



Analysis and Comparison of Lambda Iteration, Genetic Algorithm and Particle Swarm Optimization to Solve Economic Load Dispatch Problem

Mohd. Asif Iqbal,

Department of Electrical Engineering, Poornima College of engineering

Jaipur, Rajasthan, India

E-mail: asif@poornima.org

Abstract: Electrical power systems are designed and operated to meet the continuous variation of power demand the main aim of modern electric power utilities is to provide high-quality reliable power supply to the consumers at the lowest possible cost while operating to meet the limits and constraints imposed on the generating units and environmental considerations. These constraints formulates the economic load dispatch (ELD) problem for finding the optimal combination of the output power of all the online generating units that minimizes the total fuel cost, while satisfying an equality constraint and a set of inequality constraints. The Traditional methods include Newton- Raphson method, Lambda Iteration method, Base Point and Participation Factor method, Gradient method etc.. However, these classical dispatch algorithms require the incremental cost curves to be monotonically increasing or piece-wise linear. Practically the input to output characteristics of the generating units are highly non-linear, non-smooth and discrete in nature owing to prohibited operating zones, ramp rate limits and multifuel effects. Thus the resultant ELD becomes a challenging non-convex optimization problem, which is difficult to solve using the traditional methods. Methods like dynamic programming, genetic algorithm, evolutionary programming, artificial intelligence, and particle swarm optimization solve non-convex optimization problems efficiently and often achieve a fast and near global optimal solution. Although these heuristic methods do not always guarantee the global optimal solution, they generally provide a fast and reasonable solution (sub optimal or near global optimal). This work proposes evolutionary optimization techniques namely Genetic Algorithm (GA) and Particle Swarm optimization (PSO) to solve ELD in the electric power system, which are generic population, based probabilistic search optimization algorithms and can be applied to real world problem.

Keywords: Lambda Iteration method, Genetic Algorithm (GA) and Particle Swarm optimization (PSO)

I. INTRODUCTION

Electrical power systems are designed and operated to meet the continuous variation of power demand. economic dispatch have been used to plan over a given time horizon the most economical schedule of committing and dispatching generating units to meet forecasted demand levels and spinning reserve requirements while all generating unit constraints are satisfied. With large interconnection of the electric networks, the energy crisis in the world and continuous rise in prices, it is very essential to reduce the running costs of electric 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. The main aim of modern electric power utilities is to provide high-quality reliable power supply to the consumers at the lowest possible cost while operating to meet the limits and constraints imposed on the generating units and environmental considerations. These constraints formulates the economic load dispatch (**ELD**) problem for finding the optimal combination of the output power of all the online generating units that minimizes the total fuel cost, while satisfying an equality constraint and a set of inequality constraints. The Traditional methods include Newton- Raphson method, Lambda Iteration method, Base Point and Participation Factor method, Gradient method, etc. However, these classical dispatch algorithms require the incremental cost curves to be monotonically increasing or piece-wise linear. Practically the input to output characteristics of the generating units are highly non-linear, non-smooth and discrete in nature owing to prohibited operating zones, ramp rate limits and multifuel effects. Thus the resultant ELD becomes a challenging non-convex optimization problem, which is difficult to solve using the traditional methods. Methods like dynamic programming, genetic algorithm, evolutionary programming, artificial intelligence, and particle swarm optimization solve non-convex optimization problems efficiently and often achieve a fast and near global optimal solution. Although these heuristic methods do not always guarantee the global optimal solution, they generally provide a fast and reasonable solution (sub optimal or near global optimal). This work proposes evolutionary optimization techniques namely Genetic Algorithm (GA) and Particle Swarm optimization (PSO) to solve ELD in the electric power system, which are generic population, based probabilistic search optimization algorithms and can be applied to real world problem. Both techniques are respectively applied to solve an ELD problem

by using the proposed algorithms mentioned respectively. And at the last the comparison between the three methods has been presented.

