Biogeographic-Based Optimization (BBO) Approach for Solving Economic Load Dispatch Problems

Narottam Dutt upadhyay[1], Arun K.S. Tomar[2]

Asst. Professor, MPCT Gwalior[1], Asst. Professor, RJIT, Tekanpur[2]

Abstract - The economic dispatch problem with nonsmooth cost function has become a major issue with depletion of coal and increasing fuel prices. A proper schedule of available generating units may save millions of dollars per year in production cost. In this paper, Biogeographic-Based Optimization (BBO) algorithm is proposed for solving economic load dispatch (ELD) problems with and without valve-point effect. Biogeography is basically a science of geographical distribution of the biological species. The models of biogeography explain how an organism arises, immigrate from an environment to another and gets eliminated. This method is based on two steps mutation and migration. The results of the proposed technique are compared with that of other techniques reported in the literature. In all cases, the proposed algorithm either matches or outperforms the solution reported for the existing algorithms. The proposed technique is also easy to implement and capable of finding feasible near global optimal solution.

Keywords: Biogeography-Based Optimization (BBO), Economic Load Dispatch (ELD), Valve-Point Effect, PSO.

I. INTRODUCTION

Electrical power systems are designed and operated to meet the continuous variation of power demand. In power system minimizing, the operation cost is very important. Economic Load Dispatch (ELD) is a method to schedule the power generator outputs with respect to the load demands, and to operate the power system most economically, or in other words, we can say that main objective of economic load dispatch is to allocate the optimal power generation from different units at the lowest cost possible while meeting all system constraints Over the years, many efforts have been made to solve the ELD problem, incorporating different kinds of constraints or multiple objectives through various mathematical programming and optimization techniques. The conventional methods include Newton- Raphson method, Lambda Iteration method, Base Point and Participation Factor method, Gradient method, etc. Over the past few decades, as an alternative to the conventional mathematical approaches, many salient methods have been developed for ELD problem such as evolutionary programming [1], particle swarm optimization [2], Genetic algorithm [3], Bacteria Foraging Optimization [4], Differential Evolution [5].Recently a new population based evolutionary algorithm has been invented by Simon, based on biogeography [6]. This has better properties than other evolutionary algorithms hence can be employing in power system optimization problems. Biogeography is way of natural for species distribution on the earth. In BBO algorithm, a good solution for a problem considered as a habitat with high HSI and a poor solution considered as a habitat with low HSI.

The BBO algorithm has some advantages in comparison to other algorithms. In BBO and PSO each solution stay survive to the end of optimization procedure but in most of evolutionary based algorithms, solutions die at the end of each generation. In some of evolutionary due to crossover step, good solutions lose their efficiency but in BBO do not have crossover step [7].In this paper a newly developed Biogeography based optimization (BBO) algorithm has been applied to the ELD problems. The BBO algorithm was developed by D. Simon in the year 2008 from the theory of Biogeography as its base [8].To show the effectiveness of the BBO, the BBO algorithm has been applied to without Valve-Point Effects and with Valve-Point Effects and comprising of three generating units .The results of BBO are compared with the PSO and its variants method and it has been found that the BBO algorithm shows superior performance.

II. ECONOMIC LOAD DISPATCH FORMULATION

The objective of ELD problem is to minimize the fuel cost of generating units for a specific period of operation so as to accomplish optimal generation dispatch among operating units while the system load demand, generator operational constraints, ramp rate limit and prohibited operating zones are satisfied. Two models for ELD are considered here, one with smooth cost function and other with non smooth cost function as below.

The objective function analogous to the generation cost can be approximated to be a quadratic function. Symbolically, it is represented as

Minimize $F_t^{cost} = \sum_{i=1}^{N_G} f_i(P_i)$ (1)

$$f_i(P_i) = a_i P_i^2 + b_i P_i + c_i \quad (2)$$

where i=1,2,3…………N_G

is the expression for cost function of ith generating unit and a_i, b_i and c_i are its cost coefficients. Pi is the real power output (MW) of ith generator corresponding to time period t. N_G is the number of generating units.

The ELD problem consists of minimizing F_t^{cost} subjected to following constraints.

