considered. ELD solutions are found by solving the conventional load flow equations while at the same time minimizing the fuel costs.

INTRODUCTION

The efficient and optimum economic operation of electric power systems has always occupied an important position in electric power industry. In recent decades, it is becoming very important for utilities to run their power systems with minimum cost while satisfying their customer demand all the time and trying to make profit. With limited availability of generating units and the large increase in power demand , fuel cost and supply limitation, the committed units should serve the expected load demand with the changes in fuel cost and the uncertainties in the load demand forecast in all the different time intervals in an optimal manner.

The basic objective of ELD of electric power generation is to schedule the committed generating unit outputs, so as to meet the load demand at minimum operating cost while satisfying all unit and system equality and inequality constraints. ELD involves different problems. The first is unit commitment or pre-dispatch problem where it is required to select optimally out of the available generating sources to meet the expected load and provide a specified margin of operating reserve over specified period of time. The second aspect of ELD is on-line economic dispatch where it is required to distribute load among the generating units actually parallel with the system in such a manner as to minimize the total cost of supplying power. In case of ELD, the generations are not fixed but they are allowed to take values again within certain limits so as to meet the particular load demand with minimum fuel consumption.

Theory of ELD

The economic load 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 schedule of load. The objective of ELD is to minimize overall cost of generation. The method of ELD for generating at different loads must have total fuel cost at the minimum point.In a power system, multiple generators are implemented to provide total output to satisfy a given total consumer load. Each of these generating stationshas a unique cost for over characteristic for its output operating range. A station has incremental operating cost for fuel and maintains and fixed cost associated with station its self that can be quite considerable in the case nuclear power plant.

Load Dispatching

The operation of modern power system has become very complex. It is necessary to maintain frequency and voltagewithin limits in addition to ensuring reliability of power supply and for maintain the frequency and voltage within limits it is essential to match generation of active and reactive power with the load demand. For ensuring reliability of power system it isnecessary to put additional generational generation capacity into the system in the event of outage of generating equipment at some station. The total interconnected network iscontrolled by the load dispatchcenter. The load dispatchcenter allocates the MW generation to each grid depending up on the prevailing MW demanding that area. Each load dispatchcenter control load and frequency of its own by matching generation in various generating stations with total required MW demand plus MW loss.

Therefore, the task of load center is to keep exchange of power between various zones and system frequency at desired values.

Generator Operating Cost

The total cost of operation includes the fuel cost, cost of labor, suppliers, andmaintenance. Generally cost of labor, suppliers and maintains are fixed percentages of incoming fuel cost. The power output of fossil plants is increased by opening set of valves to its steam turbine at the inlet

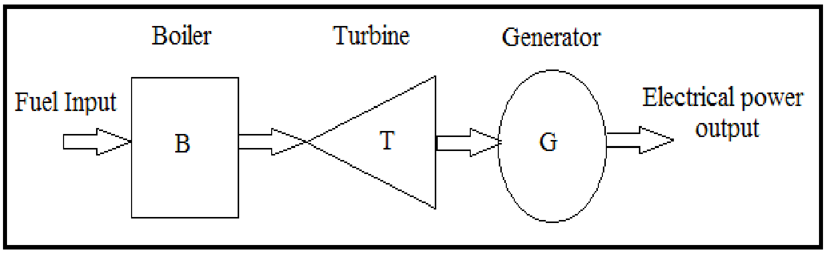

Fig 1:- Simple Model of a Fossil Plant

The above figure shows the simple model of a fossil plant dispatching purposes.The cost is usuallyapproximatedby one are more quadratic segments. The fuel cost curve in the active power generation, takes up a quadratic form given as

$$C_i = a_i + b_i P_i + c_i P_i^2 \text{ Rs/hr}$$

Where

a_i, b_i, c_i are cost co-efficients of i^{th} unit

$C_i$is the total cost of generation

$P_i$is the generation of i^{th} unit

Fuel Cost Curve

The fuel cost curve may have no of discontinuities. Thediscontinuities occur when the output power is extended by using additional boilers, steam condenser or otherequipment. They may also appear if the cost represents the operation of an entire power system and hence cost has discontinuities on paralleling of generators. Within the continuity range the incremental fuel cost may be expressed by a no of shot line or piecewise linearization

Incremental Fuel-Cost Curve

By plotting the derivative of the fuel-cost curve versus the real power we get the **incremental fuel-cost curve**

$$\frac{dC_i}{dP_i} = 2C_i P_i + b_i$$

In any plant, all units normally operate betweenP_{Gmin}, the minimum loading limit, below which it is technically infeasible to operate a unit and P_{Gmax}, which is the maximum output limit.

