Journal of Engineering Technology
Volume 5(1), January 2016, PP. 90-107

RESEARCH ARTICLE -ENGINEERNG TECHNOLOGY

The Optimization of Load Distribution Considering all Constraints with the Use of Enhanced Artificial Bee Colony Algorithm

Hamdi Abdi[1], Arash Sadeghzadeh[1] and Ghobad Radgah[2]

1-Department of Electrical Engineering, Razi University, Kermanshah, Iran
2-MSc of Electrical Engineering, Razi University, Kermanshah, Iran

Abstract

One of the most important subjects in utilization of power systems, is the economic distribution of loads. The main goal is to minimize the function of fuel cost in power plants. In general, different optimization methods have been suggested such as traditional and innovative mathematical methods. The present paper deals with the economic distribution of products with the aim of minimizing the cost of utilization and also minimizing environmental pollutions through considering non-linear limitations of power plants with the use of EABS. This algorithm has a high efficiency for the solution of non-liner problems and finding an optimized solution. At the end in order to show the efficiency of this method the reports of testing this method on networks with 3, 6, and 11 generators in different loading levels are presented and the results are compared to other optimization methods. This comparison shows that the suggested method has a high accuracy and speed for the solution of complex problems of power systems.

Keywords: enhanced artificial bee colony algorithm (EABC), economic distribution of load, environmental pollution.

1. Introduction

The aim of economic load distribution is to reach the minimum power production cost in a way that the network can provide the power demands, while the practical limitations of the power plant remain in an acceptable level (1). The economic distribution of load is a complex non-linear problem that is solvable through the use of optimization techniques. The problems of ELD in its simplest form is shown as a second grade function that is easily solvable through the use of mathematical planning (2). The nature of the cost functions of modern production units is non-linear and discrete based on the practical conditions of the power plant such as the increasing rate, the forbidden regions and the effect of pet cock that have a non-derivative nature (3). Classic algorithms such as the Lambda iteration method, gradient based methods, participation coefficients cannot be used, because they are based on derivative (4-1). With the progress of computer sciences for the solution of complex problems, the random and gravitational optimization techniques are used. There are many methods for the solution of the economic distribution of load. In the references (5,6) the fire worm algorithm FA has been used. Ant Colony Algorithm (ACO), Artificial Bee Colony algorithm (ABC) has been used. Some researchers (9-14) have used the particle crowd PSO algorithm. The algorithm used in some references (15-16) is GA, and in (17) the evolution algorithm has been used for the economic distribution of loads.

In the present study through the use of ABC algorithm the problem of economic distribution of load is solved considering the environmental effects. In this study the operational limitations of the power plant are included such as the decrease and increase rate of the plant production, forbidden places, the effect of pet cock, and the network loss. For the practicality purposes of the proposed algorithm some sample systems are used with different sizes. The results of the numerical studies shows a good performance of this method in comparison with other methods.

2. The mathematical model for the problem of the economic distribution of the load

2.1. Objective function

One of the goals for the economic distribution of load is to minimize the utilization costs of the power units and the limitations imposed on this problem, the cost function of each production unit can be expressed as a second grade function based on the output power in an equation (1):

$$F_C = \sum_{i=1}^{ng} F_i(P_i) = \sum_{i=1}^{ng} a_i P_i^2 + b_i P_i + c_i \qquad (1)$$

In which F_c is the total cost of utilization of the power production units, ng is the number of power units in the grid, F_i (P_i) is the production cost related to the i unit and a_i, b_i and c_i are the cost function coefficients for each unit.

2.2. Considering pet cock

Including the effect of pet cock in the power units that are shown in figure 1 makes the cost function change into a non-convex function and this because of the mechanical effects is related to the position of the cock, in this condition a sinusoidal sentence is added to the cost function in the following manner:

$$F_C = \sum_{i=1}^{ng} a_i P_i^2 + b_i P_i + c_i + \left| e_i \sin(fi \times (pi^{\min} - pi)) \right| \qquad (2)$$

In the above equation e_i and f_i are the number i generator coefficient to show the loading effect of the pit , $p_i^{\min}$ is the lower limit of the number i production unit (3).

