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Solution of Economic Dispatch Problem using Differential Evolution Algorithm

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Abstract

The Economic Load Dispatch Problem (ELDP) plays an important role in the operation of power system, and several models by using different techniques have been used to solve these problems. Economic Dispatch is the process of allocating the required load demand between the available generation units such that the cost of operation is minimized. There have been many algorithms proposed for economic dispatch out of which a Differential Evolution (DE) is discussed in this paper. Several traditional approaches, like lambda iteration and gradient method are utilized to find out the optimal solution of non linear problem. In solving optimization problems with a high-dimensional search space, the classical optimization algorithms do not provide a suitable solution because the search space increases exponentially with the problem size, therefore solving these problems using exact techniques (such as exhaustive search) is not practical. There is no specific algorithm to achieve the best solution for all optimization problems. Some algorithms give a better solution for some particular problems than others. Drawbacks of classical algorithms such as gradient based, interior point, linear programming etc., can be declared as insecure convergence properties, long execution time, and algorithmic complexity. Besides, the solution can be trapped in local minima. Hence searching for new heuristic optimization algorithms is an open problem.

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1- *Introduction*

ELD is solved traditionally using mathematical programming based on optimization techniques such as lambda iteration, gradient method and so on. Economic load dispatch with piecewise linear cost functions is a highly heuristic, approximate and extremely fast form of economic dispatch. Lambda iteration, gradient method can solve simple ELD calculations and they are not sufficient for real applications in deregulated market. However, they are fast. Complex constrained ELD is addressed by intelligent methods. Among these methods, some of them are evolutionary programming (EP), dynamic programming (DP), tabu search, hybrid EP, neural network (NN), adaptive Hopfield neural network (AHNN), particle swarm optimization (PSO) etc[5,6,9]. Most of the heuristic algorithms do search in a parallel fashion with multiple initial points, e.g. swarm based algorithms use a collection of agents similar to a natural flock of birds or fishes.

One can recognize two common aspects in the population-based heuristic algorithms: exploration and exploitation. The exploration is the ability of expanding search space, where the exploitation is the ability of finding the optima around a good solution. In premier iterations, a heuristic search algorithm explores the search space to find new solutions. To avoid trapping in a local optimum, the algorithm must use the exploration in the first little iteration. Hence, the exploration is an important issue in a population-based heuristic algorithm. By lapse of iterations, exploration fades out and exploitation fades in, so the algorithm tunes itself in semi-optimal points.

From a different point of view, the members of a population-based search algorithm pass three steps in each iteration to realize the concepts of exploration and exploitation: self-adaptation, cooperation and competition. Economic load dispatch problem is allocating loads to plants for minimum cost while meeting the constraints. in 2009 known as (GSA) is used for solving Economic Load Dispatch Problem (ELDP) including valve point loading effect. The GSA algorithm uses the theory of Newtonian physics and its searcher agents are the collection of masses. The basic economic dispatch problem can described mathematically as a minimization of problem of minimizing the total fuel cost of all committed plants subject to the constraints.

$$Minimize \sum_{i=1}^{n} \mathrm{F_i}(P_i) \qquad (1)$$

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$F_i(P_i)$ is the fuel cost equation of the 'i'th plant. It is the variation of fuel cost ($ or Rs) with generated power (MW).Normally it is expressed as continuous quadratic equation.

$$F_{ij}(P_i) = a_i P_i^2 + b_i P_i + c_i \tag{2}$$

$$P_i^{\min} \le P_i \le P_i^{\max}$$

The total generation should meet the total Demand and transmission loss. The transmission loss can be Determined form either B_{mn} coefficients or power flow.

