[Lenin et. al., Vol.6 (Iss.1): January, 2018] ISSN- 2350-0530(O), ISSN- 2394-3629(P)
(Received: Dec 25, 2017 - Accepted: Jan 21, 2018) DOI: 10.29121/granthaalayah.v6.i1.2018.1632

INTERNATIONAL JOURNAL OF RESEARCH – GRANTHAALAYAH
A knowledge Repository

Science

REDUCTION OF ACTIVE POWER LOSS BY CHAOTIC SEARCH BASED ARTIFICIAL BEE COLONY ALGORITHM

Dr.K.Lenin [*1]

[*1] Professor, Department of EEE Prasad V.Potluri Siddhartha Institute of Technology, Kanuru, Vijayawada, Andhra Pradesh -520007, India

Abstract

This paper presents Chaotic Search Based Artificial Bee Colony Optimization Algorithm (CSABC) for solving the optimal reactive power problem. Basic Artificial Bee Colony algorithm (ABC) has the advantages of strong robustness, fast convergence and high flexibility, fewer setting parameters, but it has the disadvantages premature convergence in the later search period and the accuracy of the optimal value which cannot meet the requirements sometimes. In this paper the Chaotic Local Search method is applied to solve the reactive power problem of global optimal value. The premature convergence issue of the Artificial Bee Colony algorithm has been improved by increasing the number of scout and rational using of the global optimal value and Chaotic Search. The proposed Chaotic Search Based Artificial Bee Colony Optimization (CSABC) algorithm has been tested in stand IEEE 30, 118- bus & practical 191 Indian utility test systems. The results show that the proposed algorithm performs well in reducing the real power loss and prevent premature convergence to high degree with rapid convergence.

Keywords: Chaotic Search Based Artificial Bee Colony Optimization; Reactive Power Optimization.

Cite This Article: Dr.K.Lenin. (2018). "REDUCTION OF ACTIVE POWER LOSS BY CHAOTIC SEARCH BASED ARTIFICIAL BEE COLONY ALGORITHM." *International Journal of Research - Granthaalayah*, 6(1), 377-388.

1. Introduction

Optimal reactive power problem plays most important role in the stability of power system operation and control. In this paper the main aspect is to diminish the real power loss and to keep the voltage variables within the limits. Previously many techniques such as, gradient based optimization algorithm [1, 2] quadratic programming, nonlinear programming [3] and interior point method [4-7]. In recent years standard genetic algorithm (SGA) [8] and the adaptive genetic algorithm (AGA) [9], Partial swarm optimization PSO [10-11] have been applied for solving optimal reactive power problem. This paper presents Chaotic Search Based Artificial Bee Colony Optimization Algorithm (CSABC) for solving the optimal reactive power problem. Artificial Bee Colony algorithm is a global optimization algorithm which is motivated by the

 ISSN- 2350-0530(O), ISSN- 2394-3629(P)
(Received: Dec 25, 2017 - Accepted: Jan 21, 2018) DOI: 10.5281/zenodo.1167630

foraging behaviour of honey bee swarms. Basic Artificial Bee Colony algorithm (ABC) [12-14] has the advantages of strong robustness, fast convergence and high flexibility, fewer setting parameters, but it has the disadvantages premature convergence in the later search period and the accuracy of the optimal value which cannot meet the requirements sometimes. In this paper the Chaotic Local Search method [15] is applied to solve the reactive power problem of global optimal value. The premature convergence issue of the Artificial Bee Colony algorithm has been improved by increasing the number of scout and rational using of the global optimal value and Chaotic Search. The proposed Chaotic Search Based Artificial Bee Colony Optimization (CSABC) algorithm has been tested in stand IEEE 30, 118- bus & practical 191 Indian utility test systems. The results show that the proposed algorithm performs well in reducing the real power loss and prevent premature convergence to high degree with rapid convergence.

2. Problem Formulation

The OPF problem is considered as a common minimization problem with constraints, and can be written in the following form:

Minimize f(x, u) (1)

Subject to g(x,u)=0 (2)

And

$$h(x, u) \leq 0 \quad (3)$$

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:

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

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

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

Or

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

Where Ng, Nt and Nc are the number of generators, number of tap transformers and the number of shunt compensators respectively.

3. Objective Function

3.1. Active Power Loss

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

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

Or

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

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.