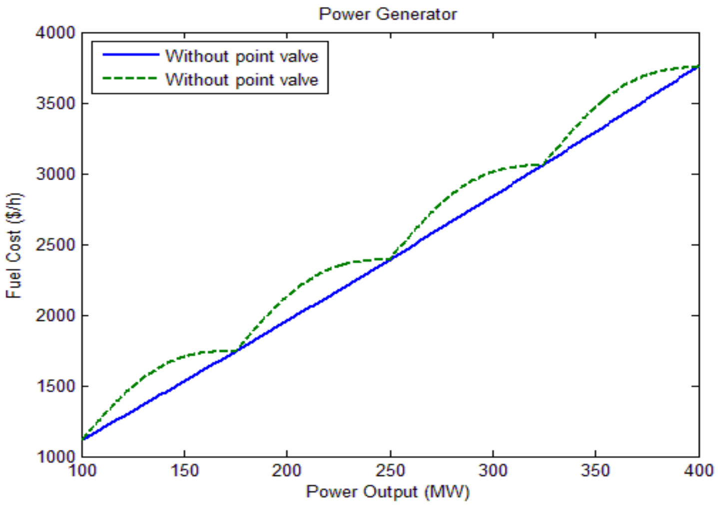

Figure1. the input-output curve considering the effect of the cock

2.3. The pollution of the thermal power plant

The output active power is the most important factor affecting the distribution of polluting gasses. The relation between the produced pollution by the power plant and the active output power is a non-linear relation and is expressed in the form of a second grade function in equation 3:

$$E_T = \sum_{i=1}^{ng} E_i(P_i) = \sum_{i=1}^{ng} \alpha_i P_i^2 + \beta_i P_i + \gamma_i \qquad (3)$$

In which E_i is the pollution rate of unit i in terms of kilogram to hour (kg/h), P_i the active output power of unit i and α, β, and γ are the coefficients of the pollution function of the power plant. In this case the objective function is in this form:

$$F_T = \omega_1 \sum_{i=1}^{ng} F_i(P_i) + \omega_2 \sum_{i=1}^{ng} h_i(E_i(P_i)) \qquad (4)$$

In which ω_1 and ω_2 are the weight coefficients for the reduction of fuel cost and have the value of 1, h_i is the penalty coefficient of the pollution for unit i and is calculated through equation 5, and its unit is $/kg (20).

$$h_i = \frac{a_i P_i^{\min^2} + b_i P_i^{\min} + c_i}{\alpha_i P_i^{\max^2} + \beta_i P_i^{\max} + \gamma_i} \qquad (5)$$

3. Limitations

a) The balance between production and consumption (utilization) in the system

The sum of the production power of the power plants should be equal to the sum of the system loads and the losses of the transferring network' power and is defined in this manner:

$$\sum_{i=1}^{ng} P_i = P_{Load} + P_{Loss} \quad (6)$$

In this equation P_{load} and P_{loss} show the rate of the load and the loss of the system respectively. The value of P_{loss} in the above equation depends on the structure of the network and the produced power in the system and is calculated through the loss matrix (1).

$$P_{Loss} = \sum_{i=1}^{ng} \sum_{j=1}^{ng} P_i . B_{ij} . P_j + \sum_{i}^{ng} B_{0i} . P_i + B_{00} \quad (7)$$

In which B_{ij}, B_{0i} and B_{00} are the coefficients of the loss function of the transfer network.

b) The production limit

The production power of each power plant should not exceed its upper and lower limits. This limitation is expressed in this form:

$$P_i^{\min} \le P_i \le P_i^{\max} \ , \ i = 1,\ldots,ng \quad (8)$$

In equation 8 P_i^{min} and P_i^{max} are the lower and upper limits for unit i respectively.

c) The limitation of the production change rate

In practice for the reason of the mechanical and thermo-dynamic limitations of boiler and turbine, each generator can have a specific amount of increase or decrease in its production in a specific period of time. In fact, this condition results in that the lower and upper limits of the power plant's production in each time period be dependent on its primary production, so equation 8 is changed in this manner:

$$\max\{P_i^{\min}, P_i^0 - DR_i\} \le P_i \le \min\{P_i^{\max}, P_i^0 + UR_i\} \quad (9)$$

In which P_i^0, DR_i and UR_i are the primary output power, the reduction rate and the increase rate of the power plant i's production respectively.

d) The forbidden areas of the generator

In some cases because of physical limitations, power plants cannot produce power between their minimum and maximum powers. These areas are known as the forbidden areas of generator and for the power plant i they are known as:

$$P_i = \in \begin{cases} P_i^{\min} \le P \le P_{i,1_i}^{l} \\ P_{i,k-1}^{u} \le P_i \le P_{i,k}^{l} \\ P_{i,z_i-1}^{u} \le P_i \le P_i^{\max} \end{cases} \quad (10)$$

In the above equation $P_{i,k}^{u}$ and $P_{i,k}^{l}$ are the lower and upper limits of region k of the forbidden region and z_i is the number of forbidden areas for unit i (21). Figure 2 shows the effect of the two forbidden areas for a production unit.