A) Power Balance Constraints

The total generation must fulfil the total demand plus losses. If total system load is P_D and losses are represented by P_L, then,

$$\sum_{i=1}^{N_G} P_i = P_D + P_L \quad (3)$$

Where transmission loss PL is expressed using B-coefficients, given by

$$P_L = \sum_{i=1}^{N_G} \sum_{f=1}^{N_G} P_i B_{ij} P_j + \sum_{i=1}^{N_G} B_{0i} P_i + B_{00} \quad (4)$$

B) Generator Capacity Constraints:

For stable operation, real power generated by each generator restricted by their lower limit P_i^{min} and upper limit P_i^{max} as follows:

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

III. BIOGEOGRAPHY-BASED OPTIMIZATION ALGORITHM (BBO) TECHNIQUE

Biogeography-Based Optimization (BBO) is a global optimization algorithm developed by Dan Simon in 2008. Biogeography is the study of distribution of species in nature over time and space; that is the immigration and emigration of species between habitats. The application of this idea to allow information sharing between candidate solutions. Each possible solution is an island and their features that characterize habitability are called suitability index variables (SIV). The fitness of each solution is called its habitat suitability index (HSI) and depends on many features of the habitat. High-HSI solutions tend to share their features with low-HSI solutions by emigrating solution features to other habitats. Low- HSI solutions accept a lot of new features from high-HSI solutions by immigration from other habitats. Immigration and emigration tend to improve the solutions and thus evolve a solution to the optimization problem. The value of HSI is considered as the objective function, and the algorithm is intended to determine the solutions which maximize the HSI by immigrating and emigrating features of the habitats. In BBO, there are two main operators: migration (which includes both emigration and immigration) and mutation .A habitat H is a vector of N (SIVs) integers initialized randomly. Before optimizing, each individual of population is evaluated and then follows migration and mutation step to reach global minima. In migration the information is shared between habitats that depend on emigration rates μ and immigration rates λ of each solution. Each solution is modified depending on probability P_{mod} that is a user defined parameter. Each individual has its own λ and μ and are functions of the number of species K in the habitat .Poor solutions accept more useful information from good solution, which improve the exploitation ability of algorithm. In BBO, the mutation is used to increase the diversity of the population to get the good solutions.

A. Features of Biogeography Based Optimization

- In BBO the original population is not discarded after each generation. It is rather modified by migration.
- Another distinctive feature is that, for each generation, BBO uses the fitness of each solution to determine its immigration and emigration rate.

IV. BIOGEOGRAPHY BASED OPTIMIZATION FOR ECONOMIC LOAD DISPATCH

A new approach to implement the BBO algorithm will be described for solving the ELD problem. Especially, suggestion will be given on how to deal with the equality and inequality constraints of the ELD problems when modifying each individual's search point in the BBO algorithm. The process of BBO algorithm can be explained as follows [8]- [11].

Step 1: *Initialization of BBO parameters*: Choose the number of generators i.e. number of SIVs, number of habitats i.e. population size, power demand, loss coefficients, habitat modification probability $Pmodify$ = 1, mutation probability = 0.1, maximum mutation rate $mmax$, maximum immigration rate I = 1, maximum emigration rate E = 1, step size for numerical integration dt = 1, elitism parameter = 2.

Step 2*: Initialization of SIVs*: Each SIV of a habitat is initialized randomly while satisfying the constraints of equation (4). Each habitat represents a potential solution to the given problem.

Step 3*: Calculation of HSIs*: HSI for each habitat is calculated for given immigration and emigration rates. HSI represents the fuel cost of the generators.

Step 4*: Identification of elite habitats*: Based on the HSI values, elite habitats are identified i.e. those habitats for which the fuel cost is minimum, are selected.

Step 5*: Performing migration operation*: For each of the non-elite habitats, migration operation is performed. HSI for each habitat is recomputed. SIVs obtained after migration must satisfy the constraints of equation (4).

Step 6: *Performing mutation operation*: Species count probability of each habitat is updated. Mutation operation is carried out on the non-elite habitats. HSI value of each new habitat set is recomputed.

Step 7: *Stopping criterion*: Go to step 3 for next iteration. If the predefined number of iterations is reached, stop the process.

V. RESULTS AND ANALYSIS

The applicability and validity of the BBO algorithm for practical applications has been tested on various test cases. All the simulations were carried out using MATLAB 9.0.1 on core i3, 2nd generation processor having 2.4 GHz. With 4 GB RAM on 64-bit operating system.

