Scientific Research and Essays Vol. 6 (13), pp. 2824-2831, 4 July, 2011
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE11.408
ISSN 1992-2248 ©2011 Academic Journals

Full Length Research Paper

Multi-objective environmental/economic dispatch solution with penalty factor using artificial bee colony algorithm

Y. Sonmez

Department of Electrical and Energy Technology, Gazi Vocational College, GU, Ankara, Turkey.
E-mail: ysonmez@gazi.edu.tr

Accepted 5 May, 2011

Multi-objective environmental/economic dispatch (EED) problem is the scheduling of generators which fulfill the load demand of the power plants using fossil fuel and also making combined production, in order for them to perform with minimum cost and emission. Actually, this is an optimization problem. In this study, multi-objective EED solution has been recommended by using artificial bee colony (ABC) algorithm. For the solution of the problem, multi-objective EED was converted into single-objective EED by using price penalty factor. In this study, the obtained results from ABC algorithm were compared to those of other algorithms in the literature. The results obviously show that ABC algorithm produce better results.

Key words: Economic dispatch, emission dispatch, artificial bee colony, multi-objective function, price penalty factor.

INTRODUCTION

The rapid increase in world population, widespread economic activities and the targeted improvements in the living standards result in a continuously increasing demand for energy services. Contrary to this increase in energy demand, the reduction of the energy sources requires the economic distribution of the produced energy (economic load dispatch, ED). Therefore, recently, most of the researchers made studies for finding the most suitable power values produced by the generators depending on the fuel costs. In these studies, they produced successful results by using various optimization algorithms (Lim et al., 2009; Gaing, 2003; Walters and Sheble, 1993). Despite the fact that traditional ED can optimize the fuel cost of the generators, it still can not produce a solution for the environmental pollution due to the excessive emission of fossil fuels.

Today, most of the needed quantity of electrical energy is produced in thermal power plants. In these plants, the mechanical energy that will move the rotor shafts of the generators is produced by fossil fuels. This situation causes a large amount of sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions to be mixed in the atmosphere, which then lead to environmental pollution (Ratniyomchai et al., 2010). For this reason, in recent years, emission control is now important in power plants, in that it is produced by the use of fossil fuels. Researchers did various studies in order to make the power plants that are correctly scheduled by the generators to perform with minimum cost and emission, simultaneously. There are many studies in literature, which show that this problem, called multi-objective environmental/economic dispatch (EED) or combined economic and emission dispatch (CEED), has been solved by using different heuristic algorithms.

Lee and Darwish (2008) used bee algorithm with a weighted sum for solving the problem. Balamurugan and Subramanian (2008) recommended dynamic programming technique, and it solved the problem by improved recursive approach. Ratniyomchai et al. (2010) used particle swarm optimization for testing three unit thermal power plants, whereas Güvenç (2010) solved the problem by using similarity crossover based genetic algorithm (GA). In his developed algorithm, new chromosomes were determined based on the relationship between the mother and father. Palanichami and Sundar (2008) searched for a solution to the problem with analytical dispatch strategy by developing a mathematical model. Sasikala and Ramaswamy (2010) developed simulated annealing (SA) based on the modified approach with a single decision variable algorithm and applied it for solving the problem. Non-dominated sorting genetic algorithm (NSGA-II) (Purkayastha and Sinha, 2010), fuzzy-tabu search (Prasanna and Somasundaram, 2008), biogeography-based optimization (BBO) (Roy et al., 2010) and artificial neural network (ANN) (Kumarappan et al., 2002) are other algorithms used for solving the EED problem.

In this study, artificial bee colony algorithm (ABC), a brand new and effective meta-heuristic algorithm, developed by Dervis Karaboğa, was applied to solve the EED problem. ABC is an algorithm that finds a possible solution for optimization problems with multi-variable functions and it is motivated by the foraging behavior of honeybees. There are many studies in literature which show that ABC has been used for solving different optimization problems (Karaboga and Basturk, 2008, 2007; Karaboga and Akay, 2009; Singh, 2009; Nayak et al., 2009; Cobanli et al., 2010). It was reported by Karaboga and Akay (2009) that ABC has a lot of advantages (more simple and flexible and has less control parameters) and it is different from other heuristic algorithms, such as particle swarm optimization (PSO), GA and differential evolution (DE). These are expressed in detail in Karaboga and Akay (2009). These differences make the ABC more powerful. Moreover, in Karaboga and Akay (2009), ABC was examined on 48 different standard benchmark functions and was compared with other heuristic algorithms, such as PSO, DE and GA. It was found that the results obtained by ABC in most cases provide superior results and in all cases, they are comparable with others. Due to all of these reasons, ABC is chosen in order to solve the EED problem in this paper. Besides, Hemamalini and Simon (2010) solved the economic/emission load dispatch problem using ABC algorithm. The EED problem is solved using the classical weighted sum method. As for this study, which is different from that of Hemamalini and Simon (2010), multi-objective EED problem was converted into single-objective by using price penalty factor and was solved by the use of ABC.

In this paper, EED solution which was performed using ABC was tested over a standard IEEE 30-bus system which consisted of six generators. The results were compared to those reported in Rughooputh and King (2003). The comparison shows that ABC algorithm produce better solutions than other algorithms in the solution of EED problem.

