Honey Bees Optimization Algorithmfor Solving Optimal Reactive Power Problem

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Abstract

This paper proposes Honey Bees Optimization (HBO) algorithm for solving Reactive Power problem in a power system.It is a nature inspired algorithm thatmimics the mating behavior of the bees, called Honey Bees Optimization (HBO) algorithm, utilized for solvingReactive Power problem. Generator terminal voltages, reactive power generation of the capacitor banks and tap changing transformer setting are taken as the optimization variables. In order to evaluate the efficiency of the proposed algorithm, it has been tested in IEEE 57 bus system &the performance of the algorithm is verified by comparing with other reported standard methods. Simulation results show that HBO approachis more efficient in reducing the real power loss & voltage profiles are within the limits.

Keywords

Honey bees optimization, swarm intelligence, optimal reactive power, transmission loss

1. Introduction

Main objective is operating the system in secure mode and also to improve the economy of the system. The sources of the reactive power are the generators, synchronous condensers, capacitors, static compensators and tap changing transformers. Various mathematical techniques have been utilized to solve this optimal reactive power problem like the gradient method [1, 2], Newton method [3] and linear programming [4-7].The gradient and Newton methods failed to handle inequality constraints. In last few years several biological and natural processes have been utilized in the methodologies of science and technology in an increasing manner. Among the most popular nature inspired approaches are Particle Swarm Optimization [8], the artificial immune systems [9], the Ant Colony Optimization [10], etc. Also, a number of swarm intelligence algorithms, based on the behaviour of the bees have been presented [11]. These algorithms are divided, mainly, in two categories according to their behaviour in the nature, the foraging behaviour and the mating behaviour. The most important methodologiesthat simulate the foraging behaviour of the bees are the Artificial Bee Colony (ABC) Algorithm is [12-23] simulate about the mating process of the queen of the hive. In this paper, a new algorithm that simulates the mating behaviour of the bees called Honey Bees Optimization (HBO)algorithm is presentedand used for solving optimal reactive power problem. The performance of HBO has been evaluated in standard IEEE 57 bus test system and the results analysis shows that our proposed approach performs well when compared to other reported algorithms.

2. Problem Formulation

The objectives of the reactive power problem is to minimize the realpower loss.

2.1 Active power loss

The objective of the reactive power dispatch problem is to minimize the active power loss and can be written in equations as follows:

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

Where F- objective function, P_L – power loss, g_k- conductance of branch,V_i and $V_j$are voltages at buses i,j, Nbr- total number of transmission lines in power systems.

2.2 Voltage profile improvement

To minimize the voltage deviation in PQ buses, the objective function (F) can be written as:

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

Where VD - voltage deviation,ω_v- is a weighting factor of voltage deviation.

And the Voltage deviation given by:

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

Where Npq- number of load buses

2.3 Equality Constraint

The equality constraint of the problem is indicated by the power balance equation as follows:

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

Where P_G- total power generation, P_D - total power demand.

2.4 Inequality Constraints

The inequality constraint implies the limits on components in the power system in addition to the limits created to make sure system security. Upper and lower bounds on the active power of slack bus (P_g), and reactive power of generators (Q_g) are written as follows:

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

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

Upper and lower bounds on the bus voltage magnitudes (V_i) is given by:

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

Upper and lower bounds on the transformers tap ratios (T_i) is given by:

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

Upper and lower bounds on the compensators (Q_c) is given by:

$$Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C \quad (9)$$

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

3. Proposed HoneyBees Optimization (HBO) Algorithm

In the Honey Bees OptimizationHBO algorithm, there are three kinds of bees in the colony, the queen, the workers and the drones. Primarily, a number of bees are selected arbitrarily. Each bee represents a candidate solution of the problem. Let n be the total number of variables. The bees are represented by vectors of dimension n.We use a real valued representation where initially the values of each of the bees are arbitrary numbers between 0 and 1.