Case A - Effect of population size in 10-generating units without valve point loading effects

TABLE 1. EFFECT OF POPULATION SIZE ON 10-UNIT SYSTEM WITHOUT VALVE POINT LOADING

Population Size	Minimum Cost	Maximum Cost	Mean Cost	Standard Deviation
10	28238.856557	29292.497734	28707.760993	238.929909
20	28181.693248	29367.422319	28695.127347	223.469725
30	28140.075719	29147.955662	28600.070603	216.442241
40	28009.899499	29231.647122	28651.531704	211.022203

The cost coefficients and other data for 10 generating units system is listed in Table A1 in the appendix section, the load demand is 1036 MW. Their best results are shown in Table 1 that the minimum, mean, maximum, and standard deviation of the population out of 100 trials goes on improving with increase in population. It can be observed that the population size= 10,20,30 and 40 are show in the figure 1,fig 2,fig 3 and fig 4 for best parameters for 10-generating units without valve point effect after 100 Trials, which is very close to global minima.

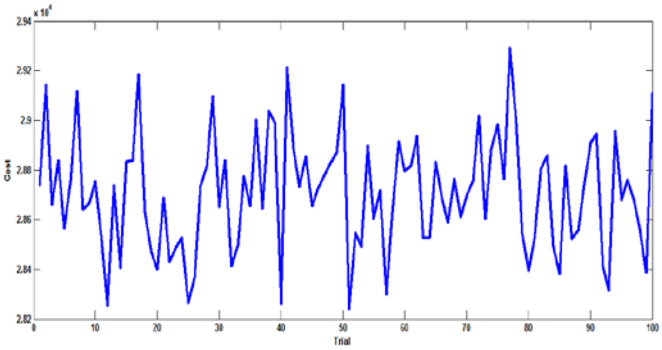

Fig.1 Results for the 10-Unit for without VPL Population size =10 out of 100 trials

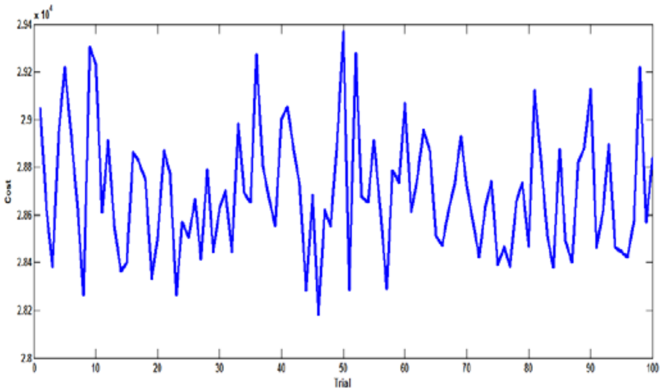

Fig.2 Results for the 10-Unit for without VPL Population size =20 out of 100 trials

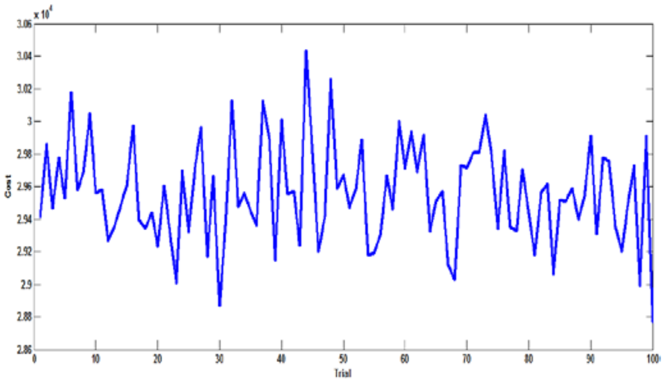

Fig.3 Results for the 10-Unit for without VPL Population size =30 out of 100 trials

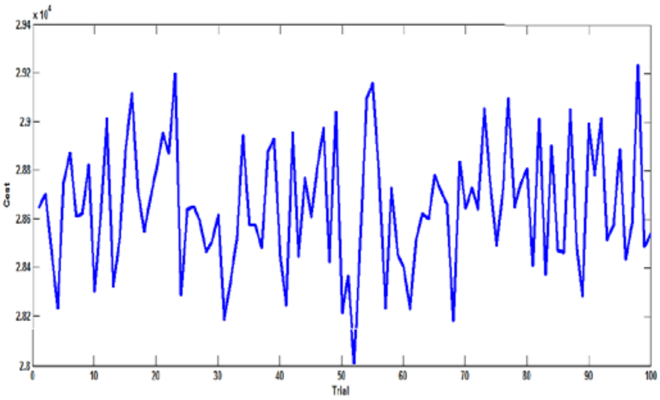

Fig.4 Results for the 10-Unit for without VPL Population size =40 out of 100 trials