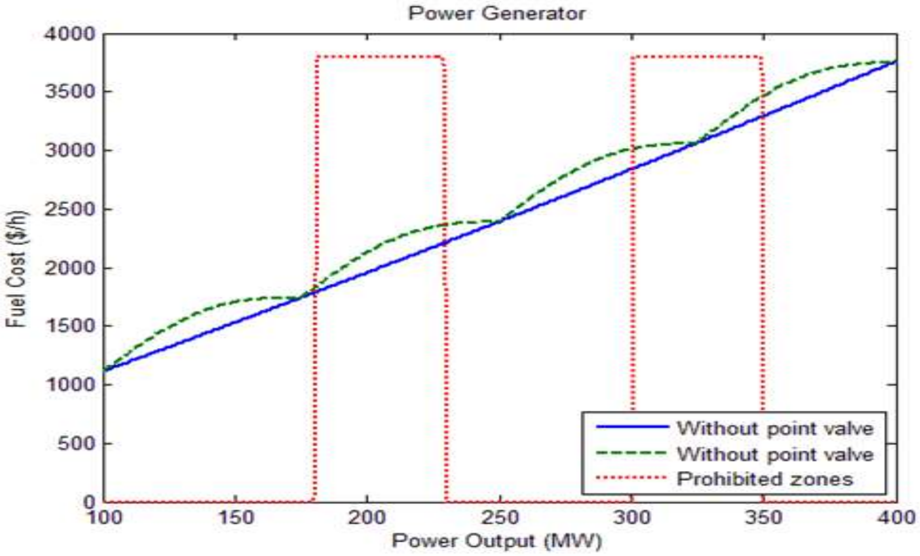

Figure2. the effect of the forbidden area on the cost function

4. Enhanced Artificial Bee Colony Algorithm

4.1. Bee Colony Algorithm

The BC loading model is an enhanced algorithm based on the collective intelligence and the intelligent behavior of a bee colony. This algorithm imitates the group food search of a bee colony. In its basic model, this algorithm shows a neighborhood search combined with random search and can be used for both combinational optimization or functional optimization. EABC algorithm was first introduced by Dervis Karaboga in 2005 for the real optimization of parameters. This algorithm simulates the discovering behavior of bee colonies for the optimization problems without any limitations. In a real bee colony there are duties that some specific bees do. These bees try to optimize the saved nectar in the hive through division of labor and self organization. In the ABC algorithm there are three types of bees: worker bees, onlooker bees and scout bees. The scout bees first search for the food- rich areas and through some specific dances provide their information to the monitoring bees. This type of dance is repeatedly done by the bees that shows the quality and the distance to the food source. So, the monitoring bees through looking at the turning rate, choose the better quality resources. In the ABC first a set of food sources are randomly chosen, then the worker bees go to the sources and check the nectar quality and amount and return to the hive and provide their information to the other bees. Then each bee goes to the area and based on the information chooses a source near the main source, i.e, bees decide to stay there or move on based on the type of flower and its nectar amount. When the quality of the resource is reduced, they move to a new source and this is repeated until reaching the optimum goal. The steps of the implementation of this algorithm that is based on the searching behavior of bees is shown in the following flowchart which is explained later.

ABC similar code:

```
1. Initialization Phase
2. REPEAT
3. Employed Bees Phase
4. Onlooker Bees Phase
5. Scout Bees Phase
6. Memorize the best solution
7. UNTIL(Cycle=Maximum Cycle Number)
```

A) Providing the primary population

The primary food sources are expressed randomly in the range of the defined parameters by equation 11:

$$X_{ij} = X_j^{\min} + rand(0,1)(X_j^{\max} - X_j^{\min}) \quad (11)$$

Where i=1, ..., nPop and j=1,...,nVar. Here nPop and nVar are respectively the primary population and the number of production units. The value attribution of the primary population is done by the scout bees whose duty is thorough exploration or global search.