II. HISTORY OF ECONOMIC DISPATCH

Economic dispatch is also defined as the process of allocating generation levels to the generating units, so that the system load may be supplied entirely and most economically. As early as the 1920's, engineers were concerned with the problem of economic allocation of generation or the proper division of load among the generating units available. The methods in use in the 1930's are as follows: the 'base load' method where the most efficient unit is loaded to its maximum capability, then the second most efficient unit is loaded etc. the 'best point' loading where units were successively loaded to their lowest rate point beginning with the most efficient unit working down to the least efficient unit. Eventually, it was recognized that the incremental method, later known as the equal incremental method, yielded the most economic results. The theoretical work on optimal dispatch later led to the development of analog computers for properly executing the coordination equations in a dispatching environment. A transmission loss penalty factor computer was developed in 1954 and was used in conjunction with an incremental loading slide rule for producing daily generation schedules in a load dispatching office. An electronic differential analyzer was developed for use in economic scheduling for off-line or on-line use by 1955. The use of digital computers for obtaining loading schedules was investigated in 1954 and is used to this day. Economic Dispatch (ED) and Load Frequency Control (LFC) both have the task of adjusting the area generation such that it matches the area load while, simultaneously, both area frequency and the net tie-line exchange are at their set points. Even though ED and LFC have different time horizons, they are not independent because ED provides the set point for LFC. Now both of these control actions fall under a single activity called "Automatic Generation Control (AGC)". But this was not the case in the early years. Traditionally, there was minimal interface between area control (economic dispatch plus load frequency control) and local unit control. With modern equipment now available for generation, AGC has been improved considerably.

Mathematical optimization algorithmic methods have been used over the years for many power systems planning, operation, and control problems. Mathematical formulations of real-world problems are derived under certain assumptions and even with these assumptions; the solution of large-scale power systems is not simple. On the other hand, there are many uncertainties in power system problems because power systems are large, complex, and geographically widely distributed. More recently, deregulation of power utilities has introduced new issues into the existing problems. It is desirable that solution of power system problems should be optimum globally, but solutions searched by mathematical optimization are normally optimum locally but not globally. These facts make it difficult to deal effectively with many power system problems through strict mathematical formulation alone. Therefore, Artificial Intelligence (AI) techniques which promise a global optimum or nearly so, such as Expert Systems (ES), Artificial Neural Network (ANN), Genetic Algorithm (GA), fuzzy logic have emerged in recent years in power systems as a complement tool to mathematical approaches.

III. GENETIC ALGORITHM

GA is a global search technique based on mechanics of natural selection and genetics. It is a general-purpose optimization algorithm that is distinguished from conventional optimization techniques by the use of concepts of population genetics to guide the optimization search. Instead of point-to-point search, GA searches from population to population. The advantages of GA over traditional techniques are It needs only rough information of the objective function and places no restriction such as differentiability and convexity on the objective. The method works with a set of solutions from one generation to the next, and not a single solution, thus making it less likely to converge on local minima. The solutions developed are randomly based on the probability rate of the genetic operators such as mutation and crossover; the initial solutions thus would not dictate the search direction of GA. 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. 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. 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 explore the new combination with the available knowledge to find the new generation with better fitness or objective function value.

Genetic operators are a set of random transition rules employed by a Genetic Algorithm. In Genetic operation, a new and improved population is generated from the previous population using genetic operators. Genetic operators which are used in a Genetic Algorithm are :

1. Reproduction
2. Crossover
3. Mutation

Different forms of crossover are:

- 1.) Single point crossover 2.) Two point crossover 3.) Multi point crossover 4.) Uniform crossover

1.) Single point crossover: In the single point crossover, two individual strings are selected at random from the mating pool. Next, a crossover site is selected randomly along the string length and binary digits (alleles) are swapped between the two strings at crossover site. Suppose site 3 is selected at random. It means starting from the 4th bit and onwards, bits of strings will be swapped to produce offspring which is given.

Parent 1: $x_1 = \{0\ 1\ 0\ 1\ 1\ 0\ 1\ 0\ 1\ 1\}$

Parent 2: $x_2 = \{1\ 0\ 0\ 0\ 0\ 1\ 1\ 1\ 0\ 0\}$

Offspring 1: $x_1 = \{0\ 1\ 0\ 0\ 0\ 1\ 1\ 1\ 0\ 0\}$

Offspring 2: $x_2 = \{1\ 0\ 0\ 1\ 1\ 0\ 1\ 0\ 1\ 1\}$

2.) Two point crossover: In a two point crossover operator, two random sites are chosen and the contents bracketed by these sites are exchanged between two mated parents. If the cross site 1 is three and cross site 2 is six, the strings between three and six are exchanged which is shown in figure.3.4.

