MULTI-OBJECTIVE ECONOMIC EMISSION DISPATCH USING BAT ALGORITHM WITH MULTIPLE LOADS

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Abstract— The main aim of power utilities is to provide high quality power supply to the consumer at lowest possible cost and minimum emission while operating to meet the limits and constraints imposed on the generating units. The combustion of fossil fuel gives rise to particular material and gaseous pollutants apart from the discharge of heat to water courses as by-products. Several contaminants, such as Sulphur oxides, nitrogen oxides and carbon dioxide show destructive effects on human life. In the Multi-objective problem formulation, there is minimum emission dispatch for in operating strategy, which can ensure minimum pollution level at minimum operating cost. The economic and emission dispatch problem with multiple loads has been addressed in this paper using Bat algorithm with weighting method. In the experimental study, Bat algorithm is analysed and demonstrated on standard IEEE 30 bus system consisting of six generating units.

Keywords - Economic Emission Dispatch, Emission Dispatch, Multi-Objective Optimization, Bat algorithm, Weighting Method.

1. INTRODUCTION

Economic emission dispatch (EED) has become an essential function in operation and control of modern power system and it is a sub problem of an optimal power flow. The main aim of the economic emission dispatch problem is to find an optimal combination of the output power of all the online generating units that minimize the total fuel cost and reduction of pollution level up to a safe limit of the generation and supplies the power demand while satisfying unit constraints, equality and inequality constraints [1]. The major part of the power is generated due to the fossil fired plants and hence their emission contribution cannot be ignored. Fossil fired electric power plants use coal, oil, gas as primary energy resources and produce atmospheric emission whose nature and quantity depend upon fuel type and its quality. The particulate matter such as ash and gaseous pollutant i.e. CO2, NOX (oxides of nitrogen) etc. are produced due to coal. Hence it is a needed to reduce the emission from there fossil fired plants either by design or by operational strategies [2]. In classical Economic Load Dispatch (ELD) problem, mathematical model of fuel cost function has been approximated as a single quadratic cost function [3]. A number of conventional optimization techniques have been applied to solve the EED problem such as linear Programming (LP) [4], nonlinear programming (NLP) [5], quadratic programming (QP) [6], and interior point methods [7]. Although these conventional techniques offer good results but when the search space is non-linear and has discontinuities they become very complicated with a slow convergence ratio and sometimes unable to find the optimal solution. To overcome these difficulties new numerical methods are needed which have high speed search to the global optima and does not suffer from the problem of local minima [8]. In the recent years the soft computing techniques such as Genetic algorithm (GA) [9], Evolutionary programming (EP), Simulated annealing (SA), Tabu search (TS) technique, Particle Swarm Optimization (PSO) [10-11-12] etc. may prove to be very effective in solving nonlinear EED problems.

In this paper a bio inspired optimization, i.e., BAT algorithm is proposed to solve economic dispatch problems is presented and the effectiveness of proposed algorithm is tested using six generating unit test systems with different loads. As a novel feature, bat algorithm (BA) was based on the echolocation features of micro bats (Yang, 2010), and BA uses a frequency-tuning technique to increase the diversity of the solutions in the population, while at the same, it uses the automatic zooming to try to balance exploration and exploitation during the search process by mimicking the variations of pulse emission rates and loudness of bats when searching for prey. As a result, it proves to be very efficient with a typical quick start. Obviously, there is room for improvement. This bat algorithm method is extended to the economic emission dispatch problems. A big advantage BA has over other algorithms is that it has a number of tuneable parameters giving a greater control over the optimization process. BA and its variants have also been used to solve the ELD problem [13–15]. It has proven efficient in for lower dimensional optimization problem but ineffective for high dimensional problems because of fast initial convergence.

2. MULTI-OBJECTIVE OPTIMIZATION PROBLEM FORMULATION

In the multi objective problem formulation, four important non commensurable objectives in an electrical thermal power system- operating cost F_1, NO_x emission F_2, SO_2

emission F_3 and CO_2 emission F_4 are considered. The Multiobjective optimization problem is defined as

Minimize $F_1 = \sum_{i=1}^{N}(a_i P_i^2 + b_i P_i + c_i)$Rs/h (1)

Minimize $F_2 = \sum_{i=1}^{N}(d_{1i} P_i^2 + e_{1i} P_i + f_{1i})$ kg/h (2)

Minimize$F_3 = \sum_{i=1}^{N}(d_{2i}\, P_i^2 + e_{2i} p_i + f_{2i})$ kg/h (3)

Minimize$F_4 = \sum_{i=1}^{NG}(d_{3i}\, P_i^2 + e_{3i} P_i + f_{3i})$ kg/h (4)

