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Optimization of Power System with Economic Load Dispatch Using Soft Computing Approach

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Abstract — Economic load dispatch (ELD) problem is a common task in the operational planning of a power system, which requires to be optimized technique. This paper presents an effective and reliable BBO technique for the economic load dispatch problem. The results have been demonstrated for ELD of standard 3-generator and 6-generator .The final results obtained using BBO are compared with GA Technique.

Keywords—Optimization, Biogeography-Based, GA, Economic Load Dispatch, power system

I. INTRODUCTION

In recent years, developments in technology cause more energy demand in power systems and make these systems more complicated. Operation of power systems on optimal conditions and planning of it are required due to the increased energy demand. The Economic Dispatch (ED) problem, one of the nonlinear optimization problems in electrical power systems, has an important place in the economical operation of the power system. In solving the ED problem, the objective is to minimize the total fuel cost, while satisfying the various physical and operational constraints. In the traditional ED problem, the fuel cost function of a generator is performed as quadratic function. The economic load dispatch (ELD) of power generating units has always occupied an important position in the electric power industry [1]. Engineer is always concerned with the cost of products and services, the efficient optimum economic operation and planning of electric power generation system have always occupied an important position in the electric power industry. The classic problem is the economic load dispatch of generating systems to achieve minimum operating cost. For the purpose of optimum economic operation of this large scale system, modern system theory and optimization techniques are being applied with the expectation of considerable cost savings. The Economic Dispatch Problems (EDPs) is to determine the optimal combination of power outputs of all generating units to minimize the total fuel cost while satisfying the load demand and operational constraints [2]. ELD is used in real-time energy management power system control by most programs to allocate the total generation among the available units. ELD focuses upon coordinating the production cost at all power plants operating on the system. The Economic load dispatch is a main function in modern power system like unit Commitment, Load Forecasting, Security Analysis, Scheduling of fuel purchase etc. Intelligent methods are iterative techniques that can search not only local optimal solutions but also a global optimal solution. Among these methods, some of them are Particle swarm optimization (PSO) [3] and [4], evolutionary programming (EP) [5], Tabu search [6], neural Network (NN) [7], GA [8], Gravitational Search Algorithm [9], Ant colony optimization [10] and SA [11].In this paper the BB0 is proposed as a methodology for economic load dispatch. It requires less computation time and memory and the results are compared with the iteration methods GA.

II. Economic Load Dispatch Formulation

The practical static ELD problem with generator nonlinearities such as prohibited operating zones are solved in this paper using PSO variants to find the optimal generation dispatch for different operating conditions. The objective of the economic dispatch problem is to minimize the total fuel cost at thermal power plants subjected to the operating constraints of a power system. Therefore, it can be formulated mathematically with an objective function and two constraints. The equality and inequality constraints are represented by (1) and (2) given by

$$\sum P_i - (P_d + P_l) = 0 \qquad (1)$$

$$P_{imin} \le P_i \le P_{imax} \qquad (2)$$

In the power balance criterion, an equality constraint must be satisfied, as shown in (1). The generated power should be the same as the total load demand plus total line losses. The generating power of each generator should lie between maximum and minimum limits represented by (2), where Pi is the power of it generator, n is the number of generators in the system; Pd is the system total demand; Pl represents the total line losses; and are, respectively, the output of the minimum and maximum operation of the generating unit. The total fuel cost function is formulated as follows:

$$MinF_T = \sum_{i=1}^{N} F_i(P_i) \qquad (3)$$

where Fi is the total fuel cost for the ith generator (in $/h) which is defined by,

$$F_i(P_i) = (a_i P_i^2 + b_i P_i + c_i) \qquad (4)$$

For a given total real load PD the system loss Pl is a function of active power generation at each generating unit. To calculate system losses, methods based on penalty factors and constant loss formula coefficients or B-coefficients [1] are in use. The latter is adopted in this paper as per which transmission losses are expressed as

$$P_l = \sum_{i=1}^{N} \sum_{j=1}^{N} P_i B_{ij} P_j + \sum_{i=1}^{N} B_{oi} P_i + B_{oo} \qquad (5)$$

III. Biogeography-Based Optimization Algorithm 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 [].

3.1. 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.

3.2 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 [13]- [14].

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.

IV. RESULT ANALYSIS

The BBO algorithm has been proposed for solving i) A practical 3-generating unit ii) 6-generating unit .The simulations are carried out using MATLAB 9.0.1 on core i3 2^{nd} generation processor having 2.4 GHz. With 4 GB RAM on 64-bit operating system.

Test case 1: -The system has 3-generating units. The cost data has been show in the in Table 1 and the load demand is 850 MW. The results obtained from proposed BBO algorithm have been compared with GA and found to match very closely, It can be observed that population size 100, and M.R. =0.2 are best parameters of this case after 100 Trials, which is very close to global minima. The solutions of 100 trials of this case are plotted in Fig 1, fig 2 and compare the results in Table 2.