3.2. Voltage Profile Improvement

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

$$F = PL + \omega_v \times VD \tag{9}$$

Where ω_v: is a weighting factor of voltage deviation.

VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \tag{10}$$

3.3. Equality Constraint

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

$$P_G = P_D + P_L \tag{11}$$

3.4. Inequality Constraints

The inequality constraints h(x,u) imitate 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:

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \tag{12}$$

 ISSN- 2350-0530(O), ISSN- 2394-3629(P)
(Received: Dec 25, 2017 - Accepted: Jan 21, 2018) DOI: 10.5281/zenodo.1167630

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} \;, i \in N_g \tag{13}$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \leq V_i \leq V_i^{max} \;, i \in N \tag{14}$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \leq T_i \leq T_i^{max} \;, i \in N_T \tag{15}$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \leq Q_c \leq Q_C^{max} \;, i \in N_C \tag{16}$$

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.

4. Artificial Bee Colony (Abc) Algorithm

The Artificial Bee Colony (ABC) algorithm contains three groups: employed bee, onlooker bee and scout. The bee going to the food source which is visited by itself previously is employed bee. The bee waiting on the dance area for making decision to choose a food source is onlooker bee. The bee carrying out random search is scout bee. The onlooker bee with scout also called unemployed bee . In the ABC algorithm, the collective intelligence searching model of artificial bee colony consists of three essential components: employed, unemployed foraging bees, and food sources. The employed and unemployed bees search for the rich food sources, which close to the bee's hive. The employed bees store the food source information and share the information with onlooker bees. The number of employed bees is equal to the number of food sources and also equal to the amount of onlooker bees. Employed bees whose solutions cannot be improved through a predetermined number of trials, specified by the user of the ABC algorithm and called “limit”, become scouts and their solutions are abandoned . The model also defines two leading modes of behaviour which are necessary for self-organizing and collective intelligence: recruitment of foragers to rich food sources resulting in positive feedback and abandonment of poorsources by scout causing negative feedback.

4.1. The Procedure of ABC

The classical ABC includes four main phases.
Initialization Phase: The food sources, whose population size is SN, are randomly generated by scout bees. The number of Artificial Bee is NP. Each food source x_m is a vector to the optimization problem, x_m has D variables and D is the dimension of searching space of the objective function to be optimized. The initiation food sources are randomly produced via the expression (17).

$$x_m = l_i + \text{rand}\,(0.1) * (u_i - l_i) \tag{17}$$

 ISSN- 2350-0530(O), ISSN- 2394-3629(P)
DOI: 10.5281/zenodo.1167630

where u_i and l_i are the upper and lower bound of the solution space of objective function, rand(0,1) is a random number within the range [0,1].

Employed Bee Phase: A employed bee flies to a food source and finds a new food source within the neighborhood of the food source. The higher quantity food source will be selected. The food source information stored by employed bee will be shared with onlooker bees. A neighbor food source vmi is determined and calculated by the following equation (18).

$$v_{mi} = x_{mi} + \Phi_{mi}(x_{mi} - x_{ki}) \tag{18}$$

where x_k is a randomly selected food source, i is a randomly chosen parameter index, $\Phi_{mi}$is a random number within the range [-1,1]. The range of this parameter can make an appropriate adjustment on specific issues. The fitness of food source is essential in order to find the global optimal. The fitness is calculated by thefollowing formula (19). After that a greedy selection is applied between x_m and v_m.

$$\mathrm{fit}_m(x_m) = \begin{Bmatrix} \frac{1}{1+f_m(x_m)}, f_m(x_m) > 0 \\ 1 + |f_m(x_m)|, f_m(x_m) < 0 \end{Bmatrix} \tag{19}$$

where $f_m(x_m)$ is the objective function value of x_m.

Onlooker Bee Phase: Onlooker bees observe the waggle dance in the dance area and calculate the profitability of food sources, then randomly select a higher food source. After that onlooker bees carry out randomly search in the neighborhood of food source. The quantity of a food source is evaluated by its profitability and the profitability of all food sources. Pm is determined by the formula

$$P_m = \frac{\mathrm{fit}_m(x_m)}{\sum_{m=1}^{SN} \mathrm{fit}_m(x_m)} \tag{20}$$

where $\mathrm{fit}_m(x_m)$ is the fitness of x_m.