Subjected to $\sum_{i=1}^{N} P_i - (P_D + P_L) = 0$ (5)

$P_i^{min} \leq P_i \leq P_i^{max}$ (i = 1,2, …., N)

Where

a_i,$b_{i,}$ and c_i are cost coefficients of the ith generating unit

d_{1i},e_{1i} and f_{1i} are NO_x emission coefficients

d_{2i}, e_{2i} and f_{2i} are SO_2 emission coefficients

d_{3i}, e_{3i} and f_{3i} are CO_2 emission coefficients

P_D is the power demand to be met

P_L is the transmission losses, Which are approximated in terms of B-coefficients as

$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N} P_i\, B_{ij} P_j$ (6)

P_i^{min} is the lower operating generation limit

P_i^{max} is the upper operating generation limit

N is the number of generators in the power system F_1(P), F_2(P), F_3(P) and F_4(P) are the objective functions to be minimized over the set of admissible decision vector P. To generate the non-inferior solution to the multi-objective problem, the weighing method is applied. In this method, the problem converted into a scalar optimization as given below:

Minimize $\sum_{k=1}^{M} w_k\, F_k(P_i)$ (7)

Subjected to $\sum_{i=1}^{N} P_i - (P_D + P_L) = 0$ (8)

$P_i^{min} \leq P_i \leq P_i^{max}$ (i = 1,2, …., N)

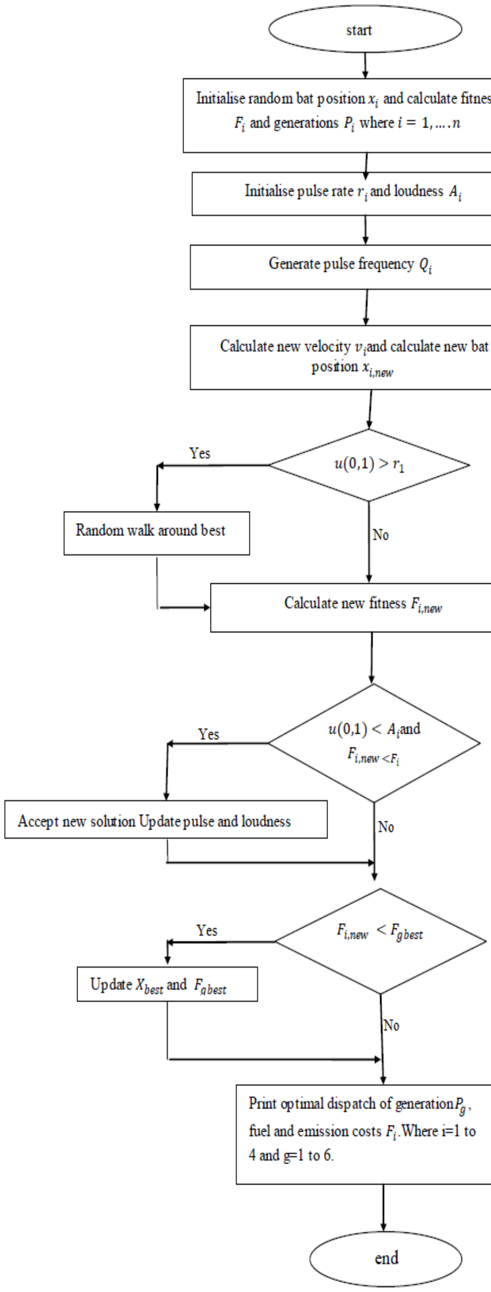
$\sum_{k=1}^{M} w_k = 1\ (w_k \geq 0)$ (9)

Where M is the number of objectives

w_k are levels of normalized weights.

This approach yields meaningful result to the decision maker when solved many times for different values $w_k(k = 1, 2, \dots, M)$. Weighing factors w_k are determined based on the relative importance of various objectives, which may vary from place to place and utility to utility.

3. BAT ALGORITHM



4. DESCRIPTION OF THE TEST SYSTEM

In the study of experiment, Bat algorithm is tested over standard IEEE 30-bus power system with six generating units as shown in figure 1.