Economic Load Dispatch Problem

Economic Load Dispatch with Losses

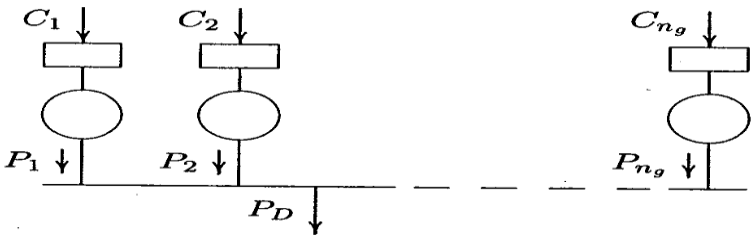

Fig 2:- Simple Power System Model

- It is the simplest economic dispatch problem
- Assume that the system is only one bus with all generation and loads connected to it
- A cost function C_i is assumed to be known for each plant
- The problem is to find the real power generation for each plant such that the objective function (i.e., total production cost) as defined by the equation
- When power is transmitted over long distances transmission losses are a major factor that affect the optimum dispatch of generation

- One common practice for including the effect of transmission losses is to express the total transmission loss as a quadratic function of the generator power outputs. The simplest quadratic form is

$$P_L = \sum_{i=1}^{n_g} \sum_{j=1}^{n_g} P_i B_{ij} P_j$$

The coefficients B_{ij} are called loss coefficients or B-coefficients

The economic dispatch problem is to minimize the overall generating costC_i, which is the function of plant output

$$C_t = \sum_{i=1}^{n_g} C_i$$

$=\sum_{i=1}^{n} \boldsymbol{a_i + b_i P_i + c_i P_i^2}$

Subject to the constraint that generation should equal total demand plus losses i.e..,

$\sum_{i=1}^{n_g} P_i = P_D + P_L$

Satisfying the inequality constraints, expressed as follows:

$P_{i(min)} \leq P_i \leq P_{i(max)}$ I = 1,2,…n_g

Using the lagrange multiplier

$$L = C_t + \lambda\,(P_D + P_L - \sum_{i=1}^{n_g} P_i)$$

Minimum of this function is found at the points where the partials of the function to its variables are zero

$$\frac{dL}{dP_i} = 0$$

$$\frac{dC_t}{dP_i} + \lambda\,(0 + \frac{dP_L}{dP_i} - 1) = 0$$

and therefore the condition for optimum dispatch is

$$\frac{dC_i}{dP_i} + \lambda\,\frac{dP_L}{dP_i} = \lambda \qquad i=1, 2\ldots n_g$$

The term $\frac{dP_L}{dP_i}$ is known as the incremental transmission loss

$$\frac{1}{1-\frac{dP_L}{dP_i}} \left(\frac{dC_i}{dP_i}\right) = \lambda \quad i=1, 2\ldots n_g$$

$$L_i \frac{dC_i}{dP_i} = \lambda$$

Genetic Algorithm Structure

A global optimization technique known as genetic algorithm has emerged as a candidate due to its flexibility and efficiency for many optimization applications. It is a stochastic searching algorithm. This method was developed by John Holland (1975). GA is inspired by the evolutionary theory explaining the origin of species. In nature, weak and unfit species within their environment are faced with extinction by natural selection. The strong ones have greater opportunity to pass their genes to future generations via reproduction. In the long run,species carrying the correct combination in their genes become dominant in their population. Sometimes, during the slow process of evolution, random changes may occur in genes. If these changes provide additional advantages in the challenge for survival, new species evolve from the old ones. Unsuccessful changes are eliminated by natural selection.

The Genetic Algorithm (GA) is a search heuristic that mimics the process of natural evolution. This heuristic is routinely used to generate useful solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover.

Genetic Algorithms are search mechanisms based on the Darwinian principle of natural evolution. They operate on the law of coincidence, which takes advantage of pre-information in order to derive improvement from it. Genetic Algorithms used for optimization are based on the principle of biological evolution. They are very different to many conventional methods in the sense that they simultaneously consider many possible solutions to the problem.