Onlooker bees search the neighborhood of food source according to the expression (21)

$$v_{mi} = x_{mi} + \Phi_{mi}(x_{mi} - x_{ki}) \tag{21}$$

Scout Phase: If the profitability of food source cannot be improved and the times of unchanged greater than the predetermined number of trials, which called "limit" and specified by the user of the ABC algorithm, the solutions will be abandoned by scout bees. Then, the scouts start to randomly search the new solutions. If solution xi has been abandoned, the new solution x_m will be discovered by the scout. The x_m is defined by expression (22)

$$x_m = l_i + rand\ (0.1) * (u_i - l_i) \tag{22}$$

Wherex_m is the new generated food source, rand (0, 1) is a random number within the range [0,1], u_i and l_i are the upper and lower bound of the solution space of objective function.

ISSN- 2350-0530(O), ISSN- 2394-3629(P)
DOI: 10.5281/zenodo.1167630

4.2. The Main Concepts of ABC Algorithm

Food sources: According to different problems, the initial food sources are randomly generated in the search space.

Local optimization strategy: In the employed bee phase, employed bees look for the local optimization value in the neighborhood of food source. Generally, different local search strategies will are used for different problems.

Random selection strategy in accordance with probability: In the onlooker bee phase, the random selection strategy will be used to looking for local optimization value in the neighborhood of food source and the higher probability solution will be chosen by onlooker bees.

Feedback strategy: In scout bee phase, food sources which are initially poor or have been made poor by exploitation will be abandoned, this means that if a solution cannot be improved and the unchanged times greater than the predetermined “limit” parameter, the new solution will be discovered by the scout using the negative feedback strategy.

Global optimization strategy: After local optimization and random selection carried out, the global optimization strategy will be used to obtain global optimal value.

4.3. Chaotic Search Based Artificial Bee Colony (CSABC) Algorithm

In the basic Artificial Bee Colony algorithm, the best solution founded by onlooker bee which adopted the local search strategy is unable to reach the ideal level of accuracy . In order to improve the accuracy of optimal solution and obtain the fine convergence ability, we use the chaotic search method to solve this problem. In the Chaotic Search based ABC algorithm, onlooker bees apply chaotic sequence to enhance the local searching behavior and avoid being trapped into local optimum. In onlooker bee phase, chaotic sequence is mapped into the food source. Onlooker bees make a decision between the old food source and the new food source according to a greedy selection strategy. In this paper, the well-known logistic map which exhibits the sensitive dependence on initial conditions is employed to generate the chaotic sequence . The chaos system used in this paper is defined by

$$x_{i+1} = \mu * x_i * (1 - x_i) \tag{23}$$

$$x = x_{mi} + R * (2 * x_i - 1) \tag{24}$$

Where*x* is the new food source and xi is the chaotic variable, *R* is the radius of new food source being generated. The food source $x_{mi}$is in the central of searching region. After the food source has been generated, onlooker bee will exploit the new food source and select the higher profitable one using a greedy selection.

Chaotic search method includes the following steps:
Step1. Setting the iterations (cycle parameter) of chaotic search and produce a vectorx_0 =$[x_{0,1}x_{0,2}x_{0,3}]$, which is the initial value of chaotic search;
Step2. The chaotic sequence is generated according to expression (23) and a new food source, which combining the chaotic sequence with the original food source, is obtained following the equation (24).
Step3. Calculating the profitability of the new food source and using the greedy selection select the higher profitability food source;
Step4. If the number of chaotic search iterations greater than maximum, the artificial bee algorithm will enter the scout bee phase, or else enter the next chaotic search iteration.

4.4. Global Search Strategy

In the basic Artificial Bee Colony algorithm only one scout, but we added another one into the modified Artificial Bee Colony algorithm in order to improve the global convergence ability. When a scout bee find the food source unchanged times greater than the limit parameter, it will produce a new food source and replace the original one .Scout bee discover the new food source using the best optimal value strategy which accelerate the global convergence rate. Assume that the solution x_i has been abandoned and the scout bee will generate the new solution x_m using the following equation

$$x_m = x_{best} \tag{25}$$

$$x_m(i) = x_{best}(i) + \Phi_{mi} * (x_{best}(i) - x_{neighbor}(i)) \tag{26}$$

Where $x_m$is new food source produced by scout bee using the global optimal value x_{best} and $\Phi_{mi}$is a random number within the range [-1, 1].