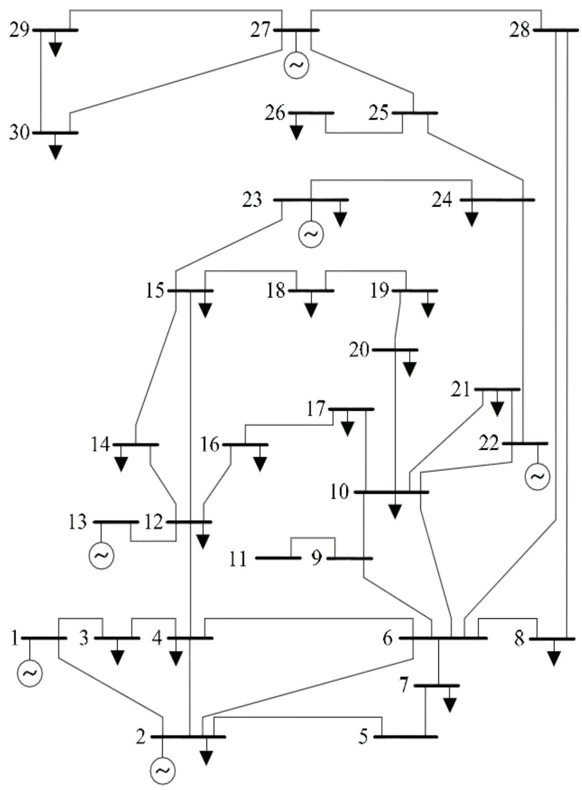


Fig 1: Single Line Diagram of IEEE 30-Bus Test System

The algorithm is tested for load demand 1800MW, 2000MW and 2200MW. The coefficients of Economic Emission Dispatch problem and transmission loss coefficients matrix are taken from Power System Optimization(D.P. Kothari and J.S. Dhillon) Text Book.

The transmission loss coefficients matrix is given by equation

$$B_{ij} = \begin{bmatrix} 0.000200 & 0.000010 & 0.000015 & 0.000005 & 0.000000 & -0.000030 \\ 0.000010 & 0.000300 & -0.000020 & 0.000001 & 0.000012 & 0.000010 \\ 0.000015 & -0.000020 & 0.000100 & -0.000010 & 0.000010 & 0.000008 \\ 0.000005 & 0.000001 & -0.000010 & 0.000150 & 0.000006 & 0.000050 \\ 0.000000 & 0.000012 & 0.000010 & 0.000000 & 0.000250 & 0.000020 \\ -0.000030 & 0.000010 & 0.000008 & 0.000050 & 0.000020 & 0.000210 \end{bmatrix}$$

the fuel cost, NO_x emission, SO_2 emission and CO_2 emission coefficients are given in Table1.

Table1: coefficients of fuel cost,NO_x, SO_2 andCO_2 emission

a_i	b_i	c_i	d_{1i}	e_{1i}	f_{1i}
0.0020	8.432	85.6348	0.0063	-0.381	80.901
0.0038	6.410	303.778	0.0064	-0.790	28.824
0.0021	7.428	847.148	0.0031	-1.360	324.177
0.0013	8.301	274.224	0.0063	-2.399	610.253
0.0021	7.428	847.148	0.0031	-1.360	324.177
0.0059	6.915	202.025	0.0061	-0.390	50.380
d_{2i}	e_{2i}	f_{2i}	d_{3i}	e_{3i}	f_{3i}
0.0012	5.059	51.377	0.2651	-61.019	5080.14
0.0023	3.846	182.26	0.1400	-29.952	3824.77
0.0012	4.456	508.52	0.1059	-9.552	1342.85
0.0008	4.976	165.34	0.1064	-12.736	1819.62
0.0012	4.456	508.52	0.1059	-9.552	1342.85
0.0035	4.149	121.21	0.4031	-121.98	11381.07

5. RESULT AND DISCUSSION

Here the Multi-objective Economic Emission Dispatch problem with different loads is solved by using Bat algorithm for the standard IEEE 30-bus power system. A Systematic variation of the $w_k$will generate non-inferior solution. Combination of weights is given in Table2 and Generation scheduling with all load demands corresponding to the weights are given in Table 3 to 5.power loss with all loads are given in Table6. Fuel costF_1, NO_x emissionF_2, SO_2 emission F_3 and CO_2 emission F_4 with all loads are given in Table 7 to 9.

Table2: Combination of weights

S No	w_1	w_2	w_3	w_4
1	1.0	0.0	0.0	0.0
2	0.0	1.0	0.0	0.0
3	0.0	0.0	1.0	0.0
4	0.0	0.0	0.0	1.0
5	0.2	0.2	0.2	0.4
6	0.4	0.4	0.1	0.1
7	0.6	0.2	0.1	0.1
8	0.1	0.1	0.6	0.2
9	0.1	0.6	0	0.3
10	0.2	0.0	0.2	0.6