B) Sending the worker bees for a random regional search

As it was mentioned the number of worker bees is nPop. The status of primary answers is attributed to the sites in a clear way by the worker bees and are evaluated. The movement and search of worker bees is done by equation 12:

$$V_{ij} = X_{ij} + \Phi_{ij}(X_{kj} - X_{ij}) \quad (12)$$

In whichV_{ij} is the new location of component j of the site i and X_{ij} was the origin and X_{kj} is the destination and Φ_{ij} is a random number with a uniform distribution that is based on equation 13:

$$\Phi_{ij} \approx u(-a, +a)$$

Now if V_i is better than X_i then it replaces X_i but if it is not better, then X_i is not changed but the site is charged, and the charge of the site is increased as much as one unit.

C) Sending onlooker bee for regional search based on the probability function and the Roulette Wheel.

In this part we have two equations 14 and 15. In equation 14 we have two equations for the calculation of the fitting function based on the positive or negative cost function that is continuous at zero, i.e. for the zero point both equations give the same value.

$$F(X_i) = \begin{cases} \dfrac{1}{1+f(x_i)} & \forall \ f(x_i) \geq 0 \\ 1+|f(x_i)| & \forall \ f(x_i) < 0 \end{cases} \quad (14)$$

In equation 14 for $f(x_i) \geq 0$ we use $\frac{1}{1+f(x_i)}$ and for $f(x_i) < 0$ we use $1 + |f(x_i)|$for the value of fitness.

Now we use equation 15 for the probability of choosing site i:

$$P_i = \frac{F(X_i)}{\sum_{k=1}^{n} F(x_k)} \quad (15)$$

After calculating the probabilities from equation 15 and choosing the site through the Roulette Wheel method, the new answer is produced and if it has a better cost function, it will replace the previous one. But if it is not better Xi is not changed but the site will be charged and the charge calculator is one unit increase.

D) Sending scout bees for random global search

If in a site the number of times a cost function is not optimized exceeds a certain value, that site will be deleted and the scout bees discover and replace a new site in a random way.

E) Improvement and modification of the weak points of ABC algorithm by the EABC algorithm.

We can summarize the ABC algorithm into three parts:

a. The process of regional choice by worker bees
b. The process of regional choice by monitoring bees
c. The process of global choice by scout bees.

In the ABC algorithm with the increase of the dimensions of the search space, the system's performance will become inappropriate and through the EABC and with adding the gravitational search to the random searching the accuracy of the responses will increase and the convergence speed is increased. This is done by making some changes and adding the gravitational search to the parts related to the worker bees, monitoring bees and also scout bees.

The improvement of algorithm can happen in each of the three phases of worker bees, monitoring bees or even scout bees, in this paper the improvement has happened in all three phases:

a. Enhancement in the phase of worker bees (EABC1)
b. Enhancement in the phase of monitoring bees (EABC2)
c. Enhancement in the phase of scout bees (EABC3)

In this algorithm in each phase first the whole population is put into order based on the cost function and instead of X_{ij} in the equation 12 the mean of three best answers are used based on equation 16, only if this condition exists: $r_1 \neq r_2 \neq r_3 \neq i \in [1 \cdots nPop]$

$$V_{ij} = (X_{r1j} + X_{r2j} + X_{r3j})/3 + \Phi_{ij}(X_{kj} - X_{ij}) \quad (16)$$

We can summarize different phases of the EABC algorithm in the following way:

EABC algorithm code:

```
1. Initialization Phase
2. REPEAT
3. Select First Three Best Solution
4. Employed Bees Phase From (16) Eq - EABC1
5. Select First Three Best Solution
6. Onlooker Bees Phase From (16) Eq - EABC2
7. Select First Three Best Solution
8. Scout Bees Phase From (16) Eq - EABC3
9. Memorize the best solution
```

10. UNTIL(Cycle=Maximum Cycle Number)

5. Case study

5.1.Case study 1

A 7-Bus IEEE system with, 3 generators and 850MW consumption load and with the cost function and the lower and upper limits of each production unit and the coefficients of the effect of pet cock is according to table 1.

Table1. the cost function coefficients and lower and upper limits and the coefficients of pet cock

Unit	a ($/MW2)	b ($/MW)	c ($)	Lower limit (MW)	Upper limit (MW)	e	f
1	0.0016	7.92	561	100	600	300	0.032
2	0.0048	7.92	78	50	200	150	0.063
3	0.0019	7.85	310	100	400	200	0.042

The result for the implementation of the algorithm is shown in table 2.

Table 2. the report of three-generator system with the effect of pet cock

Cost ($)	P3(MW)	P2(MW)	P1(MW)
8284	400	50	400

In figure 3 the curve of cost function is shown based on the number of repetitions.

