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Dwindling of real power loss by using Improved Bees Algorithm

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Abstract: **In this paper, a new Improved Bees Algorithm (IBA) is proposed for solving reactive power dispatch problem. The aim of this paper is to utilize an optimization algorithm called the improved Bees Algorithm, inspired from the natural foraging behaviour of honey bees, to solve the reactive power dispatch problem. The IBA algorithm executes both an exploitative neighbourhood search combined with arbitrary explorative search. The proposed Improved Imperialist Competitive Algorithm (IBA) algorithm has been tested on standard IEEE 57 bus test system and simulation results show clearly the high-quality performance of the projected algorithm in reducing the real power loss.**

Keywords: **Optimal Reactive Power, Transmission loss, honey bee, foraging behaviour, waggle dance, bee's algorithm, swarm intelligence, swarm-based optimization, adaptive neighbourhood search, site abandonment, random search**

I. INTRODUCTION

Optimal reactive power dispatch (ORPD) problem is to minimize the real power loss and bus voltage deviation. Various mathematical techniques like the gradient method [1-2], Newton method [3] and linear programming [4-7] have been adopted to solve the optimal reactive power dispatch problem. Both the gradient and Newton methods have the complexity in managing inequality constraints. If linear programming is applied then the input- output function has to be uttered as a set of linear functions which mostly lead to loss of accuracy. The problem of voltage stability and collapse play a major role in power system planning and operation [8]. Global optimization has received extensive research awareness, and a great number of methods have been applied to solve this problem. Evolutionary algorithms such as genetic algorithm have been already proposed to solve the reactive power flow problem [9, 10]. Evolutionary algorithm is a heuristic approach used for minimization problems by utilizing nonlinear and non-differentiable continuous space functions. In [11], Genetic algorithm has been used to solve optimal reactive power flow problem. In [12], Hybrid differential evolution algorithm is proposed to improve the voltage stability index. In [13] Biogeography Based algorithm is projected to solve the reactive power dispatch problem. In [14], a fuzzy based method is used to solve the optimal reactive power scheduling method. In [15], an improved evolutionary programming is used to solve the optimal reactive power dispatch problem. In [16], the optimal reactive power flow problem is solved by integrating a genetic algorithm with a nonlinear interior point method. In [17], a pattern algorithm is used to solve ac-dc optimal reactive power flow model with the generator capability limits. In [18], F. Capitanescu proposes a two-step approach to evaluate Reactive power reserves with respect to operating constraints and voltage stability. In [19], a programming based approach is used to solve the optimal reactive power dispatch problem. In [20], A. Kargarian et al present a probabilistic algorithm for optimal reactive power provision in hybrid electricity markets with uncertain loads. This paper proposes a new Improved Bees Algorithm (IBA) to solve the optimal reactive power dispatch problem. The aim of this paper is to solve optimal reactive power problem by utilizing Bees Algorithm, introduced by Pham [21], inspired from the natural foraging behaviour of honey bees. The IBA algorithm performs both an exploitative neighbourhood search combined with arbitrary explorative search. The proposed algorithm IBA has been evaluated in standard IEEE 57 bus test system and the simulation results show that our proposed approach outperforms all the entitled reported algorithms in minimization of real power loss.

II. PROBLEM FORMULATION

The optimal power flow problem is treated as a general minimization problem with constraints, and can be mathematically written in the following form:

Minimize f(x, u) (1)

subject to g(x,u)=0 (2)
and
$h(x, u) \leq 0$ (3)

where f(x,u) is the objective function. g(x.u) and h(x,u) are respectively the set of equality and inequality constraints. x is the vector of state variables, and u is the vector of control variables.

The state variables are the load buses (PQ buses) voltages, angles, the generator reactive powers and the slack active generator power:

$$x = \left(P_{g1}, \theta_2, .., \theta_N, V_{L1}, ., V_{LNL}, Q_{g1}, .., Q_{gng}\right)^T \quad (4)$$

The control variables are the generator bus voltages, the shunt capacitors/reactors and the transformers tap-settings:

$$u = \left(V_g, T, Q_c\right)^T \quad (5)$$

or

$$u = \left(V_{g1}, \dots, V_{gng}, T_1, .., T_{Nt}, Q_{c1}, .., Q_{cNc}\right)^T \quad (6)$$

Where ng, nt and nc are the number of generators, number of tap transformers and the number of shunt compensators respectively.

