

Diminution of factual power loss by enhanced bacterial foraging optimization algorithm

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ABSTRACT

This paper presents an enhanced bacterial foraging optimization (EBFO) algorithm for solving the optimal reactive power problem. Bacterial foraging optimization is based on foraging behaviour of *Escherichia coli* bacteria which present in the human intestine. Bacteria have inclination to congregate the nutrient-rich areas by an action called as Chemo taxis. The bacterial foraging process consists of four chronological methods i.e. chemo taxis, swarming and reproduction and elimination-dispersal. In this work rotation angle adaptively and incessantly modernized, which augment the diversity of the population and progress the global search capability. The quantum rotation gate is utilized for chemo taxis to modernize the state of chromosome projected EBFO algorithm has been tested in standard IEEE 14,300 bus test system and simulation results show the projected algorithm reduced the real power loss extensively.

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1. INTRODUCTION

Reactive power problem plays a key role in secure and economic operations of power system. Optimal reactive power problem has been solved by variety of types of methods [1-6]. Nevertheless numerous scientific difficulties are found while solving problem due to an assortment of constraints. Evolutionary techniques [7-16] are applied to solve the reactive power problem, but the main problem is many algorithms get stuck in local optimal solution and failed to balance the exploration and exploitation during the search of global solution. This research work presents an enhanced bacterial foraging optimization (EBFO) algorithm for solving the optimal reactive power problem. It is a new-fangled hybrid optimization algorithm, which merge the quantum based evolutionary algorithm with the bacterial foraging algorithm. Quantum rotation angle is set through the look-up table procedure, and rotation angle is acquired is discrete but cannot completely replicate the fundamental situation of the solution space. In this work rotation angle adaptively and incessantly modernized, which augment the diversity of the population and progress the global search capability. Projected enhanced bacterial foraging optimization (EBFO) algorithm has been tested in standard IEEE 14,300 bus test system and simulation results show the projected algorithm reduced the real power loss extensively.

2. PROBLEM FORMULATION

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

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

Voltage deviation given as follows:

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

Voltage deviation given by:

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

Constraint (Equality);

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

Constraints (Inequality);

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

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

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

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

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

3. ENHANCED BACTERIAL FORAGING OPTIMIZATION ALGORITHM

Enhanced bacterial foraging optimization algorithm is a new-fangled hybrid optimization algorithm, which merge the quantum based evolutionary algorithm with the bacterial foraging algorithm. Quantum rotation angle is set through the look-up table procedure, and rotation angle is acquired is discrete but cannot completely replicate the fundamental situation of the solution space [17].

– Quantum bit

In conventional bit have two values 0 or 1, but the superposition the values will be in qubit. With bracket data the state of a qubit can be symbolized by:

$$|\varphi\rangle = \alpha|0\rangle + \beta|1\rangle \quad (10)$$

where $|\varphi\rangle$ symbolize vector space. Classical bit values 0 and 1 can be represented by $|0\rangle$ and $|1\rangle$; c and d is complex numbers such that:

$$|c|^2 + |d|^2 = 1 \quad (11)$$

c and d symbolize the complex number of the probability amplitudes.

– Quantum revolution gate

Quantum rotation gate is frequently used and defined by:

$$U(\theta) = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \quad (12)$$

Single quantum chromosome is indicated by q_j^t ,

$$q_j^t = \left(\begin{array}{c} \alpha_1^t \mid \alpha_2^t \quad \dots \quad \alpha_m^t \\ \beta_1^t \mid \beta_2^t \quad \dots \quad \beta_m^t \end{array} \right) \quad (13)$$

“m” denotes the number of quantum bits; $j=1, 2, \dots, n$, size of population symbolized by n; and genetic algebra indicated by t. (α_i^t, β_i^t) , are initialize with $(1/\sqrt{2}, 1/\sqrt{2})$ and it designate single quantum bit chromosome which symbolize the linear superposition with the similar possibility in all probable states.

$$|\phi_{q_i^t}\rangle = \sum_{k=1}^{2^m} \frac{1}{\sqrt{2^m}} |S_k\rangle \quad (14)$$

where S_k is the number of k state of chromosome & it symbolized by the binary string (x_1, x_2, \dots, x_m) , $x_i(1, 2, \dots, m)$ will be 0 or 1. When $(t) = \{P_1^t, P_2^t, \dots, P_n^t\}$, a group of binary population attained. $P_i^t(1, 2, \dots, n)$ is a binary string of the length m and is created by possibility of quantum, with picking every bit using $|\alpha_i^t|^2$ or $|\beta_i^t|^2$ of q_i^t . $P_i^t(1, 2, \dots, n)$ is evaluate the fitness value.