Table3: Generation scheduling with 1800(MW) Load demand

P_1	P_2	P_3	P_4	P_5	P_6
143.21	321.43	362.78	400.00	335.58	250.00
167.89	194.78	488.12	307.20	483.54	171.87
171.23	400.00	397.20	296.31	367.31	181.46
242.40	345.59	365.99	400.00	360.76	99.01
237.47	400.00	358.65	365.20	353.95	98.04
209.46	284.58	322.40	307.78	600.00	92.04
224.00	314.51	347.01	336.61	340.51	250.00
228.13	320.21	338.38	342.39	333.55	250.00
219.51	298.37	324.16	400.00	320.57	250.00
228.61	400.00	347.16	400.00	343.00	94.74

Table4: Generation scheduling with 2000(MW) Load demand

P_1	P_2	P_3	P_4	P_5	P_6
215.83	400.00	434.98	364.87	402.56	197.77
182.80	209.20	517.71	321.15	600.00	186.96
214.32	400.00	439.61	359.29	406.42	196.39
250.00	400.00	428.43	400.00	422.16	115.67
250.00	389.65	432.75	400.00	424.80	118.94
250.00	367.92	439.16	400.00	434.84	124.07
250.00	376.49	436.66	400.00	427.37	125.48
250.00	400.00	427.12	400.00	419.99	119.13
234.35	324.04	361.04	400.00	600.00	98.49
216.42	400.00	316.88	400.00	600.00	86.51

Table5: Generation scheduling with 2200(MW) Load demand

P_1	P_2	P_3	P_4	P_5	P_6
134.46	318.64	600.00	400.00	600.00	167.71
170.09	400.00	492.60	309.13	600.00	250.00
214.70	400.00	600.00	400.00	407.06	196.41
250.00	400.00	600.00	400.00	446.46	122.13
222.79	309.25	600.00	400.00	600.00	88.45
250.00	379.31	460.87	400.00	600.00	131.08
250.00	400.00	600.00	400.00	438.64	129.84
221.15	309.18	600.00	400.00	600.00	89.99
250.00	400.00	463.25	400.00	456.38	250.00
250.00	400.00	600.00	400.00	445.57	123.16

Table6: Power Loss with all Load demands

P_L at 1800	P_L at 2000	P_L at 2200
13.01	16.03	20.83
13.42	17.84	21.82
13.54	16.05	18.18
12.96	16.27	18.60
13.51	16.15	20.49
16.29	16.01	21.47
12.65	16.02	18.49
12.68	16.24	20.49
12.63	18.74	19.22
13.53	19.83	18.59

Table7: Economic and emission cost with 1800(MW) Load demand

Cost	NO_x	SO_2	CO_2
17627.65	2140.62	10569.75	69363.36
17718.79	1815.00	10618.32	67920.58
17593.71	2161.59	10548.03	62630.60
17647.67	2186.99	10580.68	57361.50
17655.76	2285.21	10585.84	57754.81
17787.25	2049.65	10659.43	65001.74
17621.17	2101.91	10565.63	66999.95
17624.71	2131.20	10568.01	66948.89
17646.56	2169.61	10581.64	67392.99
17668.17	2336.76	10593.76	57908.98

Table8: Economic and emission cost with 2000(MW) Load demand.

Cost	NO_x	SO_2	CO_2
19454.99	2512.82	11662.97	76237.47
19659.58	2218.13	11778.66	86658.40
19455.14	2503.87	11662.88	76274.53
19501.82	2585.64	11690.55	72398.11
19495.82	2553.75	11686.79	72397.86
19489.08	2492.68	11682.36	72532.69
19487.59	2515.04	11681.70	72474.82
19498.26	2584.68	11688.49	72403.93
19622.41	2491.71	11759.65	77256.54
19657.77	2697.27	11781.81	78089.94

Table9: Economic and emission cost with 2200(MW) Load demand

Cost	NO_x	SO_2	CO_2
21514.91	2766.52	12889.70	101840.16
21463.98	2874.46	12862.10	104044.40
21399.50	2926.99	12825.14	95246.75
21441.84	2953.15	12849.41	91994.63
21571.59	2807.01	12923.24	97052.17
21457.84	2897.37	12858.67	92407.96
21433.54	2950.82	12844.61	92025.28
21569.58	2804.22	12922.04	97056.65
21365.97	2936.14	12807.46	96339.33
21440.69	2957.78	12848.73	91995.17

5. CONCLUSION

The projected research work carries a fresh approach based on Non-Inferior Solution by Weighted method of multi objective economic emission dispatch with multiple loads has been offered using Bat algorithm. In order to prove the effectiveness of algorithm it is applied to three different cases with six generating units. Cases 1, 2 & 3 are 1800 MW, 2000 MW & 2200 MW. The problem has been formulated as multi objective economic dispatch problem with consisting fuel cost and environmental impact objectives. The results show that the method is efficient for solving multi objective economic and emission dispatch problem with different loads.

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