Parent 1: $x_1 = \{0\ 1\ 0\ 1\ 1\ 0\ 1\ 0\ 1\ 1\}$

Parent 2: $x_2 = \{1\ 0\ 0\ 0\ 0\ 1\ 1\ 1\ 0\ 0\}$

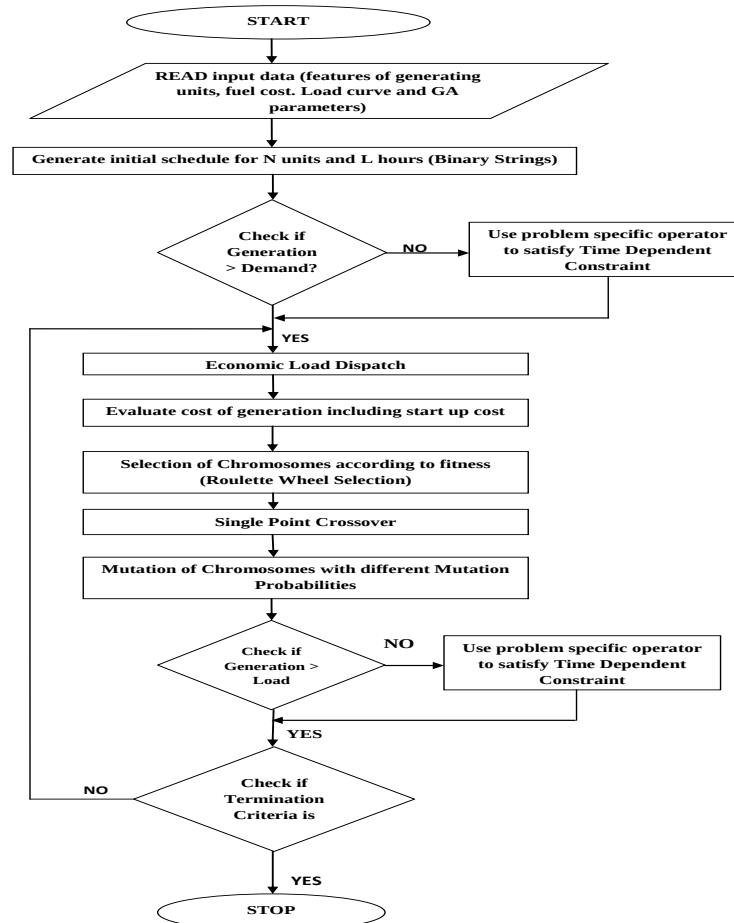
Offspring 1: $x_1 = \{0\ 1\ 0\ 0\ 0\ 1\ 1\ 0\ 1\ 1\}$

Offspring 2: $x_2 = \{1\ 0\ 0\ 1\ 1\ 0\ 1\ 1\ 0\ 0\}$

3.) Multipoint crossover: In a multipoint crossover, again there are two cases. One is even number of cross sites and other is odd number of sites. For even number of sites the string is treated as a ring and cross sites are selected around the circle uniformly at random if the number of cross sites is odd, and then a different cross point is always assumed at the string beginning. For multipoint crossover, from m crossover positions along the string length, l are chosen at random with no duplicates and sorted into ascending order.

$k_i \in \{1, 2, \dots, l-1\}$ where k is the i^{th} crossover point, l is the length of the chromosome.

The bits between successive crossover points are exchanged alternatively between two parents to give two new offspring.

Flow chart of methodology

IV. PARTICLE SWARM OPTIMIZATION (PSO)

Particle Swarm optimization (PSO) is a population based algorithm in which each particle is considered as a solution in the multimodal optimization space. There are several types of PSO proposed but here in this work very simplest form of PSO is taken to solve the Economic Load Dispatch (ELD) problem. The particles are generated keeping the constraints in mind for each generating unit. When economic load dispatch problem considered it can be classified in two different ways.

1. Economic load dispatch without considering the transmission line losses
2. Economic load dispatch considering the transmission line losses.

V. STEPS OF IMPLEMENTATION

1. Initialize the Fitness Function ie. Total cost function from the individual cost function of the various generating stations.
2. Initialize the PSO parameters Population size, C1, C2, WMAX, WMIN, error gradient etc.
3. Input the Fuel cost Functions, MW limits of the generating stations along with the B-coefficient matrix and the total power demand.
4. At the first step of the execution of the program a large no (equal to the population size) of vectors of active power satisfying the MW limits are randomly allocated.
5. For each vector of active power the value of the fitness function is calculated. All values obtained in an iteration are compared to obtain Pbest. At each iteration all values of the whole population till then are compared to obtain the Gbest. At each step these values are updated.
6. At each step error gradient is checked and the value of Gbest is plotted till it comes within the pre-specified range.
7. This final value of Gbest is the minimum cost and the active power vector represents the economic load dispatch solution.