Case B-Comparison of Results for 10 unit system

BBO achieved quite effective result. Results obtained from proposed BBO algorithm have been compared with PSO, CPSO, WIPSO and MRPSO [1],without valve Point Loading Effects. The best results of all evolutionary methods are shown in Table 2 and fig 5 shows that the proposed BBO algorithm provided better results compared to other reported evolutionary techniques.

TABLE 2 comparison 10-units system without valve point loading

Unit power output	PSO	CPSO	WIPSO	MRPSO	BBO
P1 (MW)	203.0951	215.034	203.095	225.016	181.017266
P2 (MW)	171.213	165.032	171.213	157.09	140.435484
P3 (MW)	126.9716	136.0432	126.971	126.971	84.000000
P4 (MW)	60	75.032	59.034	71.02	75.065381
P5 (MW)	89.7482	112.012	89.7482	119.76	170.433323
P6 (MW)	89.0969	82.2217	89.0969	89.0969	156.918750
P7 (MW)	130	123.02	131.241	121.01	127.189523
P8 (MW)	101.7198	66.8902	101.719	68.032	68.450896
P9 (MW)	50.0356	44.8738	50.0356	39.023	20.634938
P10 (MW)	13.9524	16.032	13.9021	19.03	11.854641
Power Demand	1036	1036	1036	1036	1036
Total Cost with out Valve Point	28295.02	28297.4	28291.8	28245.5	27933.025528

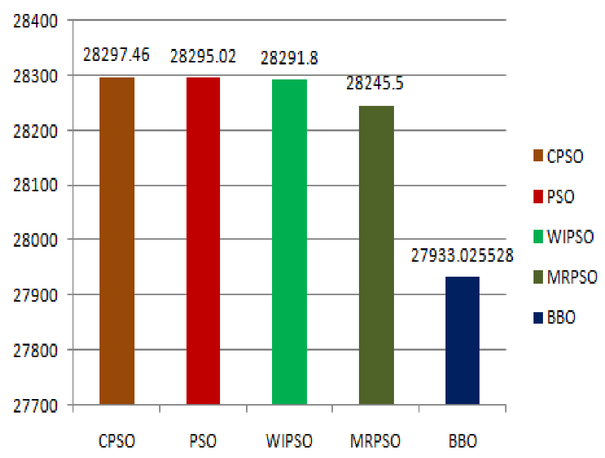

Fig 5- Comparison of total cost CPSO, PSO, WIPSO, MRPSO and BBO for 1036 MW

VI. CONCLUSION

This paper BBO optimization approach for the solution of power system economic dispatch with constraints. The proposed method has been applied to different test case. Overall we can conclude that today when there is competition amongst power generating companies, fast emerging difference between demand and supply then we need to develop a requisite for proper operation policies for power generating companies. It can be accomplished only when a proper mathematical formulation of ELD problem is there and all practical constraints are taken into account. It is clear from the results obtained by different trials that the proposed BBO method has good convergence property and can avoid the shortcoming of premature convergence of other optimization techniques to obtain better quality solution, so Soft computing techniques like the BBO use random operators for achieving the optimal result therefore in every fresh trial, these methods converge to different solutions near the global best solution.

VII. APPENDIX

Table A1-Data For 10-Generating unit system WITHOUT VPL

Unit	c_i	b_i	a_i	P_i^{min}	P_i^{max}
1	958.2	21.60	0.00043	150	470
2	1313.6	21.05	0.00063	135	460
3	604.97	20.81	0.00039	73	390
4	471.6	23.90	0.00070	60	300
5	480.29	21.62	0.00079	73	243
6	601.75	17.87	0.00056	57	160
7	502.7	16.51	0.00211	20	130
8	639.4	23.23	0.00048	47	170
9	455.6	19.58	0.10908	20	80
10	492.4	22.54	0.00951	10	55

VIII. REFERENCES

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