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Emission and Economic Load Dispatch through Black Hole Algorithm

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Abstract: The main aim of Economic load dispatch is to reduce the total production cost of the generating system and at the same time the necessary equality and inequality constraints should also be fulfilled. Real power generation optimization is necessary for minimizing the production cost. Real power generations from different generators are the control parameters in this project. These control parameter values are adjusted for minimization of cost of real power generation from different generating stations. In this project, the newly introduced Black Hole (BH) algorithm is proposed for finding suitable values of the control parameters that optimizes real power generation. The algorithm has less number of operators and can be easily implemented for any optimization problems. The proposed algorithm tested on 40 generator units system and the results produce better optimal solution.

Keywords: Economic load dispatch (ELD), Thermal generation constrains, Black Hole algorithm (BH), fuel cost.

I. INTRODUCTION

Economic dispatch problem is one of the most important problems in electric power system operation. In large scale system, the problem is more complex and difficult to find out optimal solution because it is nonlinear function and it contains number of local optimal. Economic and Emission dispatch problem is to schedule the committed generating units output to meet the required load demand at minimum operating cost with minimum emission simultaneously [1]. Optimal solution of the ED problem provides significant economic advantages. With the increased interest in environmental pollution, the traditional ED, which ignores the pollutant emissions of the fossil fuels used by the thermal plants, no longer satisfies the needs. Therefore, the environmental economic dispatch (EED), as an alternative, has become more attractive, because it considers the pollutant emissions as well as economic advantages [1]. The solution of the EED problem comprises some important evaluation criteria such as fuel cost, environmental impact and total active power loss. Fossil fuels cause atmospheric waste emission composed of gases and particles such as carbon dioxide, sulphur dioxide, nitrogen oxide. These waste gases endanger all living creatures and even lead to global warming. Emission of sulphur dioxide , one of the waste gases, is dependent only on the fuel consumption therefore easier to model mathematically [1]. On mathematical modeling of nitrogen Dioxide emission is more far more difficult since it depends on a few factors such as boiler temperature and air fuel mixture. So, the Emission and Economic Dispatch problem is a multi-objective mathematical problem in which conflicting objectives are optimized simultaneously. This makes the Economic Dispatch problem a large-scale highly constrained nonlinear optimization problem [4].

The remainder of this paper is organizes as follows. Section II describes the formulation of the problem. Section III investigates the black hole algorithms. Section IV shows the simulation results. Section V contains the conclusion.

II. FORMULATION OF THE PROBLEM

2.1 Objective Function

The objective function of this work is to find the optimal settings of real power generation which minimizes the cost. Hence, the objective function can be expressed as

$$f = \min \left[w \sum_{n=1}^{NG} F_n(P_{g,n}) + (1-w)\gamma \sum_{n=1}^{NG} E_n(P_{g,n}) \right] \quad (1)$$

Where,

γ - Scaling factor
w- Weight factor

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2.2 Economic Dispatch

The economic dispatch problem is to determine the optimal mixture of power generation in a manner that the entire production cost of the entire system is reduced while satisfying the total power demand and few key power system factors. Therefore, the total production cost function of economic dispatch problem is defined as the total sum of the fuel costs of all the generating plant units as mentioned below. The first objective is fuel cost minimization given by

$$F_n(P_{g,n}) = a_n + b_n P_{g,n} + c_n P_{g,n}^2 \quad (2)$$

Where,

$P_{g,n}$ - Generating power

a_n, b_n, c_n - fuel cost coefficient

2.3 Emission Dispatch

The solution of economic dispatch problem will provide the quantity of active power to be produced by various units at the minimum production cost for a certain power requirement. On the other hand, the total quantity of pollutant emission is not considered in conventional economic dispatch problem. The quantity of pollutant emission resulting from a fossil-fired thermal generating unit is based on the amount of power generated by every unit. For reducing the complexity, the total emission produced can be modeled as a direct sum of a quadratic function and an exponential term of the active power output of the generating units. The pollutant emission dispatch problem can be described as the optimization of total amount of pollutant emission given as below:

The emission is calculated by the following expression.

$$E_n(P_{gn}) = \propto_n + \beta_n P_{g,n} + \xi_n \exp(\lambda_n P_{g,n}) \quad (3)$$

Where

$\alpha_n, \beta_n, \eta_n, \lambda_n, \xi_n$ -Emission cost coefficients

2.4 Constraints

The minimization problem is subject to the following equality and inequality constraints

Equality constraints:

Load Flow Constraints:

$$P_{Gi} - P_{Di} - \sum_{j=1}^{N_B} V_i V_{ij} Y_{ij} = 0 \quad (4)$$

$$Q_{Gi} - Q_{Di} - \sum_{j=1}^{N_B} V_i V_{ij} Y_{ij} = 0 \quad (5)$$

Inequality constraints:

Real power generation constraints:

$$P_i^{min} \leq P_i \leq P_i^{max};\ i \in N_G \quad (6)$$

Transmission line flow limit:

$$S_i \leq S_i^{max};\ i \in N_l \quad (7)$$

III. BLACK HOLE ALGORITHMS

The Black Hole algorithm is a population-based method that has some common features with other population-based methods. As with other population-based algorithms, a population of candidate solutions to a given problem is generated and distribute randomly in the search space. The population-based algorithms evolve the created population towards the optimal solution via certain mechanisms. For example, in GAs, the evolving is done by mutation and crossover operations. In PSO, this is done by moving the candidate solutions around in the search space using the best found locations, which are updated as better locations are found by the candidates. In the proposed BH algorithm the evolving of the population is done by moving all the candidates towards the best candidate in each iteration, namely, the black hole and replacing those candidates that enter within the range of the black hole by newly generated candidates in the search space. The black hole terminology has been used for the first time in solving benchmark functions. However, that method is different from the proposed.

In this method, at each iteration, a new particle is generated randomly near to the best particle, and then, based on two random generated numbers, the algorithm updates the locations of the particles either by the PSO or the new mechanism. In other words, that method is an extension of the PSO and a new generated particle called the black hole attracts other particles under certain conditions, which used to accelerate the convergence speed of the PSO and also to prevent the local optima problem. In this method there is nothing about the event horizon of the black hole and the destruction of the stars (candidates). The proposed BH algorithm in this paper is more similar to the natural black hole phenomenon and is completely different from the black hole PSO. In our BH algorithm the best candidate among all the candidates at each iteration is selected as a black hole and all the other candidates form the normal stars. The creation of the black hole is not random and it is one of the real candidates of the population. Then, all the candidates are moved towards the black hole based on their current

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location and a random number. The details of the BH algorithms are as follows, like other population-based algorithms, in the proposed black hole algorithm (BH) randomly generated populations of candidate solutions – the stars – are placed in the search space of some problem or function. After initialization, the fitness values of the population are evaluated and the best candidate in the population, which has the best fitness value, is selected to be the black hole and the rest form the normal stars. The black hole has the ability to absorb the stars that surround it.

After initializing the black hole and stars, the black hole starts absorbing the stars around it and all the stars start moving towards the black hole. The absorption of stars by the black hole is formulated as follows:

$$x_i(t+1) = x_i(t) + \text{rand} \times (x_{BH} - x_i(t)) \quad i = 1, 2, N \qquad (8)$$

Where x_i(t) and x_i (t + 1) are the locations of the ith star at iterations t and t + 1, respectively. x_{BH} Is the location of the black hole in the search space? rand is a random number in the interval [0, 1]. N is the number of stars (candidate solutions). While moving towards the black hole, a star may reach a location with lower cost than the black hole. In such a case, the black hole moves to the location of that star and vice versa. Then the BH algorithm will continue with the black hole in the new location and then stars start moving towards this new location. In addition, there is the probability of crossing the event horizon during moving stars towards the black hole. Every star (candidate solution) that crosses the event horizon of the black hole will be sucked by the black hole. Every time a candidate (star) dies – it is sucked in by the black hole – another candidate solution (star) is born and distributed randomly in the search space and starts a new search. This is done to keep the number of candidate solutions constant. The next iteration takes place after all the stars have been moved.

The radius of the event horizon in the black hole algorithm is calculated using the following equation:

$$R = \frac{f_{BH}}{\sum_{i=1}^{N} f_i} \qquad (9)$$

Where

f_{BH} - Fitness value of the black hole
f_i - Fitness value of the ith star
N - Number of stars (candidate solutions).

When the distance between a candidate solution and the black hole (best candidate) is less than R, that candidate is collapsed and a new candidate is created and distributed randomly in the search space.

3.1 Steps by Step Procedure for Black Hole Algorithm

Step1: Initialize a population of stars with random locations in the search Space
Step2: For each star, evaluate the objective function
Step3: Select the best star that has the best fitness value as the black hole
Step4: Change the location of each star
Step5: If a star reaches a location with lower cost than the black hole, Exchange their locations
Step6: If a star crosses the event horizon of the black hole, replace it with a new star in a random location in the search space
Step7: If a termination criterion (a maximum number of iterations or a sufficiently good fitness) is met, exit the loop.

IV. SIMULATION RESULTS

The proposed Black Hole algorithms have been applied to the test systems. When the termination condition is satisfied, the best-so-far location is determined as the solution of the algorithm. In almost all studies on optimization of economic power dispatch problems in literature, parameters of algorithms have been determined without parameter analysis. In this paper, contrary to what other studies have done, we have worked on parameter configuration task. The following subsection explains how the parameters of algorithms have been configured. Then experimental results for each test system are presented in the remaining subsections.

