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Economic Load Dispatch with Valve - Point Result Employing a Binary Bat Formula

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ABSTRACT

This paper proposes application of BAT algorithm for solving economic load dispatch problem. BAT algorithmic rule is predicated on the localization characteristics of micro bats. The proposed approach has been examined and tested with the numerical results of economic load dispatch problems with three and five generating units with valve point loading without considering prohibited operating zones and ramp rate limits. The results of the projected BAT formula are compared with that of other techniques such as lambda iteration, GA, PSO, APSO, ABC and basic principle. For each the cases, the projected algorithmic program outperforms the answer reported for the existing algorithms. Additionally, the promising results show the hardiness, quick convergence and potency of the projected technique.

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1. INTRODUCTION

Economic load dispatch (ED) is an important task in the power plants operation which aims to allocate power generations to match load demand at minimal possible cost while satisfying all the power units and system constraints [1-3]. The complexity of the problem is due to the nonlinear and non-smooth characteristics of the input-output curves of the generators, because of valve-point impact, ramp rate limits and prohibited operating zones. The mathematical programming based mostly optimization methods such as lambda iteration, base point participation technique, Gradient and Newton’s ways will solve successfully the convex ED problems [4]. But unfortunately, these methods are ineffective to handle the non convex ED problems with non-differentiable characteristics due to high completeness. Dynamic programming will solve such variety of drawback, but it suffers from curse of dimensionality [5-6]. Therefore for optimum resolution this downside wants a fast, robust and accurate solution methodology. Now days heuristic search methods such as simulated annealing (SA) [3]-[4], genetic algorithm (GA) [7], evolutionary programming (EP) [8], particle swarm optimization (PSO) [9]-[12], Bacteria foraging optimization (BFO) [13], differential evolution (DE) [14] and chaotic ant swarm optimization [15-17] are employed to solve the ED problems All the approaches have achieved success to a certain extent.

This paper presents the application of proposed BAT algorithm to economic load dispatch problem with valve point loading. The paper is organized as follows. Section 2 describes mathematical modeling of economic load dispatch problem with valve point loading without considering prohibited operating zones and ramp rate limits. The proposed BAT algorithm is described in section 3 and the description of test systems, results and comparisons of proposed algorithm with other methods are presented in section 4. Finally conclusion is given in section 5.

2. ECONOMIC LOAD DISPATCH PROBLEM

The economic load dispatch problem is defined as to minimize the total operating cost of a power system while meeting the total load plus transmission losses with in the generator limits. Mathematically, the problem is outlined on minimize equation (1) subjected to the energy balance equation given by (2) and the inequality constraints given by equation (3).

$$F_i(P_i) = \sum_{i=1}^{NG} (a_i P_i^2 + b_i P_i + c_i) \tag{1}$$

$$\sum_{i=1}^{NG} P_i = P_D + P_L \tag{2}$$

$$P_{imin} \le P_i \le P_{imax} (\mathrm{i} = 1, 2 \ldots \mathrm{NG}) \tag{3}$$

where

a_i, b_i, and c_i are the cost coefficients
P_D is the load demand
P_{gi} is the real power generation
P_L is the transmission power loss
NG is the number of generation buses.

One of the important, simple but approximate methods of expressing transmission loss as a function of generator powers is through B- coefficients. The general form of the loss formula using B- coefficients is

$$P_i = \sum_{i=1}^{NG} \sum_{j=1}^{NG} P_i B_{ij} P_j \quad \mathrm{MW} \tag{4}$$

where

P_i and P_j are the real power generations at the i^{th}, j^{th} buses respectively
B_{ij} are loss coefficients.

The above transmission loss formula of Eq. (4) is known as the George's formula.

In normal economic load dispatch problem the input - output characteristics of a generator are approximated using quadratic functions, underneath the idea that the progressive cost curves of the units are monotonically increasing piecewise-linear functions. However, real input- output characteristics display higher order nonlinearities and discontinuities due to valve – point loading in fossil fuel burning plants.