Genetic Algorithm vs Traditional Methods of Optimization

Genetic algorithms are based on the principles of natural genetics and natural selection. The basic elements of natural genetics: reproduction, crossover, mutation are used in the genetic search procedure. Genetic Algorithms differ from the traditional methods of optimization in the following respect:

1.) A population of points (trial design vectors) is used for starting the procedure instead of a single design point. If the number of design variables is n, usually the size of the population is taken as 2n to 4n. Since several points are used as candidate solutions, Genetic Algorithms are less likely to get trapped at a local optimum.

2.) Genetic Algorithms use only the values of objective function. The derivatives are not used in search procedures.

3.) In GAs the design variables are represented as strings of binary variables that correspond to the chromosomes in natural genetics. Thus the search method is naturally applicable for solving discrete and integer programming problems. For continuous design variables, the string length can be varied to achieve any desired resolution.

4.) The objective function value corresponding to design vector plays the role of fitness in natural genetics.

5.) In every new generation, a new set of strings is produced by using randomized parents selection and crossover from the old generation (old set of strings). Although randomized, GAs are not simple random search techniques. They efficiently explorethe new combination with the available knowledge to find the new generation withbetter fitness or objective function value.

The process of GA follows this pattern:-

1.) An initial population of a random solution is created.

2.) Each member of the population is assigned a fitness value based on its evaluation against the current problem.

3.) Solution with highest fitness value is most likely to parent new solutions during reproduction.

4.) The new solution set replaces the old, a generation is completed and the process continues at step (2).

Flow Chart of Genetic Algorithm

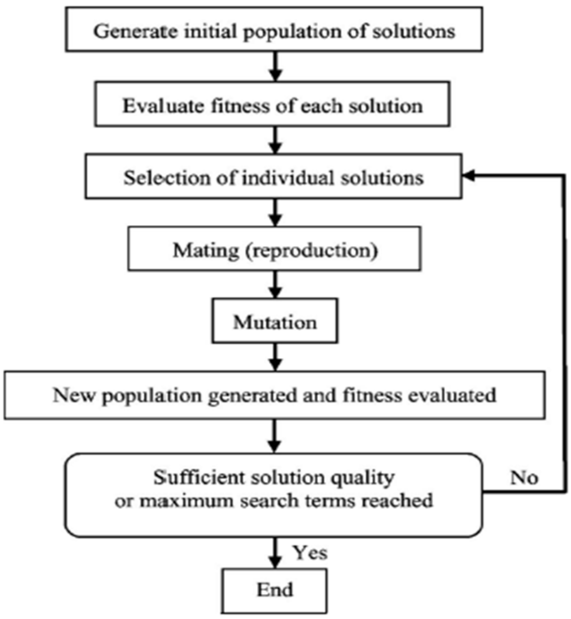

Fig 3:-Flow Chart of Genetic Algorithm

EXPERIMENTAL DIAGRAM AND RESULT:

CASE STUDY 1: THREE GENERATOR SYSTEM

The coefficients of fuel cost and minimum&maximum power limits are given in below table. The power demand is considered to be 150 (MW).

UNIT NO	a_i	b_i	c_i	P_{min} (MW)	P_{max} (MW)
1	0.008	7	200	10	85
2	0.009	6.3	180	10	80

3	0.007	6.8	140	10	70

Table 1:- Coefficients of Fuel Cost and Minimum & Maximum Power Limits of 3 Generator System

Total load = 150MW
The loss co-efficient are given by the matrix

B_{ij}= [0.000218 0.000093 0.0000287
0.000093 0.000228 0.000017
0.000028 0.000017 0.000179]

P1 (MW)	**32.8863**
P2 (MW)	**64.8209**
P3 (MW)	**54.6411**
TOTAL POWER LOSS(MW)	**2.3470**
TOTAL COST(Rs/hr)	**1598.8**

***Table2:-* Optimal Result of GA for Case Study 1**

Upon optimization of economic load dispatch of 3 generator system using genetic algorithm provides better results.