III. OBJECTIVE FUNCTION

A. Active power loss

The objective of the reactive power dispatch is to minimize the active power loss in the transmission network, which can be described as follows:

$$F = PL = \sum_{k \in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j cos\theta_{ij}\right) \quad (7)$$

Or

$$F = PL = \sum_{i \in Ng} P_{gi} - P_d = P_{gslack} + \sum_{i \neq slack}^{Ng} P_{gi} - P_d \quad (8)$$

where g_k : is the conductance of branch between nodes i and j, Nbr: is the total number of transmission lines in power systems. P_d: is the total active power demand, P_{gi}: is the generator active power of unit i, and P_{gsalck}: is the generator active power of slack bus.

B. Voltage profile improvement

For minimizing the voltage deviation in PQ buses, the objective function becomes:

$$F = PL + \omega_v \times VD \quad (9)$$

where ω_v: is a weighting factor of voltage deviation.

VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \qquad (10)$$

C. Equality Constraint

The equality constraint g(x,u) of the ORPD problem is represented by the power balance equation, where the total power generation must cover the total power demand and the power losses:

$$P_G = P_D + P_L \qquad (11)$$

This equation is solved by running Newton Raphson load flow method, by calculating the active power of slack bus to determine active power loss.

D. Inequality Constraints

The inequality constraints h(x,u) reflect the limits on components in the power system as well as the limits created to ensure system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators:

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \qquad (12)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} \ , i \in N_g \qquad (13)$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \leq V_i \leq V_i^{max} \ , i \in N \qquad (14)$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \leq T_i \leq T_i^{max} \ , i \in N_T \qquad (15)$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \leq Q_c \leq Q_C^{max} \ , i \in N_C \qquad (16)$$

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.

IV. BEHAVIOUR OF HONEY BEES

A colony of honey bees can exploit a huge number of food sources in big fields and they can fly up to 12 km to exploit food sources [22, 23]. The colony utilize about one-quarter of its members as searcher bees. The foraging process begins with searching out hopeful flower patches by scout bees. The colony keeps a proportion of the scout bees during the harvesting season. When the scout bees have found a flower area, they will look further in hope of finding an even superior one [23]. The scout bees search for the better patches randomly [24]. The scout bees notify their peers waiting in the hive about the eminence of the food source, based amongst other things, on sugar levels. The scout bees dump their nectar and go to the dance floor in front of the hive to converse to the other bees by performing their dance, known as the waggle dance [22]. The waggle dance is named based on the wagging run, which is used by the scout bees to communicate information about the food source to the rest of the colony. The scout bees present the following information by means of the waggle dance: the quality of the food source, the distance of the source from the hive and the direction of the source [23- 25]. Figure 1a,b [25]. The scout then circles back, alternating a left and a right return path . The speed/duration of the dance indicates the distance to the food source; the frequency of the waggles in the dance and buzzing convey the quality of the source; see Figure 1c [25]. This information will influence the number of follower bees.

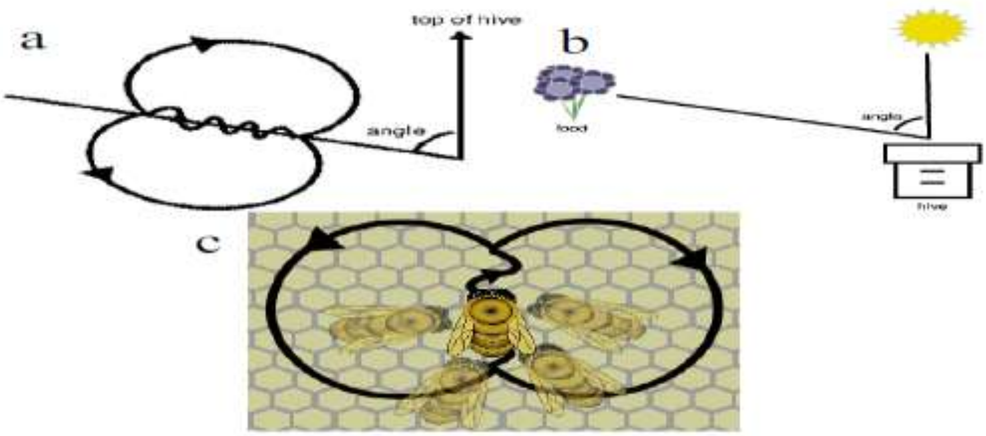

Fig1. (**a**) Orientation of waggle dance with respect to the sun; (**b**) Orientation of waggle dance with respect to the food source, hive and sun; (**c**) The Waggle Dance and followers.