The Procedure of Chaotic Search based Artificial Bee Colony (CSABC) algorithm
The procedure of CABC is as following:
Initial Phase
According to equation (17) discovering the initial food sources Iter time = 1;
While (Iter time<= Max Cycle)
Employed Bee Phase
Step1. According to expression (18) searching the neighborhood food source;
Step2. Calculate the function value;
Step3. According to formula (19) evaluate fitness of the food sources.
Onlooker Bee Phase
Step1. According to expression (20) calculate the profitability;
Step2. Onlooker bee in the guide of equation (21) exploiting the local optimal solution;
Step3. Calculating the function value of new food source;
Step4. Evaluate the new food source fitness according to equation (20).
Scout Bee Phase
if (trial>limit)
Step1. The first scout randomly discovering the new food source;

[Lenin et. al., Vol.6 (Iss.1): January, 2018] ISSN- 2350-0530(O), ISSN- 2394-3629(P)
(Received: Dec 25, 2017 - Accepted: Jan 21, 2018) DOI: 10.5281/zenodo.1167630

Step2 The second scout bee updating the food source, which hit the limit parameter, according to formula (25) and (26).
Search the global optimal value
Global Min
End while

5. Simulation Results

Validity of proposed Chaotic Search Based Artificial Bee Colony Optimization Algorithm (CSABC) has been verified by testing in IEEE 30-bus, 41 branch system and it has 6 generator-bus voltage magnitudes, 4 transformer-tap settings, and 2 bus shunt reactive compensators. Bus 1 is taken as slack bus and 2, 5, 8, 11 and 13 are considered as PV generator buses and others are PQ load buses. Control variables limits are given in Table 1.

Table 1: Primary Variable Limits (Pu)

Variables	**Min.**	**Max.**	**category**
Generator Bus	0.95	1.1	Continuous
Load Bus	0.95	1.05	Continuous
Transformer-Tap	0.9	1.1	Discrete
Shunt Reactive Compensator	-0.11	0.31	Discrete

In Table 2 the power limits of generators buses are listed.

Table 2: Generators Power Limits

Bus	**Pg**	**Pgmin**	**Pgmax**	**Qgmin**	**Qmax**
1	96.00	49	200	0	10
2	79.00	18	79	-40	50
5	49.00	14	49	-40	40
8	21.00	11	31	-10	40
11	21.00	11	28	-6	24
13	21.00	11	39	-6	24

Table 3 shows the proposed CSABC approach successfully kept the control variables within limits.Table 4 narrates about the performance of the proposed CSABC algorithm and Table 5 list out the overall comparison of the results of optimal solution obtained by various methods.

Table 3: After optimization values of control variables

Control Variables	**CSABC**
V1	1.0462
V2	1.0414
V5	1.0226
V8	1.0328
V11	1.0716
V13	1.0501
T4,12	0.00

T6,9	0.00
T6,10	0.90
T28,27	0.90
Q10	0.10
Q24	0.10
Real power loss	4.1284
Voltage deviation	0.9090

Table 4: Performance of CSABC algorithm

Iterations	27
Time taken (secs)	7.62
Real power loss	4.1284

Table 5: Comparison of results

Techniques	**Real power loss (MW)**
SGA(Wu et al., 1998) [16]	4.98
PSO(Zhao et al., 2005) [17]	4.9262
LP(Mahadevan et al., 2010) [18]	5.988
EP(Mahadevan et al., 2010) [18]	4.963
CGA(Mahadevan et al., 2010) [18]	4.980
AGA(Mahadevan et al., 2010) [18]	4.926
CLPSO(Mahadevan et al., 2010) [18]	4.7208
HSA (Khazali et al., 2011) [19]	4.7624
BB-BC (Sakthivel et al., 2013) [20]	4.690
MCS(Tejaswini sharma et al.,2016) [21]	4.87231
Proposed CSABC	4.1284

Secondly, Chaotic Search Based Artificial Bee Colony Optimization Algorithm (CSABC), has been tested in standard IEEE 118-bus test system [22].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 6, with the change in step of 0.01.

Table 6: 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 7 and the results clearly show the better performance of proposed Chaotic Search Based Artificial Bee Colony Optimization Algorithm (CSABC), approach.

