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**MINIMIZATION OF REAL POWER LOSS BY ENHANCED
GRAVITATIONAL SEARCH ALGORITHM**



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Abstract

In this paper, Enhanced Gravitational Search (EGS) algorithm is proposed to solve the reactive power problem. Gravitational search algorithm (GSA) results are improved by using artificial bee colony algorithm (ABC). In GSA, solutions are fascinated towards each other by applying gravitational forces, which depending on the masses assigned to the solutions, to each other. The heaviest mass will move slower than other masses and pull others. Due to nature of gravitation, GSA may pass global minimum if some solutions stuck to local minimum. ABC updates the positions of the best solutions that have obtained from GSA, preventing the GSA from sticking to the local minimum by its strong penetrating capability. The proposed algorithm improves the performance of GSA in greater level. In order to evaluate the performance of the proposed EGS algorithm, it has been tested on IEEE 57,118 bus systems and compared to other standard algorithms.

Keywords: Gravitational Search Algorithm; Artificial Bee Colony Algorithm; Reactive Power; Transmission Loss.

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1. Introduction

Various mathematical techniques have been adopted to solve this optimal reactive power dispatch problem. These include the gradient method [1, 2], Newton method [3] and linear programming [4-7]. The gradient and Newton methods suffer from the difficulty in handling inequality constraints. To apply linear programming, the input- output function is to be expressed as a set of linear functions which may lead to loss of accuracy. Recently Global Optimization techniques such as genetic algorithms have been proposed to solve the reactive power flow problem [8-14]. In this paper, Enhanced Gravitational Search (EGS) algorithm is proposed to solve the reactive power problem. Gravitational search algorithm (GSA) performance is improved by using artificial bee colony algorithm (ABC). GSA [15] can be considered as a collection of agents (candidate solutions) whose have masses proportional to their value of

fitness function. During generations, all masses attract each other by the gravity forces between them. Artificial Bee Colony (ABC) [16] Algorithm is an optimization algorithm based on the intellectual foraging behavior of honey bee swarm. Due to nature of gravitation, GSA may pass global minimum if some solutions stuck to local minimum. ABC updates the positions of the best solutions that have obtained from GSA, preventing the GSA from sticking to the local minimum by its strong penetrating capability. Both the exploration & exploitation ability of the proposed EGS algorithm has been enhanced. The performance of Enhanced Gravitational Search (EGS) algorithm has been evaluated in standard IEEE 57,118 bus test systems and the results analysis shows that our proposed approach outperforms all approaches investigated in this paper.

2. Objective Function

Active power loss

Main aim of the reactive power dispatch problem is to reduce the active power loss in the transmission network, which can be described as:

$$F = PL = \sum_{k \in Nbr} g_k (V_i^2 + V_j^2 - 2V_i V_j \cos \theta_{ij}) \quad (1)$$

Where g_k : is the conductance of branch between nodes i and j , Nbr : is the total number of transmission lines in power systems.

Voltage profile improvement

For minimization of the voltage deviation in PQ buses, the objective function turns into:

$$F = PL + \omega_v \times VD \quad (2)$$

Where ω_v : is a weighting factor of voltage deviation.

VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{N_{pq}} |V_i - 1| \quad (3)$$

Equality Constraint

The equality constraint of the Reactive power problem is represented by the power balance equation, and can be written as, where the total power generation must cover the total power demand and total power loss:

$$P_G = P_D + P_L \quad (4)$$

Where, P_G - Total Power Generation, P_D -Total Power Demand, P_L – Total Power Loss.

Inequality Constraints

Inequality constraints define the limitations in power system components and power system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators are written as follows:

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \quad (5)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, i \in N_g \quad (6)$$

Upper and lower bounds on the bus voltage magnitudes are described as follows:

$$V_i^{min} \leq V_i \leq V_i^{max}, i \in N \quad (7)$$

Upper and lower bounds on the transformers tap ratios are given as follows:

$$T_i^{min} \leq T_i \leq T_i^{max}, i \in N_T \quad (8)$$

Upper and lower bounds on the compensators reactive powers are written as follows:

$$Q_c^{min} \leq Q_c \leq Q_c^{max}, i \in N_c \quad (9)$$

Where N is the total number of buses, N_T is the total number of Transformers; N_c is the total number of shunt reactive compensators.