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Table 1 cost coefficients data

No. units	Cost Coefficients			Real Power	
	a_i	b_i	c_i	Min	Max
1	0.001562	7.92	561	150	600
2	0.00194	7.85	310	100	400
3	0.00482	7.97	78	50	200

Table 2 Performance Comparison of BBO and GA

Optimization method	GA Result	**BBO Results**
P (MW)	393.0103	**393.000000**
P (MW)	319.2256	**335.000000**
P3 (MW)	137.7642	**122.000000**
Total Power(MW)	**850.00**	**850.00**
Total Cost(Rs/MWh)	**8195.9790**	**8194.356718**

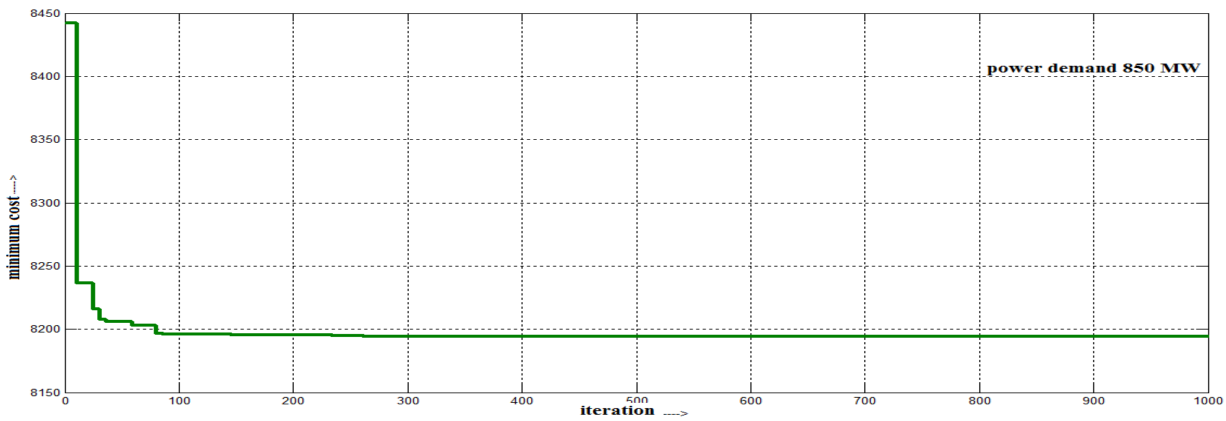

Fig 1 Best Results for the 3-Unit system for Population size =100 out of 100 trials, PD=850 MW

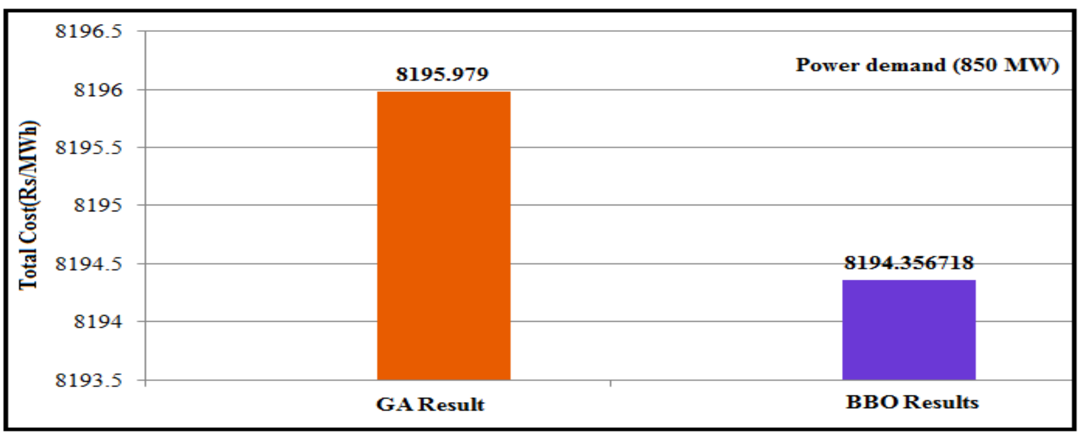

Fig 2 compares GA with BBO

Test case 2:-The system has 6-generating units. The cost data has been show in the in Table 3 and the load demand is 450 MW. The results obtained from proposed BBO algorithm have been compared with GA and found to match very closely, It can be observed that population size 100, and M.R. =0.2 are best parameters of this case after 100 Trials, which is very close to global minima. The solutions of 100 trials of this case are plotted in Fig 3, Fig 4 and compare result with GA Algorithm show in Table 4.