Bacterial foraging optimization is based on foraging behaviour of *Escherichia coli* bacteria which present in the human intestine. Bacteria have inclination to congregate the nutrient-rich areas by an action called as chemo taxis. The bacterial foraging process consists of four chronological methods i.e. chemo taxis, swarming and reproduction and elimination-dispersal. Chemo taxis: -In the computational chemo taxis, the progression of i^{th} bacterium subsequent to one step can be symbolized as:

$$\theta^i(j+1, k, l) = \theta^i(j, k, l) + C(i)\varphi(j) \quad (15)$$

Swarming: -Cell to Cell indication in *E. coli* swarm is scientifically symbolized as:

$$j_{cc}(\theta, P(j, k, l)) = \sum_{i=1}^s j_{cc}(\theta, \theta^i(j, k, l)) = \sum_{i=1}^s [-d_{attractant} \exp(-\delta_{attractant} \sum_{m=1}^p (\theta_m - \theta_m^i)^2)] + \sum_{i=1}^s [h_{repellent} \exp(-\delta_{repellent} \sum_{m=1}^p (\theta_m - \theta_m^i)^2)] \quad (16)$$

Reproduction: subsequent to the conclusion of all N_c chemo tactic stage, reproduction action will begin. In ascending order fitness value of the bacteria will be stored. Elimination and dispersal: it is necessary to spread the bacteria may be steadily or abruptly hence opportunity of being ensnared in to local minima will be eliminated. Dispersion operation takes place after a definite number of reproduction procedures. In the period of the chemo taxis loop topple direction is modernized by:

$$\varphi(j+1) = \omega * \varphi(j) + C_1 * rand * (pbest - pcurrent) + c_2 * rand * (gbest - pcurrent) \quad (17)$$

The customized operator of probability amplitude is defined as:

$$\begin{bmatrix} \alpha_i^* \\ \beta_i^* \end{bmatrix} = \begin{cases} (\sqrt{\gamma}, \sqrt{1-\gamma})^T, & |\alpha_i^*|^2 \leq \gamma \\ (\sqrt{1-\gamma}, \sqrt{\gamma})^T, & |\alpha_i^*|^2 \geq \gamma \\ (\alpha_i^*, \beta_i^*)^T & \text{else} \end{cases} \quad (18)$$

Enhanced quantum rotation angle is done by:

$$M_1 = \text{sign}((x_i - 0.5)\alpha_i\beta_i) \quad (19)$$

$$M_2 = \text{sign}(\theta_i - \theta_b) \quad (20)$$

$$\theta = M_1 M_2 \theta_0 e^{(-\eta)} \quad (21)$$

Direction of the rotation angle is controlled by M_1 and M_2 and size of the rotation angle is controlled by η , θ_0 . Present fitness value of chemo tactic step size varying is likely to endow with improved convergence performance. Adaption scheme for the step size for i^{th} bacterium is given by:

$$C(i) = \frac{|j^i(\theta)|}{|j^i(\theta) + \Psi|} = \frac{1}{1 + \frac{\Psi}{j^i(\theta)}} \quad (22)$$

Where Ψ is positive constant.

$j^i\theta$ = Cost function of the i^{th} bacterium

$C(i)$ = Variable run (step) length of i^{th} bacterium

Step a : Initialize the parameters

Step b : Procedure of elimination and dispersal loop

Step c : Begin of reproduction loop

Step d : Begin of chemo taxis loop

- Step e : When $j < N_c$, then go to Step d chemo taxis will be continued because bacteria life is not over.
- Step f : Reproduction procedure applied
- Step g : When $k < N_{re}$, then go to Step c; when specific number of reproduction steps are not reached, then commence the subsequent generation of the chemo tactic loop.
- Step h : Elimination-dispersal: For $i = 1, 2, \dots, S$ with the probability p_{ed} , each bacterium are eliminated and disperse, then number of bacteria in the population will be constant. For above action, when a bacterium is eradicated, merely disperse one to an arbitrary location in the domain. When $l < N_{ed}$ then go to Step b, or else end;
- Step i : When the end condition of the projected algorithm is fulfilled, then the optimal fitness value and the consequent individual position rank are the output, or else return to Step c.

4. SIMULATION RESULTS

At first in standard IEEE 14 bus system the validity of the proposed EBFO algorithm has been tested and comparison results are presented in Table 1. Then IEEE 300 bus system [18] is used as test system to validate the performance of the EBFO algorithm. Table 2 shows the comparison of real power loss obtained after optimization.

Table 1. Comparison of results

Control variables	ABCO [19]	IABCO [19]	EBFO
V1	1.06	1.05	1.03
V2	1.03	1.05	1.00
V3	0.98	1.03	1.00
V6	1.05	1.05	1.00
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	4.1648

Table 2. Comparison of real power loss

Parameter	Method EGA [20]	Method EEA [20]	Method CSA [21]	EBFO
PLOSS (MW)	646.2998	650.6027	635.8942	618.0482

5. CONCLUSION

In this work EBFO algorithm has been successfully solved the optimal reactive power problem. Rotation angle adaptively and incessantly modernized which augmented the diversity of the population and progress the global search capability. The quantum rotation gate is utilized for chemo taxis to modernize the state of chromosome projected EBFO algorithm has been tested in standard IEEE 14,300 bus test system and simulation results show the projected algorithm reduced the real power loss extensively.

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