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Gravitational Search Algorithm for solving Unit Commitment Problems

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Abstract: This paper proposes a new approach for solving unit commitment problem using gravitational search algorithm (GSA). The proposed search is based on law of gravity and mass interaction applied to determine the optimal unit commitment schedule includes with minimum up/down time and spinning reserve constraints. The GSA approach is useful to decide the optimal setting of control variables of unit commitment. The performance of the proposed approach initially examined and tested on 10 unit system later extended up to 40 unit system with 24-hr horizon. The results obtained from the proposed GSA approach indicate that GSA provides effective and robust solution of unit commitment.
Keywords: unit commitment, cost function, search space, gravitational search algorithm

I. INTRODUCTION

Unit commitment (UC) is the problem of formative schedule of generating units within a power system subject to device and operating constraints. This means the resultant UC schedule should get the most out of the profit, which can be regarded as to implying the minimization of the system production cost as well, during the period, given for a day and so longer time, while simultaneously satisfying the constraints of individual generator [1]. UC is a large scale optimization problem since it involves a large number of 0/1 scheduling variables that represent up/down time status of generators. Some techniques already have been applied to this problem [2-3], such as branch and bound [4], dynamic programming [5], lagrangian programming [6], genetic algorithm [7], differential evolution [8], hybrid methods [9-10].recently a new heuristic search algorithm namely gravitational search algorithm(GSA) motivated by gravitational law and law of motion have been proposed[11-12]. In this paper GSA method has been proposed for solving unit commitment problem.

II. MATHEMATICAL PROBLEM FORMULATION OF UC

The objective of unit commitment problem is to minimize the production cost over the scheduled time horizon (24hours) under the generator operational and spinning reserve constraints. The objective function to be minimized is

$$F(P_i^t, U_{i,t}) = \sum_{t=1}^{T}\sum_{i=1}^{N}[F_i(P_i^t) + ST_{i,t}(1 - U_{i,t-1})]U_{i,t} \tag{1}$$

Subject to the following constraints Power balance constraint

$$\sum_{i=1}^{N} P_i^t U_{i,t} = P_D^t \tag{2}$$

Spinning reserve constraint

$$\sum_{i=1}^{N} P_{i,\max} U_{i,t} \geq P_D^t + R^t \tag{3}$$

Generator limit constraints

$$P_{i,\min} U_{i,t} \leq P_i^t \leq P_{i,\max} U_{i,t}, \quad i = 1,...., N \tag{4}$$

Minimum up and down time constraints

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$$U_{i,t} = \begin{cases} 1, & if\ T_{i,on} < T_{i,up}, \\ 0, & if\ T_{i,off} < T_{i,down}, \\ 0\ or\ 1, & otherwise \end{cases}$$

Startup cost

$$ST_{i,t} = \begin{cases} HSC_i & if\ T_{i,down} \le T_{i,off} \le T_{i,cold} + T_{i,down}, \\ CSC_i & if\ T_{i,off} > T_{i,cold} + T_{i,down} \end{cases} \quad (5)$$

III. GRAVITATIONAL SEARCH ALGORITHM

The gravitational search algorithm (GSA), is one of the newest heuristic search algorithm was developed by Rashedi et al. in 2009[11]. GSA is followed the physical law of gravity and the law of motion. The gravitational force between two particles is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. In the proposed algorithm, agents are considered as objects and their performance is measured by their masses.

$$P_i = (p_i \ldots p_i^d, \ldots, p_i^n), i=1,2,\ldots..m \quad (6)$$

Where.pid is the position of the ith mass in the dth dimension and n is the dimension of the search space. At specific time 't' a gravitational force form mass j act on mass i and is defined as follows.

$$F_{ij}^d(t) = G(t)\frac{M_{pi}(t) \times M_{ai}(t)}{R_{ij}(t)+\varepsilon}(p_j^d(t) - p_i^d(t)) \quad (7)$$

Where Mi is the mass of the of the object i,Mj is the mass of the object j , G(t) is the gravitational Constant at time t, Rij(t) is the Euclidian distance between the two objects i and j , and ε is a small constant.

$$R_{ij}(t) = \|p_i(t), p_j(t)\|_2 \quad (8)$$

The total force acting on the agent i in the dimension d is calculated as follows.

$$F_i^d(t) = \sum_{j=i, j\neq i}^{m} F_{ij}^d\, rand_j \quad (9)$$

where rand j is a random number in the interval [0, 1].