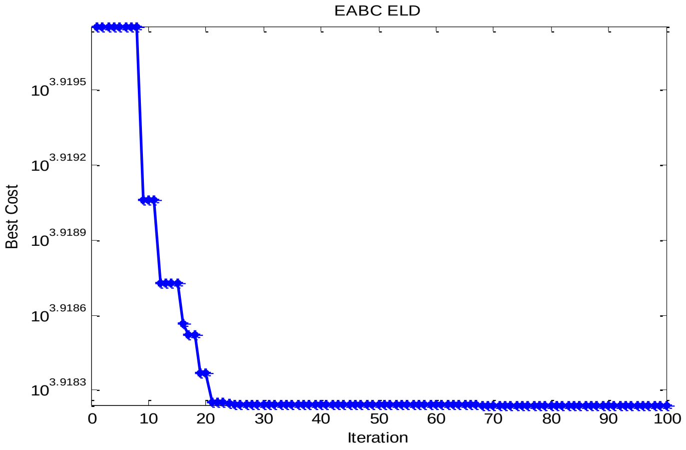

Figure3. the curve of cost function based on the number of repetitions

5.2.Case study 2

A 7- Bus IEEE system with 3 generators and 1000MW load and with the cost function and upper and lower limits for each production unit is shown in table3.

Table 3. the coefficients of cost function and the upper and lower limits of each unit

Unit	a	b ($/MW)	c ($)	Lower	Upper

	($/MW2)			limit (MW)	limit (MW)
1	0.00156	7.29	561	150	600
2	0.00194	7.85	310	100	400
3	0.00482	7.97	78	50	200

In table 4 the pollution coefficients of each unit is shown.

Table4. the coefficients of the pollution function for each unit

Unit	d (Kg/MW2)	e (Kg/MW)	f (Kg)
1	1.4721848e-7	-9.4868099e-6	0.04273254
2	3.0207577e-7	-9.7252878e-5	0.055821713
3	1.9338531e-7	-3.5373734e-4	0.027731524

And the matrix related to the system loss is shown in table 5.

Table5. the matrix of the system loss

B_{ij}	0.00003	0	0
	0	0.00009	0
	0	0	0.00012

And finally table 6 shows the forbidden zones.

Table 6. forbidden zones

Unit	Forbidden zone 1 (MW)	Forbidden zone2 (MW)
1	[164, 170]	[293, 309]
2	[310, 340]	[410, 420]

The results related to the implementation of the algorithm is shown in table 7.

Table7. the report related to the 3 generator system with the effect of pet cock

P Loss (MW)	Cost ($)	P3 (MW)	P2 (MW)	P1 (MW)
24.61	17946	50	400	574.61

In figure 4 the curve of cost function is shown based on the number of repetition

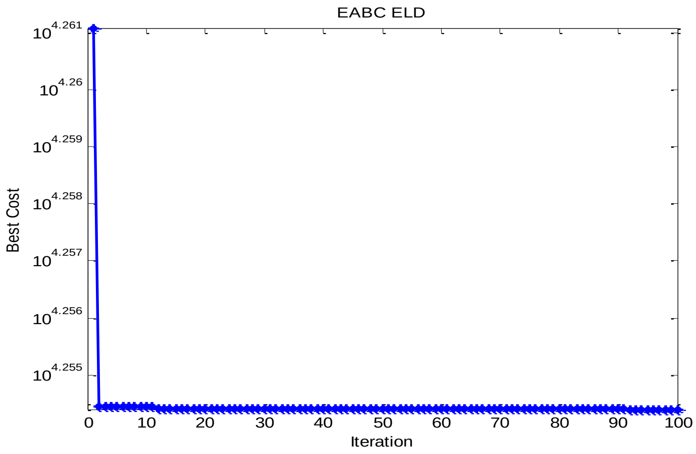

Figure4. the curve of the cost function based on the number of repetition

5.3.Case study 3

A 30-Bus IEEE system with 6 generators and load consumption of 250MW and with cost function and upper and lower limits for each production unit is shown in table 8.

Table8. the coefficients of the cost function and the upper and lower limits of each unit

Unit	a($/MW2)	b ($/MW)	c ($)	Lower limit (MW)	Upper limit (MW)
1	0.00375	2.00	0	50	200
2	0.01750	1.75	0	20	80
3	0.06250	1.00	0	15	50
4	0.00834	3.25	0	10	35
5	0.02500	3.00	0	10	30
6	0.02500	3.00	0	12	40

In table 9 the pollution coefficients of each unit are shown.