3. Gravitational Search Algorithm

Gravitational Search Algorithm (GSA) is a novel heuristic optimization method which inspired from the Newton's theory & that states: Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. GSA can be considered as a collection of agents (candidate solutions) whose have masses proportional to their value of fitness function. During generations, all masses attract each other by the gravity forces between them. A heavier mass has the bigger attraction force. Therefore, the heavier masses which are probably close to the global Optimum attract the other masses proportional to their Distances. The GSA was mathematically modelled as follow. Suppose a system with N agents. The algorithm starts with randomly placing all agents in search space. During all epochs, the gravitational forces from agent j on agent i at a Specific time t is defined as follow;

$$F_{ij}^d(t) = G(t) \frac{M_{pi}(t) \times M_{aj}(t)}{R_{ij}(t) + \epsilon} (x_j^d(t) - x_i^d(t)) \quad (10)$$

The $G(t)$ is calculated as :

$$G(t) = G_0 \times \exp\left(-a \times \frac{iter}{maxiter}\right) \quad (11)$$

In a problem space with the dimension d , the total force that acts on agent i is calculated as the following equation:

$$F_i^d(t) = \sum_{j=1, j \neq i}^N rand_j F_{ij}^d(t) \quad (12)$$

According to the law of motion, the acceleration of an agent is proportional to the result force and inverse of its mass, so the acceleration of all agents should be calculated as follow:

$$ac_i^d(t) = \frac{F_i^d(t)}{M_{ii}(t)} \quad (13)$$

The velocity and position of agents are calculated as follow:

$$vel_i^d(t+1) = rand_i \times vel_i^d(t) + ac_i^d(t) \quad (14)$$

$$x_i^d(t+1) = x_i^d(t) + vel_i^d(t+1) \quad (15)$$

In GSA, at first all masses are initialized with random Values. Each mass is a candidate solution. After Initialization, velocities for all masses are defined using (14). Meanwhile the gravitational constant, total forces, and accelerations are calculated as (11), (12), and (13) respectively. The positions of masses are calculated using (15). Finally GSA will be stopped by meeting an end criterion.

4. Artificial Bee Colony Algorithm

Artificial Bee Colony (ABC) algorithm is an optimization algorithm based on the intellectual foraging behavior of honey bee swarm. The colony of artificial bees consists of three groups of bees: employed bees, onlookers and scouts. An employed bee searches the target where the food

is available. They accumulate the food and returns back to its source where they carry out waggle dance depending on the amount of food available at the target. The onlooker bee observe the dance and follows employed bee depends on the probability of the available food means more onlooker bee will follow the employed bee associated with the target having more amount of food. The employed bee whose food source becomes abandoned then it changes into a scout bee and it will search for the new food source. For solving optimization problems the population is alienated into two parts consisting of employed bees and onlooker bees. An employed bee searches the solution in the explore space and the value of objective function associated with the solution is the amount of food linked with that solution. Employed bee updates its position using Equation (16) and it updates new position if it is better than the preceding position.

$$v_{ij} = x_{ij} + R_{ij}(x_{ij} - x_{kj}) \quad (16)$$

Where v_{ij} is the new position of employee bee, x_{ij} is the current position of employed bee, k is a random number between $(1, N \text{ (population size)}/2) \neq i$ and $j = 1, 2, \dots$, Number of design variables. R_{ij} is a random number between $(-1, 1)$.

An onlooker bees prefer a food source depending on the probability value related with that food source, p_i , calculated using Equation (17).

$$P_i = \frac{F_i}{\sum_{n=1}^{N/2} F_n} \quad (17)$$

Where F_i is the fitness value of the solution i and $N/2$ is the number of food sources which is equal to the number of employed bees.

The Employed bee whose location of the food source cannot be enhanced for some predetermined number of cycles than that food source is called abandoned food source. That employed bee becomes scout and searches for the new solution randomly using Equation (18).

$$x_i^j = x_{\min}^j + \text{rand}(0,1)(x_{\max}^j - x_{\min}^j) \quad (18)$$

5. Enhanced Gravitational Search (EGS) Algorithm

The proposed Enhanced Gravitational Search (EGS) algorithm is mainly based on the improvement of the results of the gravitational search algorithm (GSA) using the artificial bee colony algorithm (ABC). The half of the best population found by gravitational search algorithm sent to the artificial bee colony algorithm to start employed bees.

Algorithm steps are given below.

- 1) Initialize parameters.
- 2) Create starting population.
- 3) Calculate fitness for current solution set.
- 4) Calculate Mass, Forces and Acceleration for each solution.
- 5) Update velocities and positions of candidate solutions.
- 6) Calculate fitness for updated solution set.
- 7) Select best number of populations/2 from solution set.
- 8) Send employed bees to food sources (solutions).
- 9) Send onlooker bees to food sources provided by employed bees.
- 10) If termination criteria provided return best solution else return step 4 and run until termination criteria provided.

6. Simulation Results

At first Enhanced Gravitational Search (EGS) algorithm has been tested in standard IEEE-57 bus power system. The reactive power compensation buses are 18, 25 and 53. Bus 2, 3, 6, 8, 9 and 12 are PV buses and bus 1 is selected as slack-bus. The system variable limits are given in Table 1.