Afterwards, the fitness of each bee is computed using each one of the test functions depending of the problem and the best bee is selected as the queen. All the other bees in the initialization phase of the algorithm are the drones. The queen selects the drones that are used for mating by using the second mating behaviour where it is assumed in the algorithm that the fittest males let larger amount of pheromone in their flight paths and, thus, the queen selects the most promising paths. This technique is realized by sorting of all drones based on their fitness function. Each time the queen successfully mates with a drone, the genotype of the drone is stored in her spermatheca until the maximum number of mating's has been reached. After the mating, the queen finds a place to hibernate and in the next cycle finds a place to create the hive and to begin to lay eggs.There are three kinds of bees that a queen lays: new queens, workers and drones. The first two kinds of bees are created by crossover of the genotype of the queenand the genotype of the drones using a specific crossover operator. In this crossoveroperator, the points are selected arbitrarily from the selected drones and from thequeen. Thus, initially a crossover operator number is selected (C_{r1}) that controlsthe fraction of the parameters that are selected for the drones and the queen. TheC_{r1}value is compared with the output of a random number generator, $rand_i(0,1)$. Ifthe random number is less or equal to the$C_{r1}$the corresponding value is inheritedfrom the queen, otherwise it is selected, randomly, from the solutions of one of thedrones' genotypes that are stored in spermatheca. Thus, if the

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solution of the brood *i*is denoted by $b_{ij}(t)$ (*t* is the iteration number and *j* is the dimension of the problem, *j*=1,…,*n*), the solution of the queen is denoted by $q_j(t)$ and the solution of thedrone *k* is denoted by $d_{kj}(t)$:

$$b_{ij}(t) = \begin{cases} q_j(t), if\ rand_i(0,1) \leq cr_1 \\ d_{kj}(t), otherwise. \end{cases} \quad (10)$$

The fittest of the broods are selected as new queens while the rest are the workers. The new queens are selected to be equal to the maximum number of the queens. Initially, the new queens are fed from the old queen andafterwards, from the workers and the old queen. The reason that we use this procedure is to improve the genotype of each new queen. This is achieved by using a local search phase where each new queen selects which of the workers and the old queens are going to feed her by using the following equation:

$$nq_{ij} = nq_{ij} + \left(b_{max} - \frac{(b_{max}-b_{min})*lsi}{lsi_{max}}\right) * \left(nq_{ij} - q_j\right) + \frac{1}{M} * \sum_{K=1}^{M} \left(b_{min} - \frac{(b_{max}-b_{min})*lsi}{lsi_{max}}\right) ** \left(nq_{ij} - w_{kj}\right) \quad (11)$$

where $nq_{ij}$is the solution of the new queen *i*, *qj*is the solution of the old queen, $w_{kj}$is the solution of the worker, *M* is the number of the workers thateach queen selects for feeding her and it is different for each queen, b_{max},b_{min}aretwo parameters with values in the interval (0,1) that control if the new queen isfed from the old queen (or queens), from the workers or from both of them, *lsi*isthe current local search iteration and $lsi_{max}$is the maximum number of local searchiterations. Initially, the new queens are fed more from the old queen andas the local search iterations increase, and then only the workers feed the new queen.The appropriate choice of the values of $b_{max}$and b_{min}controls the feeding process,i.e. in order to have the feeding process described previously, a large value for $b_{max}$and a value almost equal to zero for $b_{min}$are necessary. Afterwards, the new queensleave from the hive.

The drones are formed by mutate the old queen's genotype or by mutate the fittest workers genotype using anarbitrary mutation operator. In this mutation operator, the changes in the genotype of the old queens or the workers are performed arbitrarily. The drones, then, leave from the hive and they are looking for new queens for mating. As the drones leave from the hive they are moving in a swarm in order to find the best places to wait for the new queens to find them by their marked flight paths. The movement of the drones away from the hive is calculated from the following equation:

$$d_{ij} = d_{ij} + \alpha * \left(d_{kj} - d_{lj}\right) \quad (12)$$

whered_{ij},$d_{kj}$and $d_{lj}$are the solutions of the drones *i,k, l* respectively and α isa parameter that determines the percentage that the drone *i*is affected by the twoother drones *k* and *l*. The new queen selects the drones that are used for matingby the procedure described previously. In the next generation, the best fertilizedqueens survive and all the other members of the population die. The Honey Bees Optimization (HBO)algorithm simulates themating process of the queen of the hive, where there are three kinds of bees, thequeen, the drones and the workers. The mating process of the queen begins whenthe queen flights away from the nest performing the mating flight during which thedrones follow the queen and mate with her in the air.

