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Economic load dispatch problem using Heuristic gravitational search algorithm

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Abstract: *This paper describes gravitational search algorithm for solving the non convex Economic load Dispatch (ELD) problem. The main objective of economic load dispatch problem is to generate the required amount of power so that the total operating cost of system is minimized, while satisfying load demand and system equality and inequality Constraints. Different heuristic optimization methods have been proposed to solve this problem in previous study. So in this paper, gravitational search algorithm (GSA) based on law of gravity and mass interaction is proposed. This proposed approach has been tested on 3, 38 test systems. Simulation results of proposed approach are compared with some well-known heuristic search methods. The obtained results verify the efficiency of the proposed method with minimum computational time in solving various nonlinear functions*

Keyword: *Economic dispatch, gravitational search algorithm, equality and inequality Constraints.*

1. INTRODUCTION

The increasing energy demand and decreasing energy resources have necessitated the optimum use of available resources. Economic load dispatch is optimization scheme intends to find the generation outputs that minimize the total operating cost while satisfying several unit and system constraints. In main aim of economic load dispatch is to schedule the output of all generating units so as to meet total load demand at minimum fuel cost, also subject to equality and inequality constraints on power output. There are many methods developed for solving the economic load dispatch problems which are classified as classical and heuristic methods. In classical method, fuel cost curve is monotonically increasing one and it represented by quadratic function. Most of classical optimization techniques such as lambda iteration method, gradient method, Newton's

method, linear programming, Interior point method and dynamic programming have been used to solve the basic economic dispatch problem. But due to non convex and nonlinear behavior of ED problem and large number constraints, classical method cannot be execute well in solving the ED problems. So in order to overcome these non linear dispatch problems heuristic technique are developed. Many heuristic techniques like Hardiansyah[2] introduced Solving economic load dispatch problem with valve point effect using modified ABC algorithm. K.Senthil, K.Manikandan [3] proposed Economic Thermal Power Dispatch With Emission Constraint and Valve Point Effect Loading Using Improved Tabu Search Algorithm. J.Jain, R.Singh [4] introduced Biogeographic-Based Optimization Algorithm for Load Dispatch in Power System. K. Meng, H. G. Wang, Z.Y. Dong, and K. P. Wong [7] proposed Quantum-Inspired Particle Swarm Optimization for Valve-Point

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Economic Load Dispatch. Chao-Lung Chiang proposed Improved Genetic Algorithm for Power Economic Dispatch of Units With Valve-Point Effects and Multiple Fuels.

Recently, a heuristic technique called as gravitational search algorithm (GSA) is proposed. Gravitational search algorithm is inspired by law of gravitational and mass interaction. Gravitational search algorithm has been proposed by Rashedi et al. Gravitational search algorithm gives better performance than other optimization techniques. In this paper, Gravitational search algorithm is applied to non linear economic load dispatch problem with equality and inequality in power systems. The results obtained for proposed technique is compared with other optimized techniques.

2. ECONOMIC LOAD DISPATCH PROBLEM FORMULATION

The main objective of economic load dispatch is to minimize operating cost of thermal power plant while satisfying the operating constraints and meeting the total demand of a power system. The ED problem is to minimize the total fuel cost which can be defined mathematically as the sum of the cost function of each generator. The ED problem mathematically formulated with constraints as following

$$\text{Min } F_T = \sum_{i=1}^n F_i(P_i) = \sum_{i=1}^n a_i P_i^2 + b_i P_i + c_i$$

Where

F_T = total fuel cost of generation

F_i = cost function of i th generator (\$/hr)

a_i, b_i, c_i = cost coefficients of i th generator

P_i = power output of i th generator

n = number of generator

Subjected to following equality and equality constraints

1. Power Balance Constraint

$$\sum_{i=1}^n P_i = P_d + P_l$$

P_d = total load demand

P_l = total transmission loss

2. Generator Constraints

$$P_i^{\text{MIN}} \leq P_i \leq P_i^{\text{MAX}}$$

P_i^{MIN} And P_i^{MAX} is minimum and maximum value of i th Generators

3. GRAVITATIONAL SEARCH ALGORITHM

Gravitational search algorithm is first introduced by Rashedi et al. in 2009. This optimization algorithm is based on the gravitational law of physics. In the proposed algorithm, agents are considered as objects and their performance is measured by their masses.[1] All these objects attract each other by the gravity force, and this force causes a global movement of all objects towards the objects with heavier masses. Hence, masses cooperate using a direct form of communication, through gravitational force. The heavy masses – which correspond to good solutions – move more slowly than lighter ones, this guarantees the exploitation step of the algorithm. In GSA, each mass (agent) has four specifications: position, inertial mass, active gravitational mass, and passive gravitational mass. The position of the mass corresponds to a solution of the problem, and its gravitational and inertial masses are determined using a fitness function. In other words, each mass presents a solution, and the algorithm is navigated by properly adjusting the gravitational and inertia masses. By lapse of time, we expect that masses be attracted by the heaviest mass. This mass will present an optimum solution in the search space. GSA algorithm can be summarized by following steps.

