Optimal Dispatch of Generation with Valve Point Loading using Genetic Optimization Technique

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Abstract – The economic dispatch of generation in power systems is one of the most important optimization problems for both the generating companies competing in a free electricity market and the systems operator in charge with a fair handling of transactions between electricity suppliers and their customers. The fuel cost component is still the major part of the variable cost of electricity generation, directly reflected in the electricity bills. This paper describes and introduces a solution to Economic dispatch problem with valve point loading using a nature-inspired algorithm, called Genetic algorithm. The Genetic Algorithm (GA) is a stochastic Meta heuristic approach based on the mechanics of natural selection and natural genetics. The aim is to minimize the generating unit's combined fuel cost having quadratic cost characteristics subjected to limits on generator real power output & transmission losses. This paper presents an application of the GA to ED with valve point loading for different Test Case system. The obtained solution, quality and computation efficiency is compared to another optimization technique, called Simulated Annealing (SA).

Keywords:-Economic Dispatch, Genetic Algorithm.

I. INTRODUCTION

Power systems analysis combines a highly nonlinear and computationally difficult environment with a need for optimality [1].

Artificial intelligence, unlike strict mathematical methods, has the apparent ability to adapt to nonlinearities and discontinuities found commonly in physical systems.

The linearization and assumptions made in the economic dispatch problem present a classic example.

Most industrial algorithms require the incremental cost curves to be piecewise-linear. The input-output characteristics produced by
generator operation can be made to approximate
this requirement. But the loss of accuracy induced by these approximations is not desirable.

The genetic algorithm emulates the optimization techniques found in nature. This optimization algorithm does not require the strict continuity of classical search techniques, but allows non-linearities and discontinuities to appear in the solution space. The application of this algorithm to the economic dispatch problem uses the payoff information of an objective function to determine optimality. Therefore any type of unit characteristic cost curve may be used with adjustments only to the objective function.

All metaheuristic algorithms use certain tradeoff a randomization and local search [2], [3], [4]. Most stochastic algorithms can be considered as metaheuristic and good examples are Genetic Algorithm (GA) [5], [12].

In this research paper, the genetic algorithm is used to solve the economic load dispatch with valve point loading optimization problem. This optimization problem constitutes one of the key problems in power system operation and planning in which a direct solution cannot be found and therefore metaheuristic approaches, such as the genetic algorithm, have to be used to find the optimal solutions.

II. OPTIMAL DISPATCH OR ECONOMIC DISPATCH PROBLEM

The classical Economic Dispatch(ED) problem is an optimization problem that determines the power output of each online generator that will result in a least cost system operating state. The objective of the economic load dispatch is to minimize the total cost of each online generators .This power allocation is done considering system balance between generation and loads, and feasible regions of operation for each generating unit. The basic economic dispatch problem can be described by the following points:

a) The Fuel Cost Objective

The aim is to minimize the total fuel cost (operating cost) of all committed plants can be stated as follows:

Minimize $$f_1(x) = \sum_{i=1}^{n} C_i(P_i)$$ …….(1)

Where Ci (Pi) is the fuel cost equation of the ‘i‘th plant. It is the variation of fuel cost in rupee with generated Power (MW).

$$C_i(P_i) = a_i P_i^2 + b_i P_i + c_i$$ ……(2)

where n is the number of units power generators of a power plant, Ci is the fuel cost of the ith generator, Pi is the out power of generator i and ai, and bi and ci are the fuel cost coefficients of the ith generator. Normally, the fuel cost equation f1(x) is expressed as continuous quadratic (higher order) equation, as here, but sometimes it can be expressed in linear form, when the coefficient ci is equal to zero. However, in both cases, the equation expresses the variation of fuel cost ($ or Rs) with generated power or time (MW or hr).

b) The Necessary Constraints of the Problem

The total power generation must satisfy the total required demand (power balance) and transmission losses. This can be formulated as follows:

$$\sum_{i=1}^{n} P_{Gi} = D + P_{loss}$$ ……..(3)

where D is the real total load demand of the system, PGi is the ith generator’s power, and Ploss is the transmission losses. These can be determined from either the load/power flow or the matrix Bij of coefficients. In this paper, only the Bij coefficients are considered

$$P_{loss} = \sum_{i=1}^{n} \sum_{j=1}^{n} B_{ij} P_i P_j$$ …….(4)

where, Bij are the elements of the loss coefficient matrix B and Pi and Pj are the out powers of the ith and jth generator; respectively. In this paper, the MW as the only unit of measurement of the power balance constrain is use. Apart from the total demand and transmission loss constrain, there is also the generator capacity constrain in which the power limits of each generator are formulated in order to have a stable operation of a plant. The upper and lower limits are defined as follows:

$$P_{Gi}^{MIN} \le P_{Gi} \le P_{Gi}^{MAX}, \quad \text{for } i = 1 \ldots\ldots n$$

where P_{Gi}^{MIN} and P_{Gi}^{MAX} are the lower and upper limit of the ith generator’s out power PGi, respectively. The power load of each generator unit is measured in MW.