The preliminary conditions for the IEEE-57 bus power system are given as follows:

$$P_{\text{load}} = 12.112 \text{ p.u.}, Q_{\text{load}} = 3.032 \text{ p.u.}$$

The total initial generations and power losses are obtained as follows:

$$\sum P_G = 12.421 \text{ p.u.}, \sum Q_G = 3.3132 \text{ p.u.}$$

$$P_{\text{loss}} = 0.25882 \text{ p.u.}, Q_{\text{loss}} = -1.2062 \text{ p.u.}$$

Table 2 shows the various system control variables i.e. generator bus voltages, shunt capacitances and transformer tap settings obtained after optimization which are within the acceptable limits. In Table 3, shows the comparison of optimum results obtained from proposed methods with other optimization techniques. These results indicate the robustness of proposed approaches for providing better optimal solution in case of IEEE-57 bus system.

Table 1: Variable Limits

Reactive Power Generation Limits							
Bus no	1	2	3	6	8	9	12
Qgmin	-1.4	-.015	-.02	-0.04	-1.3	-0.03	-0.4
Qgmax	1	0.3	0.4	0.21	1	0.04	1.50
Voltage And Tap Setting Limits							
vgmin	Vgmax	vpqmin	Vpqmax	tkmin	tkmax		
0.9	1.0	0.91	1.05	0.9	1.0		
Shunt Capacitor Limits							
Bus no	18	25	53				
Qcmin	0	0	0				
Qcmax	10	5.2	6.1				

Table 2: Control variables obtained after optimization

Control Variables	EGS
V1	1.1
V2	1.030
V3	1.033
V6	1.022
V8	1.024
V9	1.008
V12	1.016
Qc18	0.0661
Qc25	0.200
Qc53	0.0472
T4-18	1.009
T21-20	1.042
T24-25	0.866

T24-26	0.878
T7-29	1.050
T34-32	0.871
T11-41	1.012
T15-45	1.034
T14-46	0.910
T10-51	1.020
T13-49	1.060
T11-43	0.910
T40-56	0.900
T39-57	0.950
T9-55	0.950

Table 3: Comparison results

S.No.	Optimization Algorithm	Finest Solution	Poorest Solution	Normal Solution
1	NLP [17]	0.25902	0.30854	0.27858
2	CGA [17]	0.25244	0.27507	0.26293
3	AGA [17]	0.24564	0.26671	0.25127
4	PSO-w [17]	0.24270	0.26152	0.24725
5	PSO-cf [17]	0.24280	0.26032	0.24698
6	CLPSO [17]	0.24515	0.24780	0.24673
7	SPSO-07 [17]	0.24430	0.25457	0.24752
8	L-DE [17]	0.27812	0.41909	0.33177
9	L-SACP-DE [17]	0.27915	0.36978	0.31032
10	L-SaDE [17]	0.24267	0.24391	0.24311
11	SOA [17]	0.24265	0.24280	0.24270
12	LM [18]	0.2484	0.2922	0.2641
13	MBEP1 [18]	0.2474	0.2848	0.2643
14	MBEP2 [18]	0.2482	0.283	0.2592
15	BES100 [18]	0.2438	0.263	0.2541
16	BES200 [18]	0.3417	0.2486	0.2443
17	Proposed EGS	0.22062	0.23012	0.22302

Then Enhanced Gravitational Search (EGS) algorithm has been tested in standard IEEE 118-bus test system [19]. The system has 54 generator buses, 64 load buses, 186 branches and 9 of them are with the tap setting transformers. The limits of voltage on generator buses are 0.95 -1.1 per-unit., and on load buses are 0.95 -1.05 per-unit. The limit of transformer rate is 0.9 -1.1, with the changes step of 0.025. The limitations of reactive power source are listed in Table 4, with the change in step of 0.01.

Table 4: Limitation of reactive power sources

BUS	5	34	37	44	45	46	48
QCMAX	0	14	0	10	10	10	15
QCMIN	-40	0	-25	0	0	0	0
BUS	74	79	82	83	105	107	110

QCMAX	12	20	20	10	20	6	6
QCMIN	0	0	0	0	0	0	0

The statistical comparison results of 50 trial runs have been list in Table 5 and the results clearly show the better performance of proposed Enhanced Gravitational Search (EGS) algorithm in reducing the real power loss.

Table 5: Comparison results

Active power loss (MW)	BBO [20]	ILSBBO/strategy1 [20]	ILSBBO/strategy1 [20]	Proposed EGS
Min	128.77	126.98	124.78	117.04
Max	132.64	137.34	132.39	120.08
Average	130.21	130.37	129.22	118.32

7. Conclusion

In this paper Enhanced Gravitational Search (EGS) algorithm has been used to solve reactive power dispatch problem. Both the exploration & exploitation ability of the proposed EGS algorithm has been enhanced. The effectiveness of the proposed Enhanced Gravitational Search (EGS) algorithm has been demonstrated by testing it in IEEE 57,118 bus system and simulation results reveals about the reduction of real power loss when compared with other standard algorithms and also volatge profiles are within the limits .

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