Step 1) Set up number of masses/agents, N to be processed in GSA and initialize gravitational constant G_0 .

Step 2) Initialization of the GSA: For each i th mass, the agents are randomly generated in the range (0-1) and located between the maximum and the minimum operating limits of the

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generators. If there are N generating units, the ith particle is represented as

$$P_i = (P_i^1, P_i^2, \dots, P_i^d, \dots, P_i^N) \text{ where } i=1,2,3,\dots,N$$

The d-dimension of the ith particle is allocated a value of P_i^d as given below to satisfy the constraints.

$$P_i^d = P_{dmin} + \text{rand} (P_{dmax} - P_{dmin})$$

Step 3) Calculate the gravitational constant G(t) for iteration t

$$G(t) = G_0 \exp(-\alpha \frac{t}{T})$$

Where G_0 is initial value gravitational constant choose randomly, α is a user defined constant, t is current iteration and T is the total number of iteration.

Step 4) Evaluation of Fitness for All Agents in search space. $Fit_i(t)$ shows the fitness value of the ith agent at time t, and worst(t) and best(t) are defined as follows:-

$$\text{Best}(t) = \min(Fit_i(t))$$

$$\text{Worst}(t) = \max(Fit_i(t))$$

Where best(t) and worst(t) is best and worst fitness value of all agents respectively and

$$Fit_i(t) = F_T + \Lambda |(\sum_{i=1}^n P_i - P_d - P_t)|$$

Where, Λ is penalty factor

Step 5) Evaluation of gravitational mass of each agent: In this step mass of each agent is updated. A heavier mass means more efficient agent. This means that better agents have higher attractions and walk more slowly. Therefore, gravitational mass is equal to

$$m_i(t) = \frac{Fit_i(t) - \text{Worst}(t)}{\text{Best}(t) - \text{Worst}(t)}$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^N m_j(t)}$$

Step5) Evaluation of force between agents: In this step we compute the force acting in d-dimension on ith mass due to mass j at specific time t.

$$F_{ij}^d(t) = G(t) \frac{M_{pi} \times M_{aj}}{R_{ij}^{\gamma}} (x_j^d - x_i^d)$$

Where, M_{ai} is the active gravitational mass related to jth agents, M_{pi} is the passive gravitational mass of ith agent, R_{ij} is Euclidian distance between i and j agent

$$R_{ij}(t) = ||X_i(t), X_j(t)||_2$$

And γ is a small constant

Step6) Determine the total force

In this step find out total force of agent i in dimension d

$$F_i^d(t) = \sum_{j \in V_{best}} \text{rand}_j F_{ij}^d(t)$$

Where rand is random number and its value lies between (0, 1) and V_{best} is the set of first V agents with the best fitness value and biggest mass.

Step 7 Calculate Acceleration and Velocity

By applying law of motion of physics, Acceleration $a_i^d(t)$ of ith agent in d-dimension at iteration t is shown as following:

$$a_i^d(t) = \frac{F_i^d(t)}{M_i(t)}$$

Where $M_i(t)$ is inertial mass of ith agent.

And velocity of ith agent in dimension d is equal to

$$V_i^d(t+1) = \text{rand}_i \times V_i^d(t) + a_i^d(t)$$

Where, rand_i vary in interval (0, 1) and $V_i^d(t)$ is previous velocity of an agent.

Step 8 Update the position of agent: Position of ith agent in d-dimension at iteration t could be calculated as

$$X_i^d(t+1) = X_i^d(t) + V_i^d(t+1)$$

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Step 9) In last step we repeat the 3 to 8 steps until the stop criteria reached.

4. SIMULATION RESULTS

In order to demonstrate the performance of the proposed method, it is tested with 2 system tests with 3 and 38unit system are used to test the proposed approach for solving the ELD problem.

Parameters for proposed approach are shown in table 1 which contains number of iteration T, gravitational constant G_0 , number of agents N, and user defined constant α .

Table 1: Parameters used in GSA for different unit system

Parameters	3unit system	13unit system	38unit system
α	10	10	10
N	30	100	60
G_0	100	100	100
T	100	100	100

A. UNIT SYSTEMS DATA FOR 3 GENERATOR SYSTEMS [5]

The system consists of 3 thermal generating units. The total load demand on the system is 850 MW. The parameters of all thermal units are presented in Table 2. The obtained results for the 3-unit system using the GSA method are given in Table 3 and the results are compared with other methods reported in literature

TABLE 2: Cost coefficients and unit operating limits for 3 unit system

Units	Pmin	Pmax	a	b	C
1	100	600	0.001562	7.92	561
2	50	200	0.004820	7.97	78
3	100	400	0.001940	7.85	310

TABLE 3: Simulation Results and Its Comparison with Genetic Algorithm (GA)

Generator	Generator output of GSA	Generator output of GA
1	398.9907	393.26
2	327.3801	334.67
3	123.6292	122.25
Total demand	850 MW	850
Fuel Cost(\$/h)	8194.5	8196.5