According to the law of motion, the acceleration of the agent i, at time t , in the d^{th} dimension, αid(t) is given as follows:

$$\alpha_i^d(t) = \frac{F_i^d(t)}{M_n(t)} \quad (10)$$

To find the velocity of a particle is a function of its current velocity added to its current acceleration. Therefore, the next position and next velocity of an agent can be calculated as follows.

$$v_i^d(t+1) = rand_i p v_i^d(t) + \alpha_i^d(t)$$
$$p_i^d(t+1) = p_i^d(t) + v_i^d(t+1) \quad (11)$$

where $rand_i$ is a uniform random variable in the interval [0, 1].

The gravitational constant, G, is initialized at the beginning and will be decreased with the time to control the search accuracy. In other words, G is function of the initial value (G0) and time (t):

(12)

$$G(t) = G_0 e^{-\alpha\frac{1}{t}}$$

(13)

The masses of the agents are calculated using fitness evaluation. A heavier mass means a more efficient agent. This means that better agents have higher attractions and moves more slowly. Supposing the equality of the gravitational and inertia mass, the values of masses is calculated using the map of fitness.

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The gravitational and inertial masses are updating by the following equations

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - worst(t)} \tag{14}$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^{m} m_j(t)} \tag{15}$$

Where $fit_i(t)$ represents the fitness value of the agent iat time t , and the best (t) and worst (t) in the population respectively indicate the strongest and the weakness agent according to their fitness value. For a minimization problem:

$$Best(t) = \min_{j\in\{1,\ldots m\}} fit(t) \tag{16}$$

$$worst(t) = \max_{j\in\{1,\ldots m\}} fit(t) \tag{17}$$

For a Maximization problem:

$$Best(t) = \max_{j\in\{1,\ldots m\}} fit(t) \tag{18}$$

$$Worst\ (t) = \min_{j\in\{1,\ldots m\}} fit(t) \tag{19}$$

IV. GRAVITATIONAL SEARCH ALGORITHM APPLIED TO UNIT COMMITMENT PROBLEM

In order to handle the constraints conveniently, the structure of solutions for UC problem has solved by the proposed method is composed of a set of real power output decision variables for each unit in all over the scheduling periods. The section provides the solution methodology to the above-mentioned Unit Commitment problems through gravitational search algorithm.

A. Initialization

In the initialization procedure, the candidate solution of each individual (generating unit's power output) is randomly initialized within the feasible range in such a way that it should satisfy the constraint given by Eq. (4). A component of a candidate is initialized as Pit ~ U (Pimin , Pimax) ,where U is the uniform distribution of the variables ranging in the interval of (Pimin , Pimax).

B. Fitness evaluation (objective function)

The fitness evaluation in each agent in the population set is evaluated using the equation (4). Iteration count from this step, t=1. Update G (t), best (t), worst (t) and Mi for i=1, 2...m

C. Agent force calculation

The total force acting on the agent i in the dimension d is calculated in equation (7).

D. *Evaluation of acceleration of an agent*

The acceleration of an agent in dth dimension over T dispatch period has evaluated using equation (10).

E. Update the agents' position

The next velocity of an agent is calculated by adding the acceleration of an agent to the current velocity and also position of an agent will updated.

F. M Stopping criterion

Repeat the step from 4.3 to 4.7 until the stopping criteria is reached. There are various criteria available to stop a stochastic optimization algorithm. In this paper, to compare with the previous results, maximum number of iterations is chosen as the stopping criterion. If the stopping criterion is not satisfied, the above procedure is repeated from fitness evaluation with incremented iteration

V. IMPLEMENTATION OF GRAVITATIONAL SEARCH ALGORITHM TO UC

A new heuristic optimization algorithm based on Newton's law of gravity and mass interactions for solving the UC problem is described as follows

A.Step 1: Search space identification.
B.Step 2: Generate initial population between minimum and maximum values of control variables of UC problem.
C. Step 3: Calculate value of fitness function of each agent for the UC Problem.
D. Step4: Update G (t), best (t), worst (t) and Mi(t) for i=1, 2, ..N
E.Step5: Calculate force in different directions.
F.Step6: Calculation of acceleration and velocity.
G. Step7: Updating agent's position.
H. Step8: Repeat steps 3-7 until the stop criteria are created.
I. Step9: Stop

VI. NUMERICAL RESULTS

In order to evaluate the performance of the proposed GSA method, its performance for solving unit commitment is tested and evaluated initially to 10 generator systems and later on extended to till 100 generator systems.
It should be noted that 20 runs of the proposed algorithm converges to unique results.
The unit commitment schedule of 40 generator system is presented in Table1.figure 1&2 shows the cost and convergence of proposed.