$$\sum_{i=1}^{n} P_i = D + P_l \tag{3}$$

$$P_l = \sum_{i}^{n} \sum_{j}^{n} B_{ij} P_i P_j \tag{4}$$

2- *Objective function*

The objective of the ELD is to minimize the total system cost by adjusting the power output of each of the generators connected to the grid. The total system cost is modeled as the sum of the cost function of each generator (1). The generator cost curves are modeled with smooth quadratic functions, given by:

$$Minimize \sum_{i=1}^{n} (\mathrm{F}(P))_i + k * \left(\left| \left(\sum_{i=1}^{n} P_i - D - \sum_{i=1}^{n} \sum_{j=1}^{n} B_{ij} P_i P_j \right) \right| \right) \tag{5}$$

3- *Solution by Genetic Algorithm*

I. Select a reference plant. For better convergence chose a plant which has maximum capacity and range. In this program It is considered as plant 1. The reference plant allocation is fixed by the equations (3&4).

II. Convert the constrained optimization problem as an unconstrained problem by penalty function method.

$$Minimize \sum_{i=1}^{n} \mathrm{F_i}(P_i) + 1000 * abs\left(\sum_{i=1}^{n} P_i - D - \sum_{i=1}^{n} \sum_{j=1}^{n} B_{ij} P_i P_j\right) \tag{6}$$

III. This software contain two examples gatest.m and gatest.1.By running the programs as they are in the default folder. The allocation minimum fuel cost and transmission losses can be Determined.

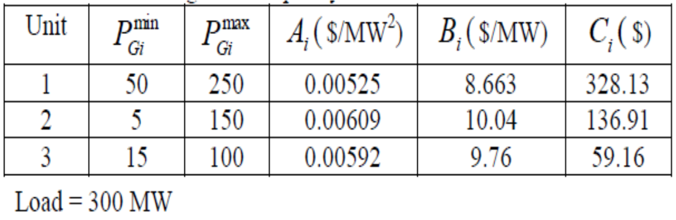
4- *Test Problem and Results*

The economic load dispatch (ELD) problem was solved using the differential evolution (GA) algorithm. The simulation was performed on the IEEE 30 bus – 6 generators test system described in [8]. Table 1 shows the data for the six generators. The parameters used for the GA algorithm are presented as follows: Scaling factor (F) was set to 0.70, the crossover constant (C_R) to 0.99 and the population size (N_P) to 26. The load was set to 2.834 pu on a 100 MVA base. The penalty factor (K) of the equality constraint was set to 5×10^5. To demonstrate the effectiveness of the GA algorithm, in under cases were considered as follows

5.1. Case Study

In this example, a simple system with three thermal units is used to demonstrate how the proposed approach works. The unit characteristics are given in Table 1. Now, Table 2 Provides the statistic results that involved the generation cost, evaluation value, and average CPU time

Table 1-Generating unit's capacity and Coefficients



Unit	$P_{Gi}^{\min}$	$P_{Gi}^{\max}$	A_i ($/MW^2)	B_i ($/MW)	C_i ($)
1	50	250	0.00525	8.663	328.13
2	5	150	0.00609	10.04	136.91
3	15	100	0.00592	9.76	59.16