The generating units with multi – valve steam turbines exhibit a greater variation in the fuel cost functions. The valve – point effects introduces ripples in the heat – rate curves. Mathematically operating cost is defined as:

$$F_i(P_i) = \sum_{i=1}^{NG} (a_i P_i^2 + b_i P_i + c_i + |d_i * \sin\{e_i * (P_i^{min} - P_i)\}|) \tag{5}$$

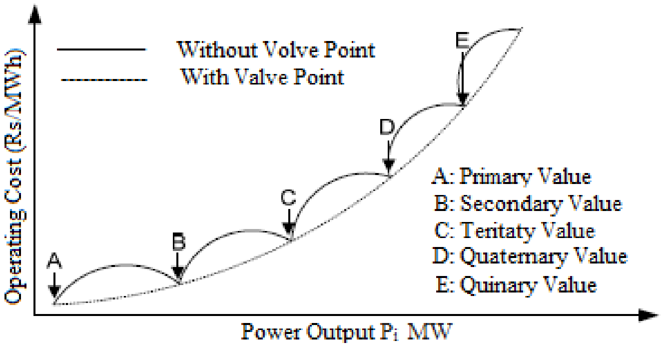

Figure 1. Operating cost characteristics with valve point loading.

where a_i, b_i, c_i, d_i and e_i are the cost coefficients of the i^{th} unit.

Mathematically, economic dispatch problem considering valve point loading is defined as equation (5) subjected to: (i) The energy balance equation is given by Eq. (2) and (ii) The inequality constraints are given by Eq. (3) respectively.

3. BAT ALGORITHM

Bats are fascinating animals. They are the only mammals with wings and they also have advanced capability of echolocation. Most of bats use echolocation to a certain degree; among all the species, microbats are famous example as microbats use echolocation extensively, while mega bats do not. Microbats use a type of sonar, called echolocation, to detect prey, avoid obstacles, and locate their roosting crevices in the dark.

If we idealize some of the echolocation characteristics of microbats, we can develop various bat-inspired algorithms or bat algorithms. For simplicity, we now use the following approximate or idealized rules:

1. All bats use echolocation to sense distance and they also know the difference between food/prey and background barriers.
2. Bats fly randomly with velocity v_i at position x_i with a fixed frequency f_{min}(or wavelength λ), varying wavelength λ (or frequency *f*) and loudness A_o to search for prey. They can automatically adjust the wavelength (or frequency) of their emitted pulses and adjust the rate of pulse emission $r \in [0,1]$depending on the proximity of their targets;
3. Although the loudness can vary in many ways, we assume that the loudness varies from a large (positive) A_o to a minimum valueA_{min}.

Another obvious simplification is that no ray tracing is used in estimating the time delay and three dimensional topography. In addition to these simplified assumptions, we have a tendency to additionally use the subsequent approximations, for simplicity. In normally the frequency f in a range $[f_{min}, f_{max}]$ corresponds to a range of wavelengths $[\lambda_{min}, , \lambda_{max}]$. For example, a frequency range of [20 kHz, 500 kHz] corresponds to a range of wavelengths from 0.7mm to 17mm.

In simulations, we use virtual bats naturally. We have got to outline the foundation however their positions x_i and velocities v_i in a d-dimensional search space are updated. The new solutions x_i^t and velocities v_i^t at time step t are given by

$$f_i = f_{min} + (f_{max} - f_{min})\beta \tag{6}$$

$$v_i^t = v_i^{t-1} + (x_i^t - x_*)f_i \tag{7}$$

where $\beta \in [0,1]$ is a random vector drawn from a uniform distribution. Here x_* is the current global best location (solution) which is located after comparing all the solutions among all the n bats. As the product $\lambda_i f_i$ is the velocity increment, we can use either f_i (or λ_i) to adjust the velocity change while fixing the other factor λ_i (or f_i), depending on the type of the problem of interest. For the local search part, once a solution is selected among the current best solutions, a replacement answer for every bat is generated regionally mistreatment stochastic process

$$x_{new} = x_{old} + \epsilon A^t \tag{8}$$

Where $\epsilon \in [-1,1]$ is a random number, while $A^t = < A_i^t >$ is the average loudness of all the bats at this timemstep.

Based on the on top of approximations and idealization, the pseudo-code of the Bat Algorithm (BA) can be summarized below.

a. Pseudo-Code of the Bat Algorithm

```
Objective function f(x), x = $(x1, \ldots, xd)^T$
Initialize the bat population $x_i$ (i = 1, 2, .., n) and $v_i$
Define pulse frequency $f_i$ at $x_i$
Initialize pulse rates $r_i$ and the loudness $A_i$
while (t <Max number of iterations)
Generate new solutions by adjusting frequency,
and updating velocities and locations/solutions [equations (6) to (8)]
if (rand > $r_i$)
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```
Select a solution among the best solutions
Generate a local solution around the selected best solution
end if
Generate a new solution by flying randomly
if (rand < $A_i$ & f( $x_i$) < f($X_*$))
Accept the new solutions
Increase $r_i$ and reduce $A_i$
end if
Rank the bats and find the current best $X_*$
end while
Post process results and visualization.
```