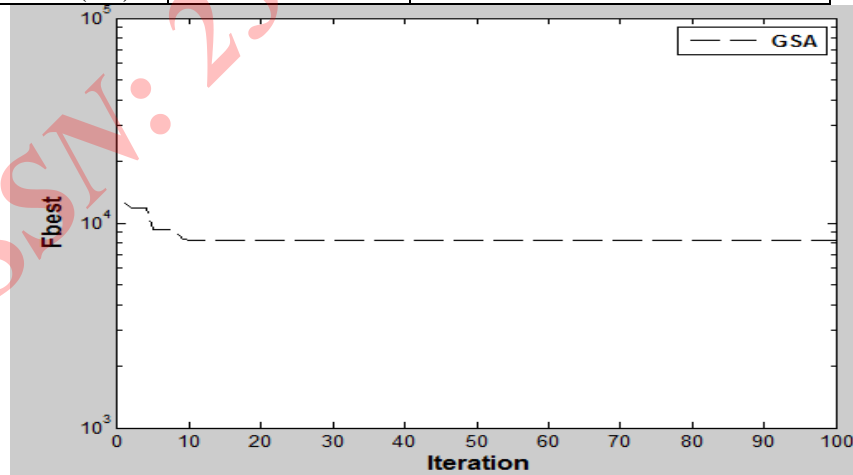


Figure 1. Convergence graph for 3-units with PD=850 MW

B. UNIT SYSTEMS DATA FOR 38 GENERATOR SYSTEMS [9]

The system consists of 38 thermal generating units. The total load demand on the system is 8600 MW. The parameters of all thermal units are presented in Table 4

The obtained results for the 38-unit system using the GSA method are given in Table 5 and the results are compared with other methods reported in literature

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TABLE 4: Cost coefficients and unit operating limits for 38 test system

UNIT	a	b	c	Pmin	Pmax
1	64782	796.9	0.3133	220	550
2	64782	796.9	.3133	220	550
3	64670	795.5	.3127	200	500
4	64670	795.5	.3127	200	500
5	64670	795.5	.3127	200	500
6	64670	795.5	.3127	200	500
7	64670	795.5	.3127	200	500
8	64670	795.5	.3127	200	500
9	172832	915.7	.7075	114	500
10	172832	915.7	.7075	114	500
11	176003	884.2	.7515	114	500
12	173028	884.2	.7083	114	500
13	91340	1250.1	.4211	110	500
14	63440	1298.6	.5145	90	365
15	65468	1290.8	.5691	82	365
16	72282	190.8	.5691	120	325
17	190928	238.1	2.5881	66	315
18	285372	1149.5	3.8734	65	315
19	271376	1269.1	3.6842	65	315
20	39197	696.1	.4921	120	272
21	45576	660.2	.5728	120	272
22	28770	803.2	.3572	110	260
23	36902	818.2	.9415	80	190
24	105510	33.5	52.123	10	150
25	22233	805.4	1.1421	60	125
26	30953	707.1	2.0275	55	110
27	17044	833.6	3.0744	35	75
28	81079	2188.7	16.765	20	70
29	124767	1024.4	26.355	20	70
30	121915	837.1	30.575	20	60
31	120780	1305.2	25.098	20	70
32	104441	716.6	33.722	20	60
33	83224	1633.9	23.915	25	60
34	111281	969.6	32.562	18	60
35	64142	2625.8	18.362	8	60
36	103519	1633.9	23.915	25	60
37	13547	694.7	8.482	20	38
38	13518	655.9	9.693	20	38

TABLE 5: Simulation Results and Its Comparison with Genetic Algorithm (GA)

Generator	Generator output of GSA	Generator output of GA
1	324.1300	550
2	324.1301	550
3	326.9905	500
4	326.9905	500
5	326.9905	500
6	326.9905	500
7	325.3919	500
8	325.3918	500
9	114.0000	398.5425
10	114.0000	398.5425
11	114.0000	396.1661
12	114.0000	420.3287
13	110.0000	272.5453
14	90.0000	175.9355
15	10.0000	165.909
16	325.0000	325
17	147.1928	239.855
18	65.0000	65
19	65.0000	65
20	272.00 00	272
21	272.0000	272
22	260.0000	260
23	96.5481	190
24	10.0000	13.87236
25	85.1938	125
26	72.2319	110
27	35.0000	75
28	24.1963	20
29	20.0000	20
30	20.0000	20
31	20.0000	20
32	20.0000	20
33	25.0000	25
34	18.0000	28
35	8.0000	8
36	25.0000	25
37	20.0000	38

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38	20.0000	38
Total demand	8600MW	8600MW
Total Cost(Rs/hr)	12295000.0	12320766.9

5. CONCLUSION

In this paper, a novel approach based on the Newton's laws of gravity and mass interaction GSA has been presented and applied to economic power dispatch optimization problem. Here GSA is applied to 3, 38 test system and effectiveness of GSA was tested. From the simulation results, it can be seen that GSA has better convergence rate and Computational time is also very less when it is compared to other methods.

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