Table 9. the coefficients of pollution function for each unit

Unit	d (Kg/MW2)	e (Kg/MW)	f (Kg)
1	0.0126	-1.1000	22.983
2	0.0200	-0.1000	22.313
3	0.0270	-0.1000	25.505
4	0.0291	-0.0050	24.900
5	0.0290	-0.0400	24.700
6	0.0271	-0.0055	25.300

And finally the system's loss matrix is shown in table 10.

Table 10. System's loss matrix

Bij	0.000218	0.000103	0.000009	-0.000010	0.000002	0.000027
	0.000103	0.000181	0.000004	-0.000015	0.000002	0.000030

	0.000009	0.000004	0.000417	-0.000131	-0.000153	-0.000107
	0.000010	-0.000015	-0.000131	0.000221	0.000094	0.000050
	0.000002	0.000002	-0.000153	0.000094	0.000243	-0.000000
	0.000027	0.000030	-0.000107	0.000050	-0.000000	0.000358
Bi0	-0.000003	0.000021	-0.000056	0.000034	0.000015	0.000078
B00	0.000014					

The result for the implementation of the algorithm is shown in table 11.

Table 11. the report of the 6 generator system with the calculation of the pollutions

P1(MW)	121.1
P2(MW)	48.6
P3(MW)	23
P4(MW)	25
P5(MW)	18.6
P6(MW)	19.2
Fuel Cost($)	1280
PLoss(MW)	5.3892

In figure 5 the curve of the cost function is shown based on the number of repetition.

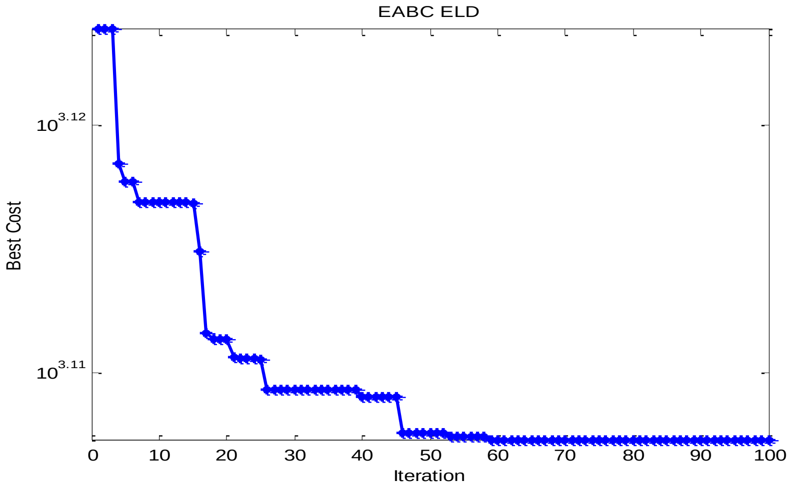

Figure5. the curve of cost function based on the number of repetition

In figure 6 the curve of the system loss is shown based on the number of repetition.

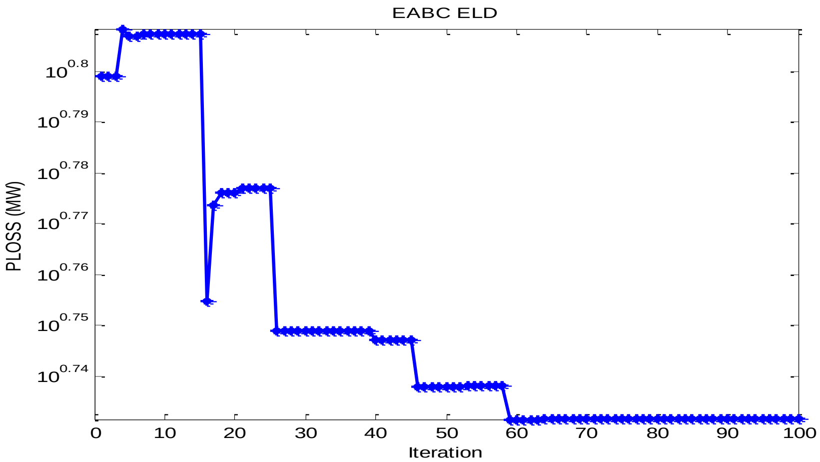

Figure6. the curve of system loss based on the number of repetition

5.4. Case study 4

A 69-Bus IEEE system with 11 generators and a load of 2500MW and with cost function and upper and lower limits for each production unit is shown in table 12.