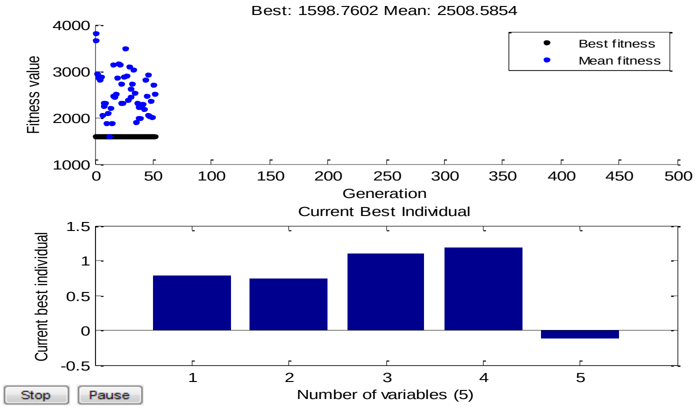

Fig 4:Results of GA for 3-Unit Gen System

The above graph clearly indicates that the best fitness for each generation remains same throughout the total generations denoted by a straight line and the mean fitness is shown by dotted lines

The above graph provides the best fitness as well as the mean fitness of fuel cost in different generations in GA. The value of best fitness is 1598.7602 while the mean fitness is 2508.5854

CASE STUDY 2: SIX GENERATOR SYSTEM

The coefficients of fuel cost and maximum & minimum power limits are given in below table. The power demands are considered

Unit no	a_i	b_i	c_i	P_{min} **(MW)**	P_{max} **(MW)**
1	**240**	**7**	**0.0070**	**100**	**500**
2	**200**	**10**	**0.0095**	**50**	**200**
3	**300**	**8.5**	**0.0090**	**80**	**300**
4	**150**	**11**	**0.0090**	**50**	**150**
5	**200**	**10.5**	**0.0080**	**50**	**200**
6	**120**	**12**	**0.0075**	**50**	**120**

Table 3:- Coefficients of Fuel Cost and Minimum & Maximum Power Limits of 6 Generator System

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The loss co-efficient are given by the matrix

B_{ij} = [0.000017 0.000012 0.000007 -0.000001 -0.000005 -0.000002
0.000012 0.000014 0.0000090.000001 -0.000006 -0.000001
0.000007 0.000009 0.000031 0.000000 -0.000010 -0.000006
-0.000001 0.000001 0.000000 0.000024 -0.000006 -0.000008
-0.000005 -0.000006-0.000010 -0.0000060.000129 -0.000002
-0.000002 -0.000001 -0.000006 -0.000008 -0.000002 0.000150]

Demand	P1	P2	P3	P4	P5	P6	PL	F
700	321.7648	72.10869	154.6886	51.77398	60.19892	50.28185	10.81676	8354.837
1000	413.2247	137.897	222.0294	88.2386	111.2172	50.50843	23.1153	12111.07
800	354.3868	94.06357	186.1426	50.15162	79.32214	50.36016	14.42691	9559.449
900	384.5018	120.241	200.5207	65.11065	97.16317	50.92907	18.46637	10813.18

***Table 4:-* Optimal Result of GA for Case Study 2**

Upon optimization of economic load dispatch of 6 generator system using genetic algorithmprovides better results

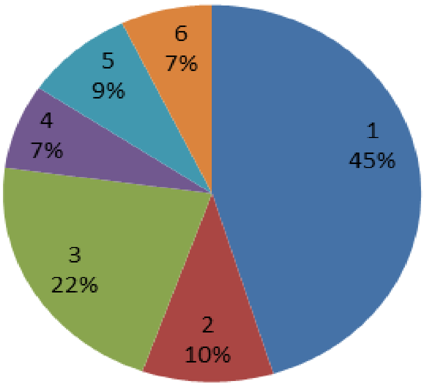

Fig -5 Dispatch of 700MW Load for 6- Generator System

CONCLUSIONS

In this Paper an attempt has been made to adopt the use of Genetic algorithm in Economic load dispatch. Even though, excellent advancements have been made in classical methods, they suffer in handling qualitative constraints, poor convergence, may get stuck to local optimum, they become too slow if the number of variables are more and computationally more complex. Whereas, the major advantages of the artificial techniques are relatively versatile for handling various qualitative constraints in a simplest manner. In this Paper an effort has been modeled to compare the artificial intelligence approach and arrived at a better solution which has a better ability to save the fuel cost and computational time.

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