4.1 Test system: 40 generator units system

To understand the real behaviour of algorithm and performance differences, it is required to be made comparison on a large-scale test system. We have used largest test system found in literature with complete data. The all values required for problem definition are shown in table1. The system having 40 generator units has also valve-point effects. Total demand for the simulation is 9000 MW. In this study, error tolerance value is 10^{-6} MW. Considering The Weight Factor is W = 1 for this test system. Maximum number of function calls is taken as 40×10,000 for each execution termination.

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Table 1: Data for 40 generator units test system

No	a_n	b_n	c_n	e_n	f_n	α_n	β_n	η_n	ε_n	λ_n	$P_{g,n}^{min}$	$P_{g,n}^{max}$
Pg1	94.705	6.73	0.00690	100	0.084	0.048	-2.22	60	1.31	0.0569	36	114
Pg2	94.705	6.73	0.00690	100	0.084	0.048	-2.22	60	1.31	0.0569	36	114
Pg3	309.54	7.07	0.02028	100	0.084	0.0762	-2.36	100	1.31	0.0569	60	120
Pg4	369.03	818	0.00942	150	0.063	0.054	-3.14	120	0.9142	0.0454	80	190
Pg5	148.89	5.35	0.01140	120	0.077	0.085	-1.89	50	0.9936	0.0406	47	97
Pg6	222.33	8.05	0.01140	100	0.084	0.0854	-3.08	80	1.31	0.0569	68	140
Pg7	278.71	8.03	0.01142	200	0.042	0.0242	-3.06	100	0.6550	0.02846	110	300
Pg8	391.98	6.99	0.00357	200	0.042	0.031	-2.32	130	0.6550	0.02846	135	300
Pg9	455.76	6.60	0.00492	200	0.042	0.0335	-2.11	150	0.6550	0.02846	135	300
Pg10	722.82	12.9	0.00573	200	0.042	0.425	-4.34	280	0.6550	0.02846	130	300
Pg11	635.20	12.9	0.00605	200	0.042	0.0322	-4.34	220	0.6550	0.02846	94	375
Pg12	654.69	12.8	0.00515	200	0.042	0.0338	-4.28	225	0.6550	0.02846	94	375
Pg13	913.40	12.5	0.00569	300	0.035	0.0296	-4.18	300	0.5035	0.02075	125	500
Pg14	1760.4	8.84	0.00421	300	0.035	0.0512	-3.34	520	0.5035	0.02075	125	500
Pg15	1728.3	9.15	0.00752	300	0.035	0.0496	-3.55	510	0.5035	0.02075	125	500
Pg16	1728.3	9.15	0.00708	300	0.035	0.0496	-3.55	510	0.5035	0.02075	125	500
Pg17	647.85	7.97	0.00708	300	0.035	0.0151	-2.68	220	0.5035	0.02075	220	500
Pg18	649.69	7.95	0.00313	300	0.035	0.0151	-2.66	222	0.5035	0.02075	220	550
Pg19	647.83	7.97	0.00313	300	0.035	0.0151	-2.68	220	0.5035	0.02075	242	550
Pg20	647.81	7.97	0.00313	300	0.035	0.0151	-2.68	220	0.5035	0.02075	242	550
Pg21	785.96	6.63	0.00313	300	0.035	0.0145	-2.22	290	0.5035	0.02075	254	550
Pg22	785.96	6.63	0.00298	300	0.035	0.0145	-2.22	285	0.5035	0.02075	254	550
Pg23	794.53	6.66	0.00298	300	0.035	0.0138	-2.26	295	0.5035	0.02075	254	550
Pg24	794.53	6.66	0.00284	300	0.035	0.0138	-2.26	295	0.5035	0.02075	254	550

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Pg25	801.32	7.10	0.00284	300	0.035	0.0132	-2.42	310	0.5035	0.02075	254	550
Pg26	801.32	7.10	0.00277	300	0.035	0.0132	-2.42	310	0.5035	0.02075	254	150
Pg27	1055.1	3.33	0.00277	120	0.077	1.842	-1.11	360	0.9936	0.0406	10	150
Pg28	1055.1	3.33	0.52124	120	0.077	1.842	-1.11	360	0.9936	0.0406	10	150
Pg29	1055.1	3.33	0.52124	120	0.077	1.842	-1.11	360	0.9936	0.0406	10	97
Pg30	148.89	5.35	0.52124	120	0.077	0.085	-1.89	50	0.9936	0.0406	47	190
Pg31	222.92	6.43	0.01140	120	0.063	0.0121	-2.08	80	0.9142	0.0454	60	190
Pg32	222.92	6.43	0.00160	150	0.063	0.0121	-2.08	80	0.9142	0.0454	60	190
Pg33	222.92	6.43	0.00160	150	0.063	0.0121	-2.08	80	0.9142	0.0454	60	200
Pg34	107.87	8.95	0.00160	200	0.042	0.0012	-3.48	65	0.6550	0.02846	90	200
Pg35	116.58	8.62	0.00160	200	0.042	0.0012	-3.24	70	0.6550	0.02846	90	200
Pg36	116.58	8.62	0.00010	200	0.042	0.0012	-3.24	70	0.6550	0.02846	90	110
Pg37	307.45	5.88	0.01610	80	0.098	0.095	-1.98	100	1.42	0.0677	25	110
Pg38	307.45	5.88	0.01610	80	0.098	0.095	-1.98	100	1.42	0.0677	25	110
Pg39	307.45	5.88	0.01610	80	0.098	0.095	-1.98	100	1.42	0.0677	25	110
Pg40	647.83	7.97	0.00313	300	0.035	0.0151	-2.68	220	0.5035	0.02075	242	550