Table 12. the coefficients of cost function and upper and lower limits for each unit

Unit	a($/MW2)	b ($/MW)	c ($)	Lower limit (MW)	Upper limit (MW)
1	0.00762	1.92699	384.85	20	250
2	0.00838	2.11969	444.62	20	210
3	0.00523	2.19196	422.57	20	250
4	0.00140	2.01983	552.5	60	300
5	0.00154	2.22181	557.75	20	210
6	0.00177	1.91528	562.18	60	300
7	0.00195	2.10681	568.39	20	215
8	0.00106	1.99138	682.93	100	455
9	0.00117	1.99802	741.22	100	455
10	0.00089	2.12352	617.83	110	460
11	0.00098	2.10487	674.61	110	465

Table 13 shows the pollution coefficients for each unit.

Table 13. the coefficients of the pollution function for each unit

f (Kg)	e (Kg/MW)	d (Kg/MW2)	unit
33.93	-0.67767	0.00419	1
24.62	-0.69044	0.00461	2
33.93	-0.67767	0.00419	3
27.14	-0.54551	0.00683	4

24.15	-0.4006	0.00751	5
27.14	-0.54551	0.00683	6
24.15	-0.40006	0.00751	7
30.45	-0.51116	0.00355	8
25.59	-0.56228	0.00417	9
30.45	-0.41116	0.00355	10
25.59	-0.56228	0.00417	11

The result for the implementation of the algorithm is shown in table 14.

Table 14. the cost function coefficients and the upper and lower limits of each unit

P1(MW)	146.56
P2(MW)	99.51
P3(MW)	150.57
P4(MW)	185.67
P5(MW)	96.83
P6(MW)	222.62
P7(MW)	109.44
P8(MW)	338.64
P9(MW)	377.70
P10(MW)	388.43
P11(MW)	384.03
Fuel Cost($)	12448
Emission Cost ($)	2088
Cost($)	14536

Figure 7 shows the curve of the cost function based on the number of repetitions.

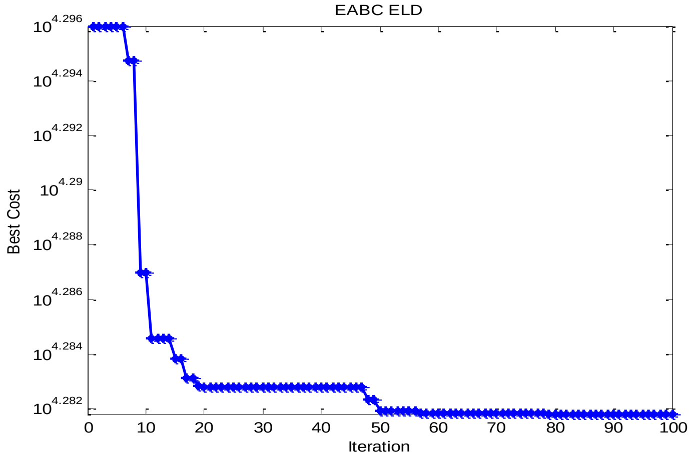

Figure7. the curve of cost function based on the number of repetition

6. Conclusion

In the present paper the problem of the economic distribution of the load was solved through a new, quick and efficient method of EABC algorithm. This method has a higher convergence speed and accuracy for finding a global optimum point. The present study has also paid attention to the minimization of the production cost, environmental pollutions and the losses of the transfer network. Also, all of the qualifications of the production units have been considered for the security of the power plants.

References

[1] Wood, J., and Wollenberg, B. F., "Power Generation, Operation, and Control", 2nd ed, Wiley, 1996.

[2] X. Xia and a. M. Elaiw, “Optimal dynamic economic dispatch of generation: A review,” *Electr. Power Syst. Res*., vol. 80, no. 8, pp. 975–986, Aug. 2010.

[3] K. T. Chaturvedi, M. Pandit, and L. Srivastava, “Self-Organizing Hierarchical Particle Swarm Optimization for Nonconvex Economic Dispatch,” *IEEE Trans. Power Syst.*, vol. 23, no. 3, pp. 1079–1087, Aug. 2008.

[4] J. Park, Y. Jeong, J. Shin, S. Member, and K. Y. Lee, “An Improved Particle Swarm Optimization for Nonconvex Economic Dispatch Problems,” vol. 25, no. 1, pp. 156–166, 2010.