TABLE 1.
UNIT SCHEDULING OF 40 UNIT SYSTEM GSA METHOD

hr	Units On/Off Schedule
1	1111111100000000000000000000000000000000
2	1111111100000000000000000000000000000000
3	1111111100000000100000000000000000000000
4	1111111100000001111000000000000000000000
5	1111111100000011111100000000000000000000
6	1111111100011111111100000000000000000000
7	1111111100111111111100000000000000000000
8	1111111111111111111100000000000000000000
9	1111111111111111111111111000000000000000
10	1111111111111111111111111111111100000000
11	1111111111111111111111111111111111110000
12	1111111111111111111111111111111111111111
13	1111111111111111111111111111111100000000
14	1111111111111111111111111000000000000000
15	1111111111111111111100000000000000000000
16	1111111111111111111100000000000000000000
17	1111111111111111111100000000000000000000
18	1111111111111111111100000000000000000000
19	1111111111111111111100000000000000000000
20	1111111111111111111111111000111111110000
21	1111111111111111111111111000000000000000
22	1111111100001111110011111000000000000000
23	1111111100000000110000000000000000000000
24	1111111100000000000000000000000000000000

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TABLE 2.COMPARISON OF VARIOUS METHODS

No of generators	TOTAL COST($)				
	LR[6]	GA[6]	EP[6]	ALR[6]	GSA
10	565,825	565,825	564,551	565,508	5,63,977
20	1,130,660	1,126,243	1,125,494	1,126,720	1,125,171
40	2,258,503	2,251,911	2,249,093	2,249,790	2,248,511

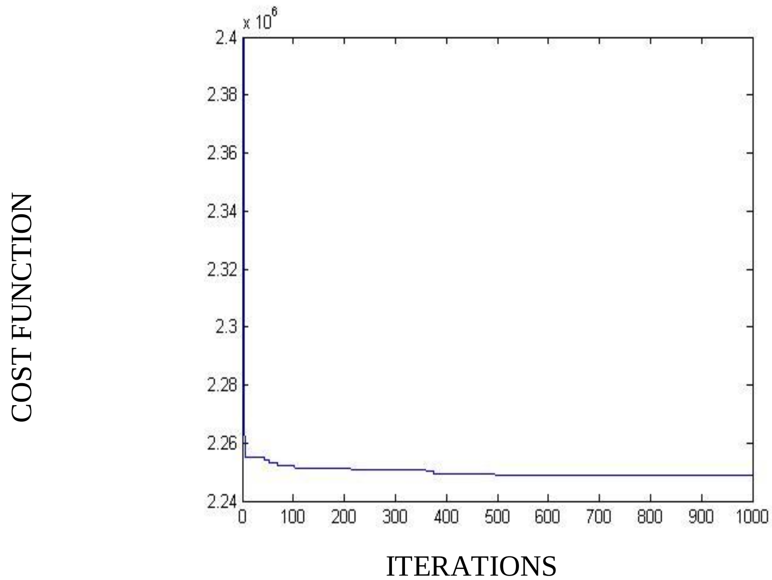

Fig 1.Total cost of 40-unit system GSA method

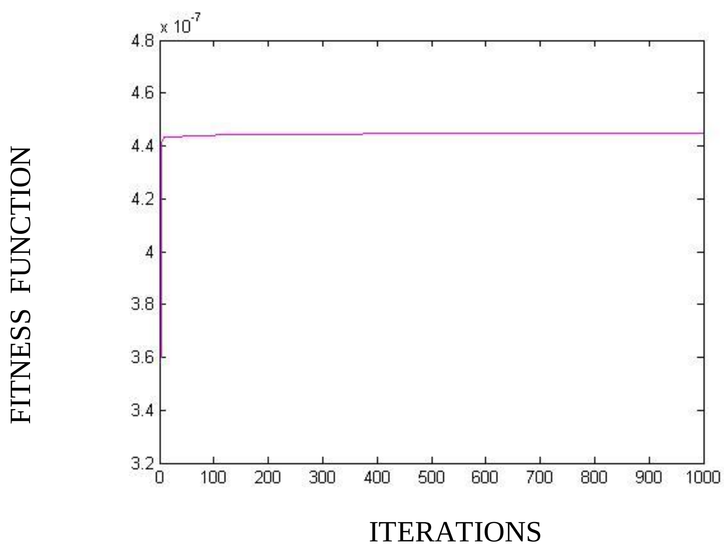

Fig 2. Fitness for 40-unit system GSA method

VII. CONCLUSION

In this paper GSA method is proposed for solving unit commitment problem by considering constraints. in order to show the usefulness of the proposed method, its performance are compared with other methods shown in table2. The proposed algorithm uses to simplify unit commitment problems successfully. Further work will spotlight on together with hydro units in the UC problem. This approach of features also adapt to smart grid environments.