Fundamental parameters of the Bees Algorithm:

Quantity of scout bees in the selected patches - *n*

Quantity of best patches in the selected patches - *m*

Quantity of elite patches in the selected best patches- *e*

Quantity of recruited bees in the elite patches -*nep*

Quantity of recruited bees in the non-elite best patches- *nsp*

The size of neighbourhood for each patch - *ngh*

Quantity of iterations- *Maxiter*

Variation between value of the first and last iterations- *diff*

Bees Algorithm:

Create the initial population size as *n*, *m*, *e*, *nep*, set *nsp*, *ngh*, *MaxIter*, and set the error limit as *Error*.

$i = 0$

Generate preliminary population.

Calculate Fitness Value of initial population.

Arrange the initial population based on the fitness result.

While $i \leq maxIter\ or\ fitness\ value_i - fitnessvalue_{i-1} \leq Error$

i. $i = i + 1$;

ii. Choose the elite patches and non-elite best patches for neighbourhood search.

iii. Engage the forager bees to the elite patches and non-elite best patches.

iv. Calculate the fitness value of each patch.

v. Arrange the results based on their fitness.

vi. Distribute the rest of the bees for global search to the non-best locations.

vii. Calculate the fitness value of non-best patches.

viii. Arrange the overall results based on their fitness.

x. Run the algorithm until stop criteria met.

End

V. IMPROVED BEES ALGORITHM BY ADAPTIVE NEIGHBOURHOOD SEARCH AND SITE ABANDONMENT STRATEGY

This segment explains the proposed improvements to the bee's algorithm (BA) by applying adaptive transform to the neighbourhood size and site abandonment approach simultaneously. Collective neighbourhood size change and site abandonment (NSSA) approach has been attempted on the BA by Koc [26] who found that the convergence rate of a NSSA-based BA can be sluggish, when the promising locations are far from the current best sites. Here an adaptive neighbourhood size change and site abandonment (ANSSA) approach is proposed which will keep away from local minima by changing the neighbourhood size adaptively. The ANSSA-based BA possesses both shrinking and augmentation strategies according to the fitness evaluation. The primary move is to implement the shrinking approach. This approach works on a best site after a definite number of repetitions. The approach works until the repetition stops. If, in spite of the shrinking approach, the number of repetitions still increases for a definite number of iterations, then an augmentation approach is utilized. Finally, if the number of repetitions still increases for a number of iterations after the use of the augmentation approach, then that site is abandoned and a new site will be generated. Koc [26] utilized the following parameter for shrinking the neighbourhood size and site abandonment approach: neighbourhood size = *ngh*, the shrinking constant = *sc*, the abandoned sites = *aband_site*. In this study four more parameters are introduced. The first is the number of repetitions for each site, denoted as *keep_point*. The *keep_point* records the number of repetitions for all the repetitive results for best sites. The second parameter is called the "Repetition Number for the shrinking" is denoted as rep*_nshr*; the number of shrinking is the number of repetitions necessary to start the shrinking strategy, as given in Equations (17) and (18). The parameter is the "Repetition Number for the enhancement" is denoted as *rep_nenh*. This parameter defines the number of repetitions until the end of the shrinking process, and the beginning of the enhancement process as shown in Equations (17) and (19) [27,28]. The enhancement process works until the number of the repetitions is equal to the *rep_naban,* which denotes the "Repetition Number for the abandonment process". Hence a non-productive site is abandoned and it is stored in *aband_site* list. If there is no better solution than the abandoned site at the end of the searching process, this is the final solution.