Load = 300 MW

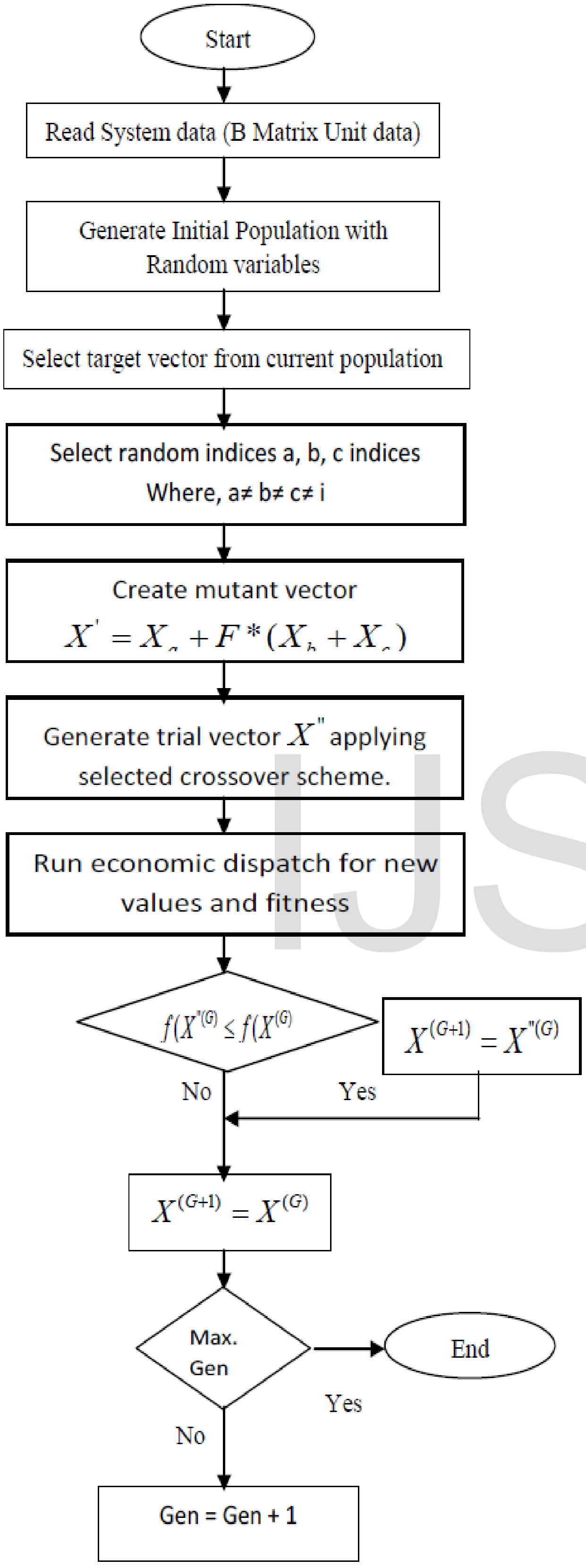
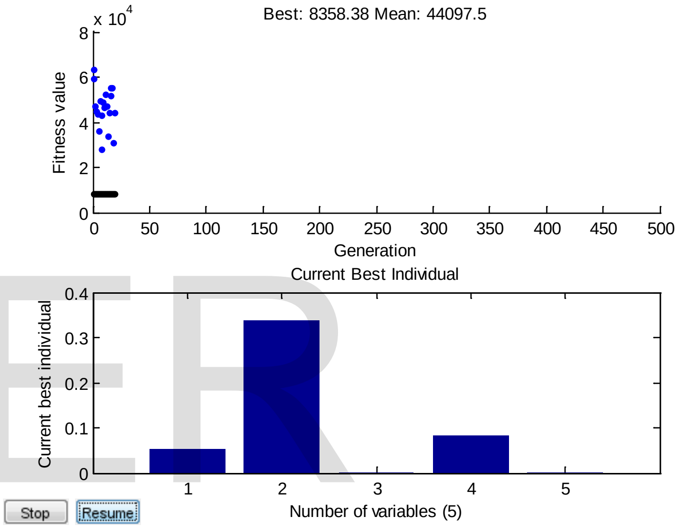


Figure 1: Flowchart of the proposed method

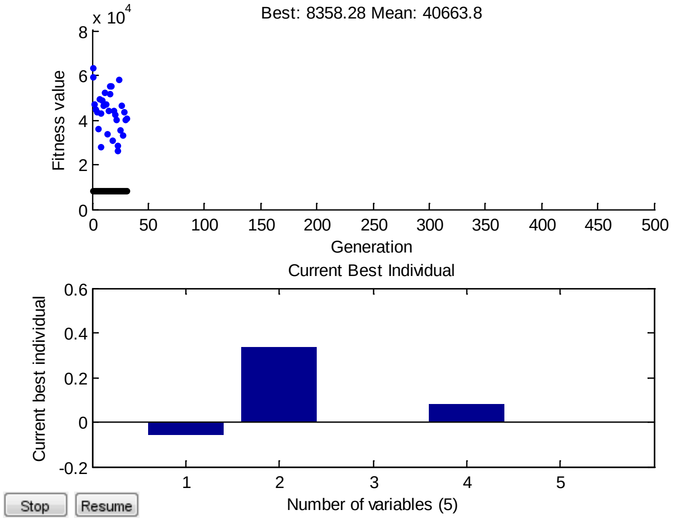
Table 2- Best Power output for three unit system