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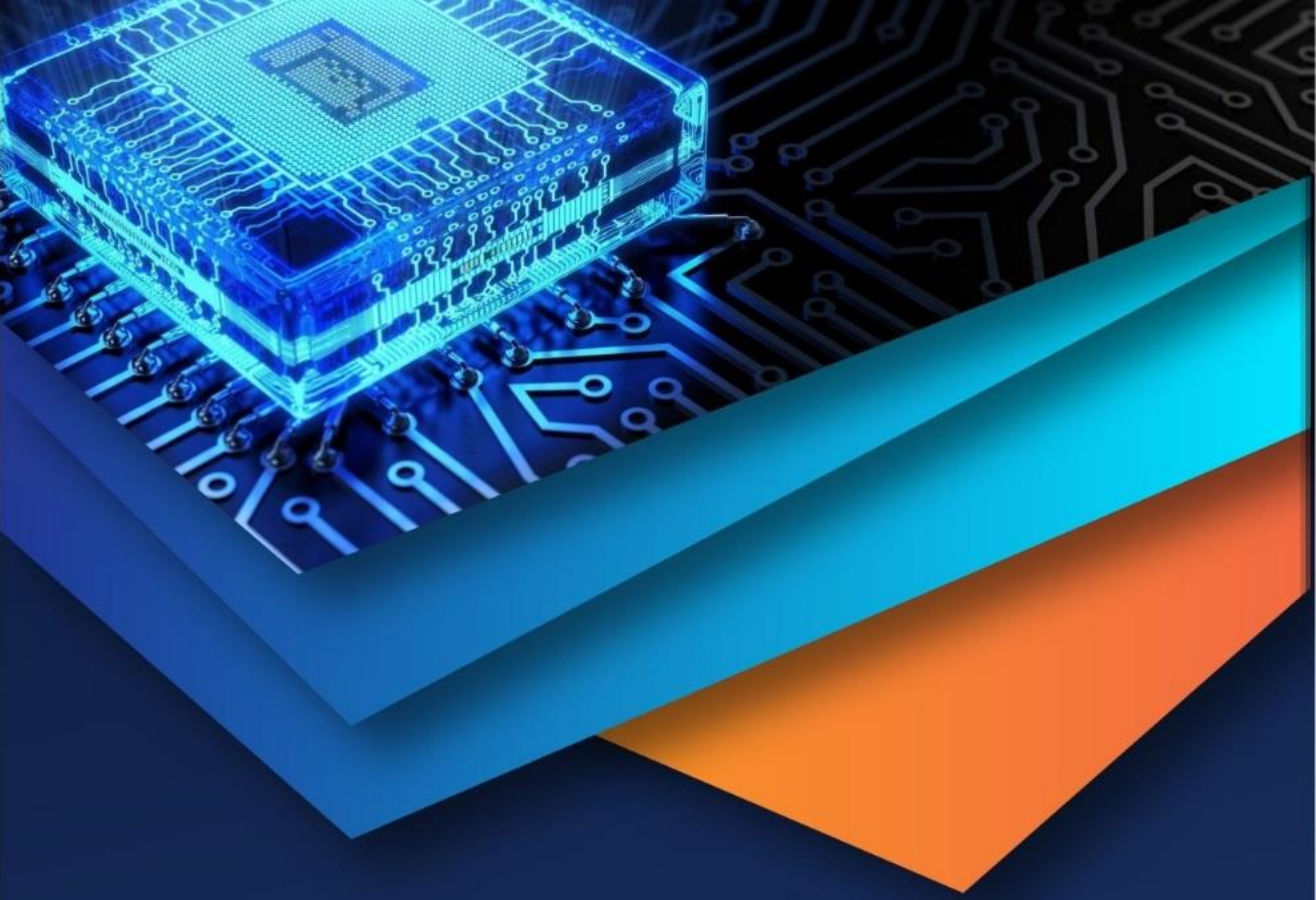

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