Active Power Balance Equation:

For power balance, an equality constraint should be satisfied. The total generated power should be same as total load demand plus the total line loss.

$$\sum_{i=1}^N P_i = P_D + P_{Loss}$$

Maximum And Minimum Power Limits:

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

$$P_{i,min} \leq P_i \leq P_{i,max}$$

Non-Smooth Cost Functions With Multi Fuels:

Since the dispatching units are partially supplied multi-fuel sources, each unit should be represented with several piecewise quadratic function reflecting the effect of fuel type changes. In general a piecewise quadratic function is used to represent the input-output curve of a generator with multiple fuels.

$$F_i(P_i) = a_n + b_n P_i + c_n P_i^2 \quad \text{if } P_{i,min} \leq P_i \leq P_n$$

$$a_{i2} + b_{i2} P_i + c_{i2} P_i^2 \quad P_n \leq P_i \leq P_{i2}$$

.....
.....

$$a_{in} + b_{in} P_i + c_{in} P_i^2 \quad \text{if } P_{i(n-1)} \leq P_i \leq P_{i,max}$$

The choice of values for learning factors is an important factor in determining the nature of the program. The explorative capability as well as the speed of convergence depends upon the relative values of the learning factors. High values of 'c1' and 'c2' mean that the swarm of particles or flock of birds is drawn violently into the cornfield whereas a higher value of 'w' will mean that the flock gradually circles over the cornfield before finally settling (converging) to the optimal solution.

V. RESULTS

Results obtained for an sample bus power system with 3 generating units:

	LAMBDA Iteration Method	Simple GA	FAST GA	PSO Method
Power generated by 1st generator	435.1958MW	435.219	435.199	438MW
Power generated by 2nd generator	299.9699MW	299.983	299.970	276MW
Power generated by 3rd generator	130.6634MW	130.667	130.660	141MW
Total power generation	865.8291MW	865.869	865.829	855MW
FC (\$/hr)	8344.6025	8344.96	8257.7	8251

The difference between PSO & Lamda Iteration methods for a sample 3 bus generating system is about 92.6025\$/hr. The difference between PSO & Lamda Iteration methods for a IEEE 26 bus system with 6 generating is about 158.5898 \$/hr.

VI. CONCLUSIONS

The comparison of results for the test cases of three unit and six unit system clearly shows that the proposed method is indeed capable of obtaining higher quality solution efficiently for higher degree ELD problems. The convergence characteristic of the proposed algorithm for the three unit system and six unit system is plotted. The convergence tends to be improving as the system complexity increases. Thus solution for higher order systems can be obtained in much less time duration than the conventional method. The reliability of the proposed algorithm for different runs of the program is pretty good, which shows that irrespective of the run of the program it is capable of obtaining same result for the problem. Many non-linear characteristics of the generators can be handled efficiently by the method. The PSO technique employed uses a inertia weight factor for faster convergence.

VII. REFERENCES

1. P.Sriyanyong, and Y.H.Song "Unit Commitment Using Particle Swarm Optimization Combined with Lagrange relaxation" IEEE 2005.
2. J.A. Momoh, M.E. El-Hawary and R. Adapa, A review of selected optimal power flow literature to 1993, Part I: Nonlinear and quadratic programming approaches, *IEEE Trans. Power Syst.*, 14 (1) (1999), pp. 96–104.
3. T.O. Ting, M.V.C. Rao and C.K.Loo. "A Novel Approach for Unit Commitment Problem via an Effective Hybrid Particle Swarm Optimization". IEEE transactions on power systems. Vol 21, No.1. February 2006.
4. D.C. Walters and G.B. Sheble, Genetic algorithm solution of economic dispatch with valve point loading, *IEEE Trans. Power Syst.*, 8 (August (3)) (1993), pp. 1325–1332.
5. Chiang C. L., "Genetic based algorithm for power economic load dispatch", IET Gener. Transm. Distrib, 1, (2), pp. 261-269, 2007.
6. Ling S. H., Lam H. K., Leung H. F. and Lee Y. S., "Improved genetic algorithm for economic load dispatch with valve- point loadings", IEEE Transactions on power systems, Vol. 1, pp. 442 – 447, 2003.