 ISSN- 2350-0530(O), ISSN- 2394-3629(P)
DOI: 10.5281/zenodo.1167630

Table 7: Comparison results

Active power loss (p.u)	**BBO [23]**	**ILSBBO/ strategy1 [23]**	**ILSBBO/ strategy1 [23]**	**Proposed CSABC**
Min	128.77	126.98	124.78	112.24
Max	132.64	137.34	132.39	119.02
Average	130.21	130.37	129.22	114.68

Then the Chaotic Search Based Artificial Bee Colony Optimization Algorithm (CSABC) has been tested in practical 191 test system and the following results have been obtained. In Practical 191 test bus system – Number of Generators = 20, Number of lines = 200, Number of buses = 191 Number of transmission lines = 55. Table 8 shows the optimal control values of practical 191 test system obtained by CSABC method. And Table 9 shows the results about the value of the real power loss by obtained by Chaotic Search Based Artificial Bee Colony Optimization Algorithm (CSABC).

Table 8: Optimal Control values of Practical 191 utility (Indian) system by CSABC method

VG1	1.100		VG 11	0.900
VG 2	0.760		VG 12	1.000
VG 3	1.010		VG 13	1.000
VG 4	1.010		VG 14	0.900
VG 5	1.100		VG 15	1.000
VG 6	1.100		VG 16	1.000
VG 7	1.100		VG 17	0.900
VG 8	1.010		VG 18	1.000
VG 9	1.100		VG 19	1.100
VG 10	1.010		VG 20	1.100

T1	1.000		T21	0.900		T41	0.900
T2	1.000		T22	0.900		T42	0.900
T3	1.000		T23	0.900		T43	0.910
T4	1.100		T24	0.900		T44	0.910
T5	1.000		T25	0.900		T45	0.910
T6	1.000		T26	1.000		T46	0.900
T7	1.000		T27	0.900		T47	0.910
T8	1.010		T28	0.900		T48	1.000
T9	1.000		T29	1.010		T49	0.900
T10	1.000		T30	0.900		T50	0.900
T11	0.900		T31	0.900		T51	0.900
T12	1.000		T32	0.900		T52	0.900
T13	1.010		T33	1.010		T53	1.000
T14	1.010		T34	0.900		T54	0.900
T15	1.010		T35	0.900		T55	0.900
T19	1.020		T39	0.900			
T20	1.010		T40	0.900			

 ISSN- 2350-0530(O), ISSN- 2394-3629(P)
DOI: 10.5281/zenodo.1167630

Table 9: Optimum real power loss values obtained for practical 191 utility (Indian) system by CSABC method

Real power Loss (MW)	CSABC
Min	139.014
Max	146.006
Average	142.028

6. Conclusion

In this paper proposed Chaotic Search Based Artificial Bee Colony Optimization Algorithm (CSABC) successfully solved optimal reactive power optimization problem. The premature convergence issue of the Artificial Bee Colony algorithm has been improved by increasing the number of scout and rational using of the global optimal value and Chaotic Search. The proposed Chaotic Search Based Artificial Bee Colony Optimization (CSABC) algorithm has been tested in stand IEEE 30, 118- bus & practical 191 Indian utility test systems. The results show that the proposed algorithm performs well in reducing the real power loss and prevent premature convergence to high degree with rapid convergence.

