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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 ith generator ($/hr)

$a_i$ , $b_i$ , $c_i$ = cost coefficients of ith generator

$P_i$ = power output of ith 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

$$P_i^{MIN} \le P_i \le P_i^{MAX}$$

$P_i^{MIN}$ And $P_i^{MAX}$ is minimum and maximum value of ith 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 Go.

Step 2) Initialization of the GSA: For each ith 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

$P_i = (P_i^1, P_i^2, \ldots\ldots P_i^d \ldots\ldots P_i^N)$ where i=1,2,3.........N

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

$P_i^d = P_{dmin}$ + 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:-

Best(t)=min($Fit_i$(t))

Worst(t)=max($Fit_i$(t))

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

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

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

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

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

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.

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

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 $\curlyvee$ is a small constant

Step6) Determine the total force

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

$$F_i^d(t) = \sum_{j \in Vbest}^{N} rand_j F_{ij}^d(t)$$

Where rand is random number and its value lies between (0, 1) and Vbest 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

$$V_i^d(t+1) = rand_i \times V_i^d(t) + a_i^d(t)$$

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 1which 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 |

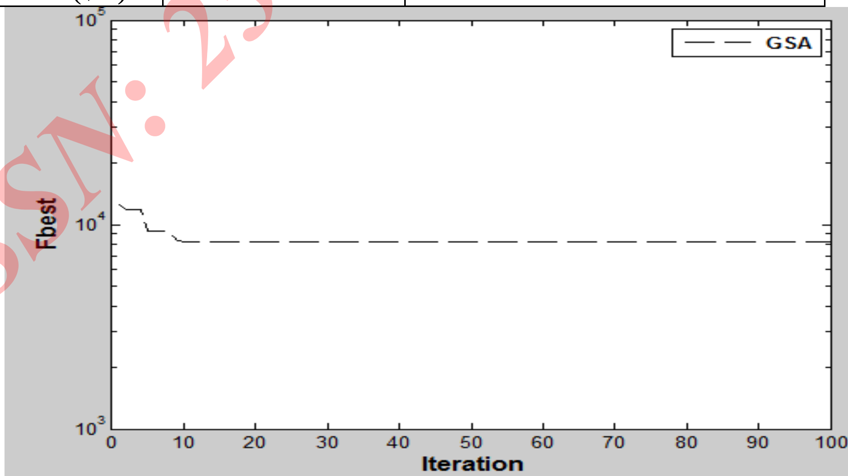


Figure 1. Convergence graph for 3-units with PD=850 MW

### 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 5and 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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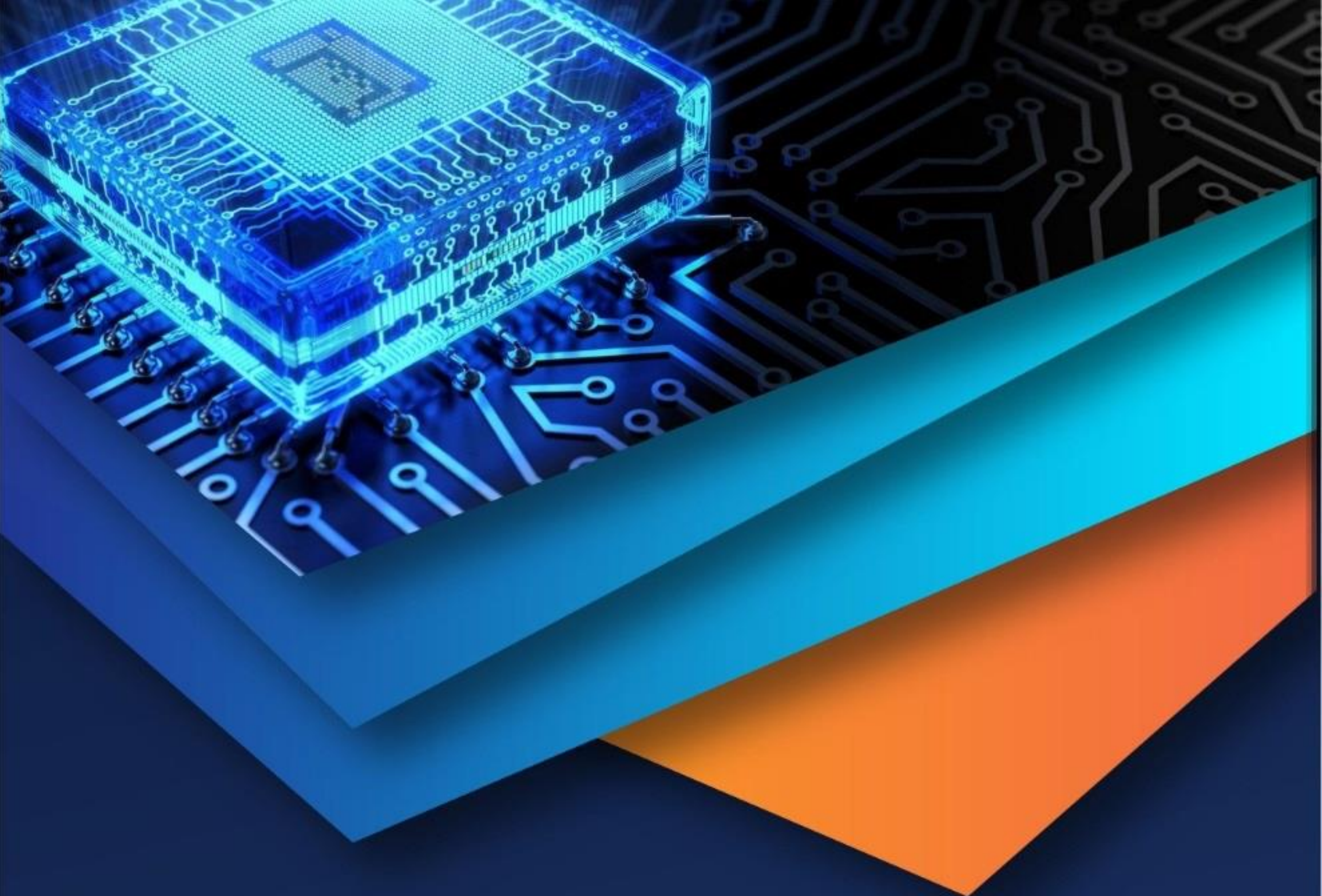


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