Honey Bees Optimization Algorithm (HBO) for solving Reactive Power Problem

a. Primarypopulations of the bees are created with respect to objective function.
b. Decide the fitness function of each bee.
c. The bee with paramount fitness function is designated as the queen and other bees will be the drones.
d. The drones have to be sorted out according to the fitness function and then according to the fitness value, drones will be selected for mating with the queen.
e. Drones have to be stockpiledrendering to the genotype.
f. Broods have to be generated by using a crossover operator.
g. Fitness function of each brood has to be calculated.
h. Broods are sorted out rendering to their fitness' functions.
i. Rendering to the fitness function, the best broods have to be designated as the new queens&rest broods will be as the workers.
j. Fresh queens are feed by the old queens and the workers Percentage of the drones are generated by mutating of the old queens' genotypes &rest of the drones are formed by mutating of the workers genotypes.
k. Fitness function has to be calculated for each drone.
l. Directions of the drones, which are moving away from the hive, have to be computed & the drones have to be sorted out according to their fitness functions.

m. If the ultimate number of mating's for each new queen has not been reached, then by fitness function, the drones has to be selected for mating by each new queen
n. The drones have to be sorted out rendering to the genotypes of each new queen.
o. Fresh queens for the subsequent iteration& wiped out of all other workers and drones of the population
p. End
q. Returnwhen finest solution is found.

4. Simulation Results

Proposed HBO algorithm for solving reactive power problem is tested in standard IEEE-57 bus power system. The IEEE 57-bus system data consists of 80 branches, seven generator-buses and 17 branches under load tap setting transformer branches. The possible 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. In this case, the search space has 27 dimensions, i.e., the seven generator voltages, 17 transformer taps, and three capacitor banks. The system variable limits are given in Table 1. The initial conditions for the IEEE-57 bus power system are given as follows:

P_{load}= 12.468p.u. Q_{load} = 3.352p.u.

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

$\sum P_G$ = 12.7812p.u. $\sum Q_G$ = 3.4754p.u.

P_{loss}= 0.27575p.u. Q_{loss} = -1.2349p.u.

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

Table 1: Variables limits

reactive power generation limits							
bus no	1	2	3	6	8	9	12
Q_{gmin}	-1.4	-.017	-.02	-0.08	-1.2	-0.01	-0.3
q_{gmax}	2	0.3	0.6	0.27	3	0.09	1.58

voltage and tap setting limits					
v_{gmin}	v_{gmax}	v_{pqmin}	v_{pqmax}	t_{kmin}	t_{kmax}
0.7	1.3	0.94	1.08	0.7	1.2

shunt capacitor limits			
bus no	18	25	53
q_{cmin}	0	0	0
q_{cmax}	10	5.5	6.4

Table 2: control variables obtained after optimization

Control Variables	HBO
V1	1.15
V2	1.092
V3	1.084
V6	1.079
V8	1.092
V9	1.087
V12	1.081
Qc18	0.0898
Qc25	0.379
Qc53	0.0682
T4-18	1.019
T21-20	1.084
T24-25	0.986
T24-26	0.978
T7-29	1.091
T34-32	0.972
T11-41	1.019

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T7-29	1.091
T34-32	0.972
T11-41	1.019
T15-45	1.089
T14-46	0.986
T10-51	1.078
T13-49	1.084
T11-43	0.901
T40-56	0.910
T39-57	0.989
T9-55	0.991

Table 3: Comparison of Real power loss

S.No.	Optimization Algorithm	Best Solution	Worst Solution	Average Solution
1	NLP [24]	0.25902	0.30854	0.27858
2	CGA [24]	0.25244	0.27507	0.26293
3	AGA [24]	0.24564	0.26671	0.25127
4	PSO-w [24]	0.24270	0.26152	0.24725
5	PSO-cf [24]	0.24280	0.26032	0.24698
6	CLPSO [24]	0.24515	0.24780	0.24673
7	SPSO-07 [24]	0.24430	0.25457	0.24752
8	L-DE [24]	0.27812	0.41909	0.33177
9	L-SACP-DE [24]	0.27915	0.36978	0.31032
10	L-SaDE [24]	0.24267	0.24391	0.24311
11	SOA [24]	0.24265	0.24280	0.24270
12	LM [25]	0.2484	0.2922	0.2641
13	MBEP1 [25]	0.2474	0.2848	0.2643
14	MBEP2 [25]	0.2482	0.283	0.2592
15	BES100 [25]	0.2438	0.263	0.2541
16	BES200 [25]	0.3417	0.2486	0.2443
17	Proposed HBO	0.22398	0.23786	0.23009

5. Conclusion

In this paper a novel approach Honey Bees optimization (HBO) algorithm successfully solved optimal reactive power problem & it has been tested in standard IEEE 57 bus system.Proposed HBO approach successfully reduced real power loss and voltage profiles are within the limits. The simulation results indicate the effectiveness and robustness of the proposed algorithm in solving optimal reactive power problem.

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