References

[1] H.W.Dommel, W.F.Tinney. Optimal power flow solutions. IEEE, Trans. On power Apparatus and Systems, VOL. PAS-87, October 1968, pp.1866-1876.
[2] Lee K, Park Y, Ortiz J. A. United approach to optimal real and reactive power dispatch. IEEE Trans Power Appar. Syst. 1985; 104(5):1147-53.
[3] Y. Y.Hong, D.I. Sun, S. Y. Lin and C. J.Lin. Multi-year multi-case optimal AVR planning. IEEE Trans. Power Syst., vol.5, no.4, pp.1294-1301, Nov.1990.
[4] J. A. Momoh, S. X. GUO, E .C. Ogbuobiri, and R. Adapa. The quadratic interior point method solving power system optimization problems. IEEE Trans. Power Syst. vol. 9, no. 3, pp. 1327-1336, Aug.1994.
[5] S. Granville. Optimal Reactive Dispatch through Interior Point Methods. IEEE Trans. Power Syst. vol. 9, no. 1, pp. 136-146, Feb. 1994.
[6] J.A.Momoh, J.Z.Zhu. Improved interior point method for OPF problems. IEEE Trans. On power systems; Vol. 14, No. 3, pp. 1114-1120, August 1999.
[7] Y.C.Wu, A. S. Debs, and R.E. Marsten. A Direct nonlinear predictor-corrector primal-dual interior point algorithm for optimal power flows. IEEE Transactions on power systems Vol. 9, no. 2, pp 876-883, may 1994.
[8] L.L.Lai, J.T.Ma, R. Yokoma, M. Zhao. Improved genetic algorithms for optimal power flow under both normal and contingent operation states. Electrical Power & Energy System, Vol. 19, No. 5, p. 287-292, 1997.
[9] Q.H. Wu, Y.J.Cao, and J.Y. Wen. Optimal reactive power dispatch using an adaptive genetic algorithm. Int. J. Elect. Power Energy Syst. Vol 20. Pp. 563-569; Aug 1998.
[10] B. Zhao, C. X. Guo, and Y.J. CAO. Multiagent-based particle swarm optimization approach for optimal reactive power dispatch. IEEE Trans. Power Syst. Vol. 20, no. 2, pp. 1070-1078, May 2005.
[11] J. G. Vlachogiannis, K.Y. Lee. A Comparative study on particle swarm optimization for optimal steady-state performance of power systems. IEEE trans. on Power Syst., vol. 21, no. 4, pp. 1718-1728, Nov. 2006.
[12] AnanBanharnsakun,Tiranee Achalakul,Booncharoen Sirinaovakul,The best-so-far selection in the Bee Clony algorithm, Applied Computing, 11,2888-2901, 2011.

[13] Fei Kang, Junjie Li, Zhenyue Ma , Rosenbrock artificial bee colony algorithm for accurate global optimization of numerical functions, Information Sciences: S0020-0255(11)00198-8,DOI: 10.1016/j.ins.2011.04.024,2011.
[14] Mustafa Sonmez, Artificial Bee Colony algorithm for optimization of truss structures,Applied Soft Computing11(2011)2406-2018,2011.
[15] Zhou Xi-xiang,Li Jia-sheng,Yang Sai-liang,The Digital PID Parameter Tuning Based on Chaos Particle Swarm Optimization, Power Electronics,44(10):62-64, 2010.
[16] Wu.Q.H,Y.J.Cao, and J.Y.Wen,(1998),"Optimal reactive power dispatch using an adaptive genetic algorithm", Int.J.Elect.Power Energy Syst. Vol 20. Pp. 563-569.
[17] Zhao.B,C.X.Guo,andY.J.CAO,(2005),"Multiagent-based particle swarm optimization approach for optimal reactive power dispatch",IEEE Trans. Power Syst. Vol. 20, no. 2, pp. 1070-1078.
[18] Mahadevan.K, KannanP.S, (2010) "Comprehensive Learning Particle Swarm Optimization for Reactive Power Dispatch", Applied Soft Computing, Vol. 10, No. 2, pp. 641–52.
[19] Khazali.A.H, M.Kalantar, (2011), "Optimal Reactive Power Dispatch based on Harmony Search Algorithm", Electrical Power and Energy Systems, Vol. 33, No. 3, pp. 684–692.
[20] Sakthivel.S, M.Gayathri, V.Manimozhi, (2013), "A Nature Inspired Optimization Algorithm for Reactive Power Control in a Power System", International Journal of Recent Technology and Engineering, pp29-33Vol.2, Issue-1.
[21] Tejaswini Sharma, Laxmi Srivastava, Shishir Dixit (2016). "Modified Cuckoo Search Algorithm For Optimal Reactive Power Dispatch", Proceedings of 38 th IRF International Conference,pp4-8. 20th March, 2016, India, ISBN: 978-93-85973-76-5.
[22] IEEE, "The IEEE 30-bus test system and the IEEE 118-test system", (1993), http://www.ee.washington.edu/trsearch/pstca/.
[23] Jiangtao Cao, Fuli Wang and Ping Li, "An Improved Biogeography-based Optimization Algorithm for Optimal Reactive Power Flow", International Journal of Control and Automation Vol.7, No.3 (2014), pp.161-176.

*Corresponding author.
E-mail address: gklenin@ gmail.com