Table 3 cost coefficients data

No. units	**Cost Coefficients**			**Real Power**	
	a_i	**b_i**	**c_i**	**Min**	**Max**
1		2.0	100	10	85
2	0.010	2.0	200	10	80
3	0.020	2.0	300	10	70
4	0.003	1.95	80	50	250
5	0.015	1.45	100	5	150
6	0.010	0.95	120	15	100

Table 4 Performance Comparison of BBO and GA

Optimization method	GA Result	**BBO Results**
P (MW)	65.197850	**85.000000**
P (MW)	29.951560	**45.000000**
P3 (MW)	11.010200	**23.000000**
P4 (MW)	161.028600	**150.000000**
P5 (MW)	95.403810	**51.000000**
P6 (MW)	87.40800	**96.000000**
Total Power(MW)	**450.0000**	**450.0000**
Total Cost(Rs/MWh)	**1971.0680**	**1929.280000**

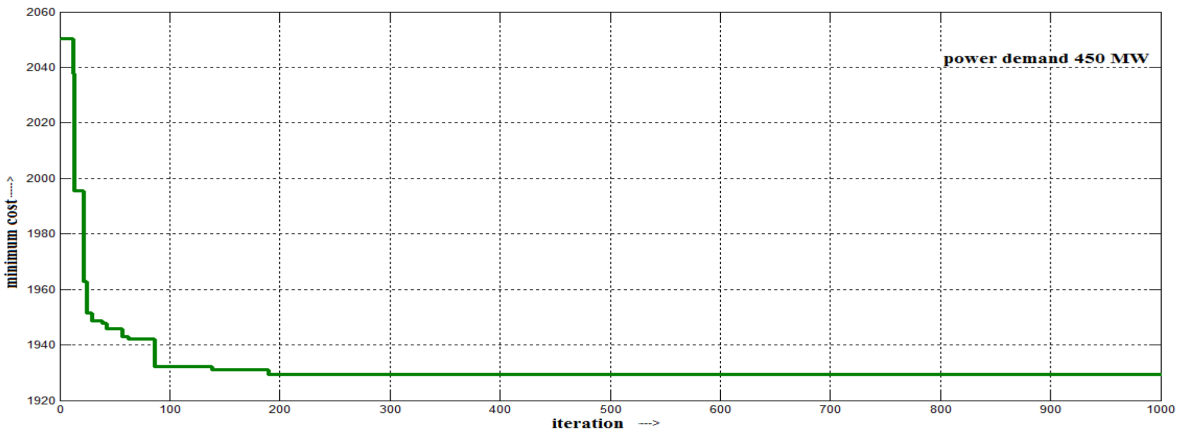

Fig 3 Best Results for the 6-Unit system for Population size =100 out of 100 trials, PD=450 MW

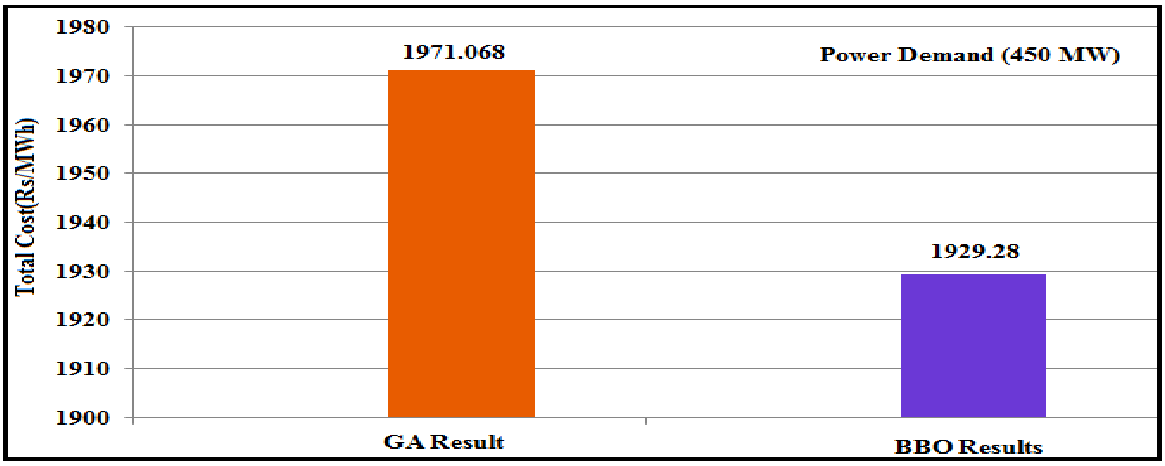

Fig 4 compares GA with BBO

V. Conclusion

This paper presents an efficient and powerful approach for solving the economic load dispatch (ELD) problem of power system. This paper demonstrates with clarity, chronological development and successful application of BBO technique to the solution of ELD. Two test systems 3-generator and 6-generator systems have been tested and the results are compared with GA. Overall, the BBO algorithms have been shown to be very helpful in studying optimization problems in power systems. The proposed approach is relatively simple, reliable and efficient and suitable for practical applications of power system.

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