(Research Article)

Active Power Loss Reduction by Improved Gravitational Search Algorithm

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Abstract

This paper proposes an Improved Gravitational Search Algorithm (IGSA) to solve the optimal reactive power problem. Corresponding to the superior fitness value with incessant movement of motion, the largest mass of the particle occupy the most excellent position in the end which lead to optimal solution of the problem. In order to perk up the optimization accurateness and convergence speed of gravitational search algorithm, mechanism of adaptive mixed arbitrary mutation is intermingled with standard GSA algorithm, such that each particle has the probability of mutation at any time, and the number of particles that modify in the population have a tendency to diminish with the augment of iteration times. Also in this work improvement of Gravitational Search Algorithm is done through by adding Metropolis principle for particle position updating. Proposed Improved Gravitational Search Algorithm (IGSA) has been tested in standard IEEE 14,300 bus test system and simulation results show the projected algorithm reduced the real power loss considerably.

Keywords: optimal reactive power, Transmission loss, Gravitational Search Algorithm.

1. Introduction

Reactive power problem plays an important role in secure and economic operations of power system. Numerous types of methods like Newton's method, interior point method; successive quadratic programming [1-6] have been utilized to solve the optimal reactive power problem. However many scientific difficulties are found while solving problem due to an assortment of constraints. Evolutionary techniques gravitational search, particle swarm optimization, symbiotic organism search algorithm, Ant Lion Optimizer, harmony search algorithm, Multi-objective Evolutionary Programming, Seeker optimization algorithm, chaotic krill herd algorithm [7-16] are applied to solve the reactive power problem. This paper proposes an Improved Gravitational Search Algorithm (IGSA) to solve the optimal reactive power problem. In the gravitational search algorithm (GSA), in space each particle is considered as a mass of moving object. By attraction cue to gravitation principle it is attracted by particles. Particles motion based on the Newton's second law. Corresponding to the superior fitness value with incessant movement of motion, the largest mass of the particle occupy the most excellent position in the end which lead to optimal solution of the problem. In order to perk up the optimization

accurateness and convergence speed of gravitational search algorithm, mechanism of adaptive mixed arbitrary mutation is intermingled with standard GSA algorithm, such that each particle has the probability of mutation at any time, and the number of particles that modify in the population have a tendency to diminish with the augment of iteration times. Uniform mutation and Laplace-normal hybrid mutation cooperate together in the entire iterations. Uniform mutation facilitates the algorithm to find the global optimal area rapidly, and then carry the interior search with hybrid mutation to perk up the optimization performance. Also in this work improvement of Gravitational Search Algorithm is done through by adding Metropolis principle for particle position updating. Proposed Improved Gravitational Search Algorithm (IGSA) has been tested in standard IEEE 14,300 bus test system and simulation results show the projected algorithm reduced the real power loss considerably.

2. Problem Formulation

Objective of the problem is to reduce the true power loss:

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

Voltage deviation given as follows:

$$F = P_L + \omega_v \times \text{Voltage Deviation} \quad (2)$$

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ISSN 2320-7590

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Voltage deviation given by:

$$\text{Voltage Deviation} = \sum_{i=1}^{Npq} |V_i - 1| \quad (3)$$

Constraint (Equality)

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

Constraints (Inequality)

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

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

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

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

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

3. Improved Gravitational Search Algorithm

Gravitational Search Algorithm (GSA) is based on the Newton's law of gravitation. Two particles in the universe attract each other with a force in the direction of the middle line. It mathematically expressed as:

$$F = G \frac{M_1 M_2}{R^2} \quad (10)$$

Attractiveness defined by

$$F_{ij}^d(t) = G(t) \frac{M_{Pi}(t)}{R_{ij}(t) + \varepsilon} (x_j^d(t) - x_i^d(t)) \quad (11)$$

Gravitational constant given by,

$$G(t) = G_0 e^{-\alpha \frac{t}{T}} \quad (12)$$

Gravity of the surrounding particles is calculated by

$$F_i^d(t) = \sum_{j=1, j \neq i}^N \text{rand} \times F_{ij}^d(t) \quad (13)$$

Acceleration of particle is calculated by,

$$a_i^d(t) = \frac{F_i^d(t)}{M_i(t)} \quad (14)$$

Inertial mass of the particle is computed by,

$$M_{ai} = M_{pi} = M_{ii} = M_i, (i = 1, 2, 3, \dots, N) \quad (15)$$

$$m_i(t) = \frac{\text{fit}_i(t) - \text{worst}(t)}{\text{best}(t) - \text{worst}(t)} \quad (16)$$

$$m_i(t) = \frac{m_i(t)}{\sum_{j=1}^N m_j(t)} \quad (17)$$

Best and worst value found out after population updating by,

$$\text{best}(t) = \min_{j \in \{1, \dots, N\}} \text{fit}_j(t) \quad (18)$$

$$\text{worst}(t) = \max_{j \in \{1, \dots, N\}} \text{fit}_j(t) \quad (19)$$

Velocity and position update is done through

$$V_i^d(t+1) = \text{rand} \times V_i^d(t) + a_i^d(t) \quad (20)$$

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t) \quad (21)$$

Where *rand* is a random number from [0, 1], $V_i^d(t)$ and $x_i^d(t)$ respectively represents the speed and position proportion at dimension *d* of particle *i* at time *t*.