$$new_{ngh} = \begin{cases} keep_{point} \le rep_{nshr} & ngh \\ rep_{nshr} < keep_{point} \le rep_{nenh} & R1 \\ rep_{nenh} < keep_{point} \le rep_{naban} & R2 \\ rep_{naban} < keep_{point} & ngh \end{cases} \quad (17)$$

$$R1 = ngh - \left(ngh * \frac{(keep_{point} - rep\_nshr)}{100} * sc\right) \quad (18)$$

$$R2 = ngh + \left(ngh * \frac{(keep_{point} - rep\_nenh)}{100} * sc\right) \quad (19)$$

VI. SIMULATION RESULTS

The proposed Improved Bees Algorithm (IBA) algorithm for solving ORPD problem is tested for 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 I. The initial conditions for the IEEE-57 bus power system are given as follows:

P_{load} = 12.310 p.u. Q_{load} = 3.322 p.u.

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

$\sum P_G$ = 12.7634 p.u. $\sum Q_G$ = 3.4468 p.u.

P_{loss} = 0.27351 p.u. Q_{loss} = -1.2248 p.u.

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

TABLE I: VARIABLES LIMITS FOR IEEE-57 BUS POWER SYSTEM (P.U.)

REACTIVE POWER GENERATION LIMITS							
BUS NO	1	2	3	6	8	9	12
Q_{GMIN}	-1.2	-.014	-.02	-0.06	-1.2	-0.03	-0.3
Q_{GMAX}	2	0.4	0.5	0.24	2	0.08	1.54

VOLTAGE AND TAP SETTING LIMITS					
V_{GMIN}	V_{GMAX}	V_{PQMIN}	V_{PQMAX}	T_{KMIN}	T_{KMAX}
0.7	1.3	0.95	1.06	0.7	1.3

SHUNT CAPACITOR LIMITS			
BUS NO	18	25	53
Q_{CMIN}	0	0	0
Q_{CMAX}	10	5.3	6.5

TABLE II: CONTROL VARIABLES OBTAINED AFTER OPTIMIZATION BY IBA METHOD FOR IEEE-57 BUS SYSTEM (P.U.)

Control Variables	IBA
V1	1.2
V2	1.084
V3	1.073
V6	1.051
V8	1.074
V9	1.052
V12	1.061
Qc18	0.0843
Qc25	0.333
Qc53	0.0628
T4-18	1.016
T21-20	1.072
T24-25	0.973
T24-26	0.945
T7-29	1.092
T34-32	0.957
T11-41	1.015
T15-45	1.074
T14-46	0.943
T10-51	1.055
T13-49	1.075
T11-43	0.921
T40-56	0.911
T39-57	0.973
T9-55	0.985

TABLE III: COMPARATIVE OPTIMIZATION RESULTS FOR IEEE-57 BUS POWER SYSTEM (P.U.)

S.No.	Optimization Algorithm	Best Solution	Worst Solution	Average Solution
1	NLP [29]	0.25902	0.30854	0.27858
2	CGA [29]	0.25244	0.27507	0.26293
3	AGA [29]	0.24564	0.26671	0.25127
4	PSO-w [29]	0.24270	0.26152	0.24725
5	PSO-cf [29]	0.24280	0.26032	0.24698
6	CLPSO [29]	0.24515	0.24780	0.24673
7	SPSO-07 [29]	0.24430	0.25457	0.24752
8	L-DE [29]	0.27812	0.41909	0.33177
9	L-SACP-DE [29]	0.27915	0.36978	0.31032
10	L-SaDE [29]	0.24267	0.24391	0.24311
11	SOA [29]	0.24265	0.24280	0.24270
12	LM [30]	0.2484	0.2922	0.2641
13	MBEP1 [30]	0.2474	0.2848	0.2643
14	MBEP2 [30]	0.2482	0.283	0.2592
15	BES100 [30]	0.2438	0.263	0.2541
16	BES200 [30]	0.3417	0.2486	0.2443
17	Proposed IBA	0.22359	0.23492	0.23121

VII. CONCLUSION

IBA has been fruitfully applied for ORPD problem. The IBA based ORPD is tested in standard IEEE-57 bus system. Performance comparisons with well-known population-based algorithms give cheering results. IBA emerges to find good solutions when compared to that of other algorithms. The simulation results presented in previous section prove the ability of IBA approach to arrive at near global optimal solution.

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