Table 2: Optimal values by Black Hole algorithm

Parameters	Initial Minimum Pg value(MW)	Initial Maximum Pg value(MW)	Final Pg value (MW)	Parameters	Initial Minimum Pg value(MW)	Initial Maximum Pg value(MW)	Final Pg value (MW)
Pg1	36	114	75.0729	Pg21	254	550	324.7776
Pg2	36	114	107.0068	Pg22	254	550	278.0316
Pg3	60	120	96.2344	Pg23	254	550	263.9328
Pg4	80	190	158.2984	Pg24	254	550	525.9151
Pg5	47	97	76.1378	Pg25	254	550	387.5015
Pg6	68	140	114.4172	Pg26	254	550	447.8379

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Pg7	10	300	253.3381	Pg27	10	150	123.1975
Pg8	135	300	266.1309	Pg28	10	150	73.9969
Pg9	135	300	171.9893	Pg29	10	150	122.7458
Pg10	130	300	289.2095	Pg30	47	97	69.1130
Pg11	94	375	156.2342	Pg31	60	190	125.4091
Pg12	94	375	251.9322	Pg32	60	190	93.1709
Pg13	125	500	328.2340	Pg33	60	190	101.4811
Pg14	125	500	365.6186	Pg34	90	200	130.1548
Pg15	125	500	404.7085	Pg35	90	200	147.0273
Pg16	125	500	256.0043	Pg36	90	200	198.0302
Pg17	220	500	348.8226	Pg37	25	110	39.2199
Pg18	220	500	496.3479	Pg38	25	110	42.7236
Pg19	242	550	376.4223	Pg39	25	110	68.9264
Pg20	242	550	457.8373	Pg40	242	550	359.8100

Real power generation from different generators is the control parameters in this work. This control parameter values are adjusted within their limits and the total fuel cost and total emission rate is minimized. The optimal values of the control variables taken by the proposed Black hole algorithm in Economic Load Dispatch Problem and final Real power generation Pg values are obtained within their minimum and maximum limits, the resultant values are obtained given in the table2 When examining table3 in terms of best total fuel cost rate, it is observed that the proposed Approaches have obtained better values than other approaches listed in the table3.

The optimization of EDP offers two benefits via total fuel cost minimization and Emission rate minimization. The results of the cost and emission reduction achieved by Black Hole algorithm is given in the table3, here considering the power demand for 9000MW.The economic load dispatch through Black Hole algorithm is proposed for finding a suitable values can be obtained through the 40generator test system.

Table 3: Minimization of Fuel cost and Emission Rate by BH algorithm

S.NO	Parameters	Best value
1	Fuel cost($/h)(w=1)	2.5368e+05
2	Emission Rate(ton/h)(w=1)	7.6969e+08

V. CONCLUSION

In the study, for the solution of the combined economic and NOx emission dispatch problem, Black Hole algorithms have tried to converge the best result for the variations of the weight factor w. The weight factor w = 1. Test systems, 40-generator units, have been used in experiments. The importance of the proposed paper is coming from two main contributions. The first contribution is the proposed algorithm itself. The proposed algorithm is an adaptive and uses few parameters to be tuned. Furthermore, experimental results showed the proposed algorithms efficiency and robustness for both small and large-size problem instances.

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The Proposed algorithms have predefined as a set of parameters which have to be initialized before an execution. Initial parameter setting has a significant impact on intensification or diversification behaviour of the algorithm. Therefore, although parameter setting is an important task before experimental study, many researchers working in power dispatch problems do not work on parameter configuration. Thus the algorithms do not present their real behaviour. In this paper, we presented a systematic approach for parameter tuning. We first defined the critical parameters in the algorithm and tried to make them adaptive. In this way, the parameters do not to be initialized carefully and they adapt their values while execution. Then, we tuned the other parameters with offline parameter tuning algorithm.

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