4. SIMILATION RESULTS AND DISCUSSION

The applicability and validity of the BAT algorithm for practical applications has been tested on various test cases. The obtained best solution in fifty runs are compared with the results obtained using GA [21]. All the programs are developed using MATLAB 7.8.0 (2009a) and the system configuration is core i3 processor with 2.30 GHz speed and 6 GB RAM.

a. Setting of Bat Algorithm Parameters

The Parameters for BAT algorithm considered here are: n=20; A=0.9; r=0.1; f_min= 0; f_max= 2. The proposed BAT algorithm stopping criteria is based on maximum-generation=100.

b. Numerical Solutions

Test case 1:

The system consists of three thermal units [1]. The cost coefficients of all thermal generating units with valve point effect are listed in Table 1. The transmission losses are neglected. Prohibited zones and ramp rate limits of generating units are not considered. The economic load dispatch problem is solved to meet a load demand of 850 MW and 1050 MW.

Table 1. Cost coefficients for Three Generating units

Unit	Fuel cost coefficients					$P_{G\,min}$ (MW)	$P_{G\,max}$ (MW)
	a_i	b_i	c_i	d_i	e_i		
G1	0.0016	7.92	561.0	300	0.032	100	600
G2	0.0048	7.92	78.0	150	0.063	50	200
G3	0.0019	7.85	310.0	200	0.042	100	400

This test system comprises of three generating units and six buses and the unit data are adapted from [3]. In this case, valve-point effect is included and transmission losses are neglected. The total load demand for the system is 850 MW and 1050MW. Results obtained for the proposed method is shown in Table 2 and the results are compared with Lambda, GA, PSO and ABC. It was reported in that the global optimum solution found for the 3-generator system is 8121.8568 Rs/hr and 10123.6953 Rs/hr. From the results in Table 2 it is explicit that BAT algorithm has succeeded in finding the global optimum solution that has been reported in the literature.

Table 2. Comparison of results for test case 1

Load demand	Parameter	Lambda	GA	PSO	ABC	BAT
850 MW	P1,MW	382.258	382.2552	394.5243	300.266	296.3495
	P2,MW	127.419	127.4184	200.000	149.733	199.6002
	P3,MW	340.323	340.3202	255.4756	400.000	334.0503
	Total cost, Rs/h	8575.68	8575.64	8280.81	8253.10	8121.8568
1050 MW	P1, MW	487.500	487.498	492.699	492.6991	492.6991
	P2, MW	162.500	162.499	157.30	157.301	158.0995
	P3, MW	400.000	400.000	400.00	400.00	399.2014
	Total cost, Rs/h	10212.459	10212.44	10123.73	10123.73	10123.6953

Figure 2 shows the convergence tendency of proposed BAT algorithm based strategy for power demand of 850 MW and 1050 MW is plotted in figure 2. It shows that the technique converges in relatively fewer cycles thereby possessing good convergence property.

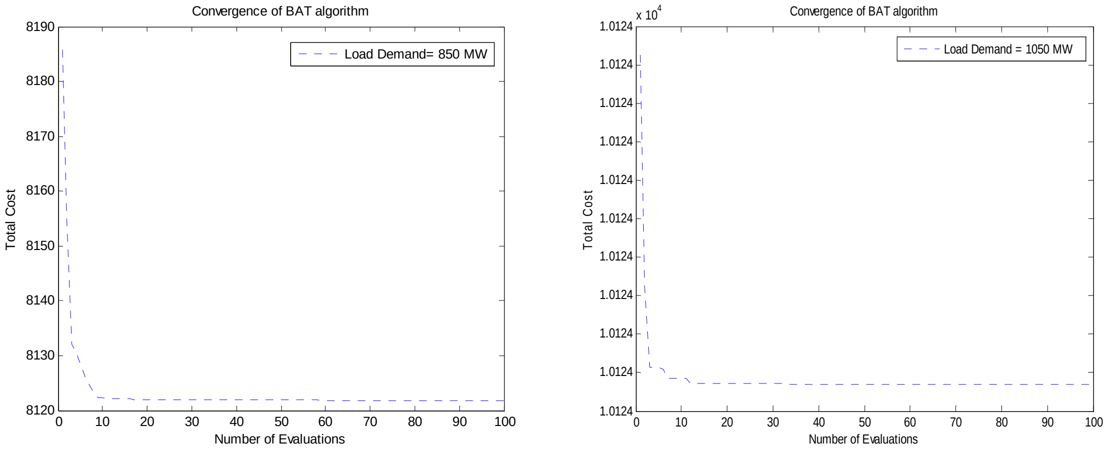

Figure 2. Convergence characteristics of three generating units.