Unit output	DE
P1 (MW)	207.637
P2 (MW)	87.2833
P3 (MW)	15
Total Power Output (MW)	309.9203
Total generation cost ($/h)	3619.8
Power Loss (MW)	9.9204
Iteration time (sec)	0.009
Total time (sec)	4.503

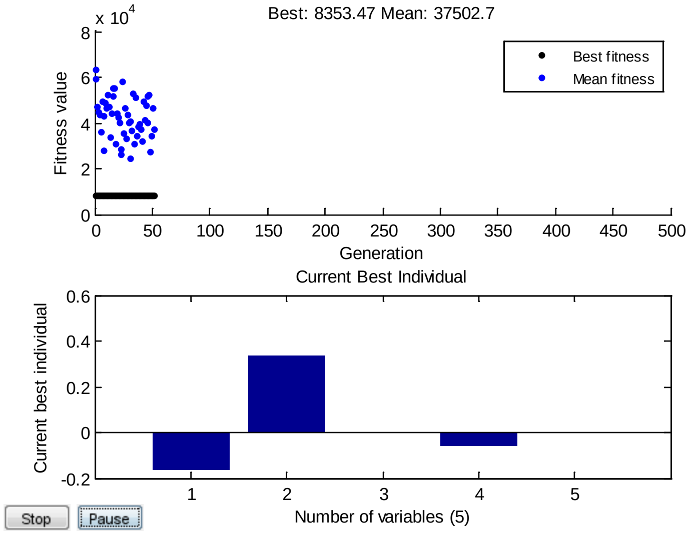
Sample Generation = 1



Sample Generation = 2



Sample Generation = 3



The system contains six thermal units and the load demand is 1263 MW. The characteristics of the six thermal units are given in Table 3. In normal operation of the system, the loss coefficients B with 100 MVA base capacities are given below. In this case, each individual PG contains six generator power outputs, such as P1, P2, P3, P4, P5, and P6, which are generated randomly. The dimension of the population is equal to 6 x 100. Table 4 provides the statistic results that involved the generation cost, evaluation value, and average CPU

Table 3-Generating unit's capacity and Coefficients

Unit	$P_{Gi}^{\min}$	$P_{Gi}^{\max}$	$A_i\ (\$/\mathrm{MW}^2)$	$B_i\ (\$/\mathrm{MW})$	$C_i\ (\$)$
1	100	500	240	7.0	0.0070
2	50	200	200	10.0	0.0095
3	80	300	220	8.5	0.0090
4	50	150	200	11.0	0.0090
5	50	200	220	10.5	0.0080
6	50	120	190	12.0	0.0075

Table 4- Best Power output for six generator system

Unit output	DE
P1 (MW)	400.00
P2 (MW)	186
P3 (MW)	289
P4 (MW)	150
P5 (MW)	200
P6 (MW)	50
Total Power Output (MW)	1275
Total generation cost ($/h)	15192
Power Loss (MW)	0.0124
Iteration time (sec)	0.0124
Total time (sec)	6.201792

4- *Conclusions*

In this paper, an evolutionary algorithm was applied to solve the economic load dispatch problem. The differential evolution algorithm has been successfully implemented to solve ED problems with the generator constraints as linear equality and inequality constraints and also considering transmission loss. The algorithm is implemented for three units and six units system. From the result, it is clear that the proposed algorithm has the ability to find the better quality solution and has better convergence characteristics, computational efficiency and less CPU time.

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