In this work improvement of Gravitational Search Algorithm (IGSA) is done through by adding Metropolis principle for particle position updating:

$$\text{if } \text{fit}_{i+1}(t) \leq \text{fit}_i(t) \text{ or } \text{rand} \leq \exp\left(-\frac{\text{fit}_{i+1}(t) - \text{fit}_i(t)}{KT}\right), x_i(t+1) = \bar{x}_i(t+1); \text{else } x_i(t+1) = x_i(t) \quad (22)$$

In Improved Gravitational Search Algorithm (IGSA) an Adaptive trigger function of mutation is formulated by,

$$TR_i^t = e^{\left(-\frac{\dim \times t}{2} \times \frac{1}{T}\right)} \times \left(\text{random} \times e^{\left(-\frac{i-1}{N}\right)} + \varepsilon\right) \quad (23)$$

Modernizing particle position with unvarying mutation is derived by,

$$x_t(t) = (1 + r)x_t(t), \text{random} \leq \left(1 - \frac{t}{T}\right) \quad (24)$$

Normal variation function is based on,

$$\text{Normal}_i(t) = \frac{1}{\sqrt{2\pi}\sigma} e^{\left(-\frac{(x_{\text{best}} - x_i^t)^2}{2\sigma^2}\right)} \quad (25)$$

The Laplace mutation function is designed as,

$$\text{laplace}_i(t) = \frac{1}{2\lambda} e^{\left(\frac{(x_{\text{best}} - x_i^t)}{\lambda}\right)} \quad (26)$$

Laplace normal hybrid mutation function is defined by,

$$\text{MLN}_i(t) = (1 - \omega)\text{laplace}_i(t) + \omega\text{normal}_i(t) \quad (27)$$

Hybrid mutation movement position update done by,

$$x_i(t) = \text{MLN}_i(t) x_i(t), \text{random} > \left(1 - \frac{t}{T}\right) \quad (28)$$

4. Simulation Results

At first in standard IEEE 14 bus system the validity of the Projected Improved Gravitational Search Algorithm (IGSA)

has been tested & comparison results are presented in Table 1. Figure . 1 shows the comparison of power loss.

Table 1. Comparison of Real Power Loss

Control variables	ABCO [19]	IABCO [19]	IGSA
V1	1.06	1.05	1.04
V2	1.03	1.05	1.00
V3	0.98	1.03	1.01
V6	1.05	1.05	1.03
V8	1.00	1.04	0.90
Q9	0.139	0.132	0.100
T56	0.979	0.960	0.900
T47	0.950	0.950	0.900
T49	1.014	1.007	1.000
Ploss (MW)	5.92892	5.50031	4.1108

Figure 1. Comparison of Real power Loss

Then IEEE 300 bus system [18] is used as test system to validate the performance of the Projected Improved Gravitational Search Algorithm (IGSA). Table 2 shows the comparison of real power loss obtained after optimization. Figure 2. Shows the real power loss comparison.

Table 2 Comparison of Real Power Loss

Parameter	Method EGA [21]	Method EEA [21]	Method CSA [20]	IGSA
PLOSS (MW)	646.2998	650.6027	635.8942	618.1082

In IEEE 14, 300 bus systems proposed Improved Gravitational Search Algorithm (IGSA) has been validated. Real Power loss reduction has been attained.

Figure 2. Real power Loss comparison

5. Conclusion

Improved Gravitational Search Algorithm (IGSA) successfully solved the optimal reactive power problem. In order to perk up the optimization accurateness and convergence speed of gravitational search algorithm, mechanism of adaptive mixed arbitrary mutation is intermingled with standard GSA algorithm, such that each particle has the probability of mutation at any time, and the number of particles that modify in the population have a tendency to diminish with the augment of iteration times. Also in this work improvement of Gravitational Search Algorithm is done through by adding Metropolis principle for particle position updating. Proposed Improved Gravitational Search Algorithm (IGSA) has been tested in standard IEEE 14,300 bus test system and simulation results show the projected algorithm reduced the real power loss considerably.

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