Test case 2:

The system consists of five thermal units [1]. The cost coefficients of all thermal generating units with valve point effect are listed in table (3). The economic load dispatch problem is solved to meet a load demand of 730 MW.

Table 3. Cost coefficients for Three Generating units

Unit	Fuel cost coefficients					$P_{G\,min}$ (MW)	$P_{G\,max}$ (MW)
	a_i	b_i	c_i	d_i	e_i		
G1	0.0015	1.8	40.0	200.0	0.035	50	300
G2	0.0030	1.8	60.0	140.0	0.040	20	125
G3	0.0012	2.1	100.0	160.0	0.038	30	175
G4	0.0080	2.0	25.0	100.0	0.042	10	75
G5	0.0010	2.0	120.0	180.0	0.037	40	250

This test system comprises of five generating units. In this case, valve-point effect is included and transmission losses are neglected. Prohibited zones and ramp rate limits of generating units are not considered. The total load demand for the system is 750 MW. Results obtained for the proposed method is shown in Table 4 and the results are compared with Lambda, GA, PSO and ABC. It was reported in that the global optimum solution found for the 5-generator system is 2029.668 Rs/hr. From the results in Table 4 it is explicit that BAT algorithm has succeeded in finding the global optimum solution that has been reported in the literature.

Table 4. Comparison of results for test case 2

Load demand	Parameter	Lambda	GA	PSO	APSO[1]	EP[1]	ABC	BAT
730 MW	P1, MW	218.028	218.0184	229.5195	225.3845	229.8030	229.5247	229.5209
	P2, MW	109.014	109.0092	125.00	113.020	101.5736	102.0669	102.9878
	P3, MW	147.535	147.5229	175.00	109.4146	113.7999	113.4005	112.6753
	P4,MW	28.380	28.37844	75.00	73.11176	75.000	75.000	75.000
	P5,MW	272.042	227.0275	125.4804	209.0692	209.8235	210.0079	209.816
	Total cost, Rs/h	2412.709	2412.538	2252.572	2140.97	2030.673	2030.259	2029.668

Figure 3 shows the convergence tendency of proposed BAT algorithm based strategy for power demand of 750 MW is plotted in figure 3. It shows that the technique converges in relatively fewer cycles thereby possessing good convergence property.

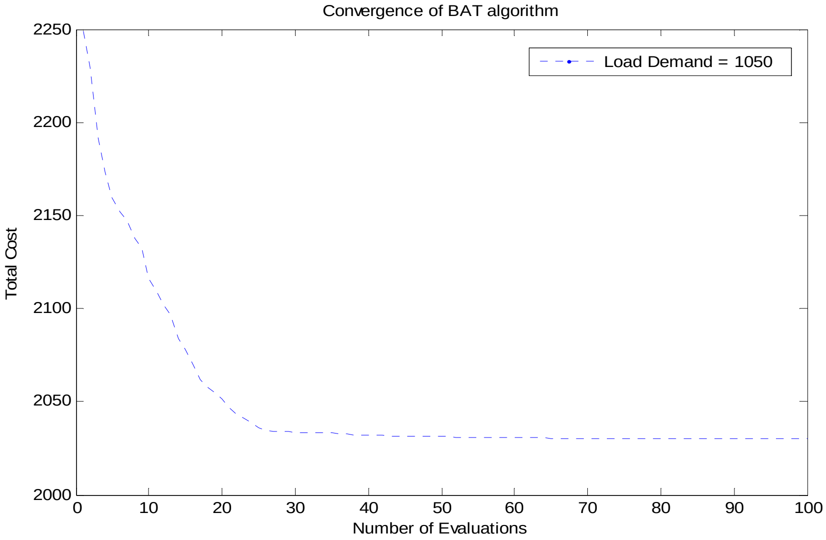

Figure 3. Convergence characteristics of five generating units

5. CONCLUSION

In this paper, a new BAT algorithm has been proposed. In order to prove the effectiveness of algorithm it is applied to economic load dispatch problem with three and five generating units. The results obtained by proposed method were compared to those obtained by lambda iteration method, GA, PSO, APSO and ABC. The comparison shows that BAT algorithm performs better than above mentioned methods. The BAT algorithm has superior features, including quality of solution, stable convergence characteristics and good computational efficiency. Therefore, this results shows that BAT optimization is a promising technique for solving complicated problems in power system.

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