III. ED WITH VALVE POINT LOADING

The Input-output characteristic(or cost function) of a generator are approximated using quadratic or piecewise quadratic function, under the assumption that the incremental cost curves of the units are monotonically increasing picewise-linear functions. However ,real input-output characteristics display higher order non linearities and discontinuities due to valve-point loading in fossil fuel burning plants. The valve-point loading effect has been modeled in as a recurring rectified sinusoidal function as shown in Fig:1.

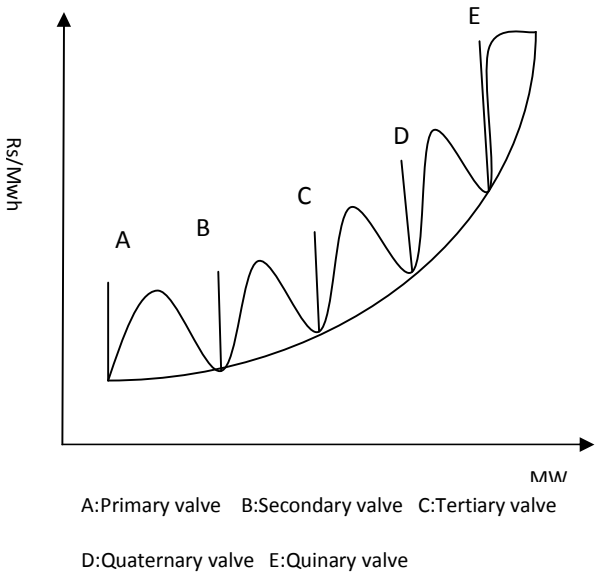

Fig:1 :- Operating cost characteristics with valve point loading

The generating units with multivalve steam turbines exhibits a greater variation in the fuel cost functions.The valve point effects introduce ripple in the heat rate curves. Mathematically ELD problem considering valve point loading is

Defined as: $$C_i(P_i) = \sum_{i=1}^{NG}\left(a_i P_i^2 + b_i P_i + c_i + \left|d_i * \sin\left\{e_i * \left(P_i^{\min} - P_i\right)\right\}\right|\right) \quad \text{.....(5)}$$

Where, ai,bi,ci,di,ei are cost coefficients of the ith unit.

Subject to:- (i) The energy balance equation

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

(ii) the inequality constraints

$$P_i^{\min} \le P_i \le P_i^{\max} \quad \text{(i=1,2.....NG)}$$

IV. THE GENETIC ALGORITHM

a) Description

Genetic algorithms (GA) were formally introduced in the United States in the 1970s by John Holland at University of Michigan. The continuing price/performance improvement of computational systems has made them attractive for some types of optimization. In particular, genetic algorithms work very well on mixed (continuous and discrete), combinatorial problems. They are less susceptible to getting 'stuck' at local optima than gradient search methods. But they tend to be computationally expensive. To use a genetic algorithm, it must represent a solution to your problem as a genome (or chromosome)[24]

The genetic algorithm then creates a population of solutions and applies genetic operators such as mutation and crossover to evolve the solutions in order to find the best one(s). This presentation outlines some of the basics of genetic algorithms.

The three most important aspects of using genetic algorithms are:

1. Definition of the objective function.
2. Definition and implementation of the genetic representation, and
3. Definition and implementation of the genetic operators.

The components that are needed to Implement a genetic algorithm are:

1. Representation
2. Initialization

3. Evaluation Function
4. Genetic Operators
5. Genetic Parameters
6. Termination

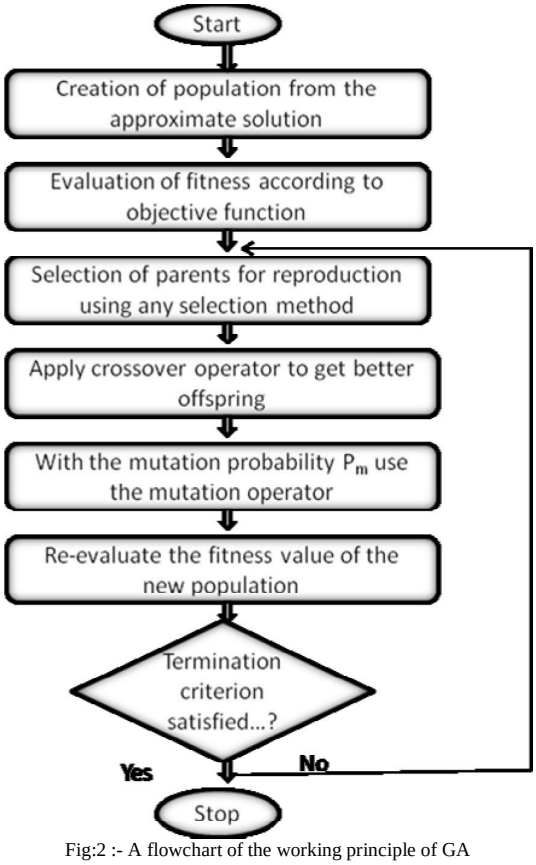

Fig:2 :- A flowchart of the working principle of GA

V. SIMULATION RESULTS AND DISCUSSION

To solve the ED problem with valve point loading, this paper implement the GA in MATLAB 2008 and it was run on a portable computer with an Intel Core2 Duo (1.8GHz) processor, 2GB RAM memory and MS Windows 7 as an operating system. Mathematical calculations and comparisons can be done very quickly and effectively with MATLAB and that is the reason that the proposed Firefly algorithm was implemented in MATLAB programming environment. In this proposed method, each chromosome represent and associate with a valid power output (i.e., potential solution) encoded as a real number for each power generator unit, while the fuel cost objective i.e., the objective function of the problem is associated and represented by the Fitness function. The values of the fuel cost, the power limits of each generator, the power loss coefficients, and the total power load demand are supplied as inputs to the Genetic algorithm. The power output of each generator, the total system power, the fuel cost with transmission losses are considered as outputs of the algorithm

The GA has been proposed for two case studies (3 and 6 generators) systems. In this system GA Algorithms were used in ED with valve point loading. In table 2, results obtained from proposed GA method has been showed.

a) Case study I: Three-unit system

This case study consists of three thermal units.

The Input and cost coefficients are shown in Tables 1 . In this case, the load demand expected to be determined is PD = 850 MW.

Unit	P_i^{min}	P_i^{max}	a	b	c	d	e
1	100	600	0.0016	7.92	561	300	0.032
2	50	200	0.0048	7.92	78	150	0.063
3	100	400	0.0019	7.85	310	200	0.042

Table 1:Data for the three thermal units of generating unit capacity and coefficients

b)Case study II: Six-unit system

This case study consists of six thermal units.

The Input and cost coefficients are shown in Tables 2. In this case, the load demand expected to be determined is PD = 1263 MW.

Unit	P_i^{min}	P_i^{max}	a	b	c	d	e
1	100	500	0.0070	7.0	240	300	0.035
2	50	200	0.0095	10.0	200	200	0.042
3	80	300	0.0090	8.5	220	200	0.042
4	50	150	0.0090	11.0	200	150	0.063
5	50	200	0.0080	10.5	220	150	0.063
6	50	120	0.0075	12.0	190	150	0.063

Table 2:Data for the six thermal units of generating unit capacity and coefficients

	GA	SA
PG1(MW)	297.27	295.23
PG2(MW)	186.32	190.32
PG3(MW)	367.63	367.2
Total power	851.22	852.6
Fuel cost(INR.)	8543.9	8544.2
Ploss(MW)	1.2005	1.2300

Table 3: Simulation results of Genetic algorithms for three-unit system.

	GA	SA
PG1(MW)	485.56	447.08
PG2(MW)	181.09	175.15
PG3(MW)	244.61	263.92
PG4(MW)	77.126	139.06
PG5(MW)	196.72	165.68
PG6(MW)	92.451	86.63
Total power	1277.5	1277.6
Fuel cost(INR.)	16251	16253
Ploss(MW)	14.569	15.62

Table 4: Simulation results of Genetic algorithms for six-unit system.

VI. CONCLUSION

The proposed GA to solve Optimal Dispatch of generation with valve point loading by considering the practical constraints has been presented in this paper. The feasibility of the proposed method for solving the non-smooth optimal dispatch problem is demonstrated using three and six units test system. Algorithm for optimal dispatch with valve point loading, is developed for GA in MATLAB. From the comparison Table 1 and Table 2, it is observed that

the proposed algorithm exhibits a comparative performance with respect to other optimization technique(SA). It is clear from the results that Genetic algorithm is capable of obtaining higher quality solution with better computation efficiency and stable convergence characteristic. The effectiveness of GA was demonstrated and tested. From the simulations, it can be seen that GA gave the best result of total cost minimization and reduced fuel cost and Power loss compared to the other method.

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