[5] X. Yang, S. Soheil, S. Hosseini, and A. Hossein, “Firefly Algorithm for solving non-convex economic dispatch problems with valve loading effect,” *Appl. Soft Comput. J.*, vol. 12, no. 3, pp. 1180–1186, 2012.

[6] M. H. Sulaiman, M. W. Mustafa, Z. N. Zakaria, O. Aliman, and S. R. A. Rahim, “Firefly Algorithm Technique for Solving EconomicDispatch Problem,” 2012, no. June, pp. 6–7.

[7] T. Sum-im, “Economic dispatch by ant colony search algorithm,” *IEEE Conf. Cybern. Intell. Syst. 2004.*, vol. 1, pp. 416–421, 2004.

[8] S. K. Nayak, K. R. Krishnanand, B. K. Panigrahi, and P. K. Rout, “Application of Artificial Bee Colony to economic load dispatch problem with ramp rate limits and prohibited operating zones,” *2009 World Congr. Nat. Biol. Inspired Comput.*, pp. 1237–1242, 2009.

[9] A. Info, “Solving Economic Dispatch Problem with Valve-Point Effect using a Modified ABC Algorithm,” vol. 3, no. 3, pp. 377–385, 2013.

[10] An Extension of Particle Swarm Optimization (E-PSO) Algorithm for Solving Economic Dispatch Problem , Zetty N. Zakaria, Azralmukmin Azmi, Muhammad , S. Laili, Syed A. Syed Jamalil , Mohd H. Sulaiman, First International Conference on Artificial Intelligence, Modelling & Simulation , (Dec. 2013),pp.157-161 .

[11] Z.-L. Gaing, “Particle swarm optimization to solving the economic dispatch considering the generator constraints,” *IEEE Trans. Power Syst.*, vol. 18, no. 3, pp. 1187–1195, Aug. 2003.

[12] Park, J.B., Lee, K.S., Shin, J.R., Lee, K.Y. "*A Particle Swarm Optimization for Economic Dispatch with Nonsmooth Cost Functions*", IEEE Transactions on Power Systems, Vol. 20, No. 1, pp. 34–42, 2005.

[13] Selvakumar, A.I., Thanushkodi, K., *"New Particle Swarm Optimization Solution to Nonconvex Economic Dispatch Problems*",IEEE Transactions on Power Systems, Vol. 22, No. 1, pp. 42–51, 2007.

[14] Lu, H., Sriyanyong, P., Song, Y.H., Dillon, T., *"Experimental Study of a New Hybrid PSO with Mutation for Economic Dispatch with Non-smooth CostFunction*", Electrical Power and Energy Systems, Vol. 32, No. 9, pp. 921–935, 2010.

[15] Chiang, C.L., "Improved Genetic Algorithm for Power Economic Dispatch of Units with Valve-Point Effects and Multiple Fuels",IEEE Transactions on Power Systems, Vol. 20, No. 4, pp. 1690–1699, 2005.

[16] Subbaraj, P., Rengaraj, R., Salivahanan, S., "Enhancement of Self-adaptive Real-coded Genetic Algorithm Using Taguchi Method for Economic Dispatch Problem", Applied Soft Computing, Vol. 11, No. 1, pp. 83–92, 2011.

[17] Solving the Economic Load Dispatch Problem considering units with different fuels using Evolutionary Algorithms , Mostafa Ramzanpour , Hamdi Abdi , International Journal of Mechatronics, Electrical and Computer Technology Austrian E-Journals of Universal Scientific Organization(Apr, 2014) , ISSN: 2305- 0543 , Vol. 4(11), ,pp. 722-743.

[18] Abido, M. A., " Environmental Economic power dispatch using multi objective evolutionary algorithms", *IEEE Transactions on Power Systems*, vol. 18, no.4, pp.1529-1537, 2003.

[19] Emmanuel, D. M., Nicodemus, A. O., " Combined Economic and Emission Dispatch Solution Using ABC-PSO Hybrid Algorithm with Valve Point Loading Effect ", *International Journal of Scientific and Research Publications*, Volume 2, Issue 12, December 2012.

[20] Balamurugan, R. and Subramanian, S. "A simplified recursive approach to combined economic emission dispatch", *Electric Power Components and Systems*. 36, 17-27, 2008.

[21] Neto, J.X.V., Bernert. D.L.A., Coelho, L.S., Improved Quantum-inspired Evolutionary Algorithm with Diversity Information Applied to Economic Dispatch Problem with Prohibited Operating Zones,Energy Conversion and Management, in press.