MATHEMATICAL FORMULATION OF MULTI-OBJECTIVE ENVIRONMENTAL/ECONOMIC DISPATCH PROBLEM

The EED problem targets to find the optimal combination of load dispatch of generating units and minimizes both fuel cost and emission while satisfying the total power demand. Therefore, EED consists of two objective functions, which are economic and emission dispatches. Then these two functions are combined to solve the problem. The EED problem can be formulated as follows (Guvenc, 2010):

$$F_T = Min\, f\left(FC, EC\right) \tag{1}$$

where, F_T is the total generation cost of the system, FC is the total fuel cost of generators and EC is the total emission of generators.

Economic dispatch (ED)

The ED problem targets to find the optimal combination of power generation by minimizing the total fuel cost of all generator units while satisfying the total demand. The ED problem can be formulated in quadratic form as follows (Guvenc, 2010; Palanichamy and Babu, 2008; Ratniyomchai et al., 2010; Rughooputh and King, 2003):

$$FC = \sum_{i=1}^{n} \left(a_i P_i^2 + b_i P_i + c_i\right) \tag{2}$$

where, P_i is the power generation of the ith unit; a_i, b_i and c_i are fuel cost coefficients of the ith generating unit and n is the number of generating units.

Emission dispatch

The classical ED problem can be found by the amount of active power to be generated by units at minimum fuel cost, but it is not considered as the amount of emissions released from burning fossil fuels. The total amount of emission such as SO_2 or NO_x depends on the amount of power generated by unit and it can be defined by the sum of a quadratic function and an exponential function as follows (Prasanna and Somasundaram, 2008; Cetinkaya, 2009; Ratniyomchai et al., 2010):

$$EC = \sum_{i=1}^{n} \left(d_i P_i^2 + e_i P_i + f_i + \xi_i \exp(\lambda_i P_i)\right) \quad \text{(kg/h)} \tag{3}$$

where Pi is the power generation of the ith unit in MW; and di, ei, fi, ξ_i and λ_i are emission coefficients of the ith generating unit.

Multi-objective environmental/economic dispatch

EED is a multi-objective problem, which is a combination of both economic and environmental dispatches that individually make up different single problems. At this point, this multi-objective problem needs to be converted into single-objective form in order to fulfill optimization. The conversion process can be done by using the price penalty factor. However, the single-objective EED can be formulated as shown in equation (4) (Ratniyomchai et al., 2010; Guvenc, 2010).

$$Min\, F_T = \sum_{i=1}^{n} \left(\left(a_i P_i^2 + b_i P_i + c_i\right) + h_i\left(d_i P_i^2 + e_i P_i + f_i\right)\right) \quad \text{(\$/h)} \tag{4}$$

where h_i is the price penalty factor, and is formulated as follows:

$$h_i = \frac{a_i P_{i\,max}^2 + b_i P_{imax} + c_i}{d_i P_{i\,max}^2 + d_i P_{imax} + e_i} \quad (5)$$

where P_{imax} is the maximum power generation of the *i*th unit in MW.

Problem constraints

There are two constraints in the EED problem which are: power balance constraint and maximum and minimum limits of power generation output constraint. The power balance constraint is the total power generated that must supply the total load demand and the transmission losses. It can be formulated as seen in equation (6). The maximum and minimum limits of power generation output constraint is the power generated *Pi* by each generator and which is constrained between its minimum and maximum limits. It can be formulated as seen in equation (7) (Ratniyomchai et al., 2010; Lee and Darwish, 2008).

$$P_{load} + P_{loss} - \sum_{i=1}^{n} P_i = 0\,; \quad \text{I} = 1,2,....,\text{n} \quad (6)$$

$$P_{imin} \le P_i \le P_{imax}\,; \quad \text{i} = 1,2,....,\text{n} \quad (7)$$

where P_{load} is the total load demand of the system in MW, P_{loss} is the total power loss in MW, P_{imin} is the minimum power generation and P_{imax} is the maximum power generation of the *i*th unit in MW.

P_{loss} is usually calculated by using the B loss coefficients matrix which can be expressed in quadratic form as follows (Rughooputh and King, 2003):

$$P_{loss} = \sum_{i=1}^{n} \sum_{j=1}^{n} P_i B_{ij} P_j \quad (8)$$

where P_i is power generation of the *i*th unit, P_j is the power generation of the *j*th unit, and B_{ij} is the loss coefficient between the *i*th and *j*th generating unit in MW^{-1}.

ARTIFICIAL BEE COLONY ALGORITHM BASED ON THE OPTIMAL SOLUTION OF MULTI-OBJECTIVE ENVIRONMENTAL/ECONOMIC DISPATCH PROBLEM

ABC algorithm is a population-based metaheuristic approach, created in 2005 by Karaboğa and developed by Karaboğa and Baştürk in 2007. Algorithm has been inspired by the life processes and attitudes of honeybees in a colony. There are three types of honeybees in ABC algorithm: employed, onlooker and scout bees. Employed ones consume the food sources and give onlookers the information about the nectar amount of the food source. Onlookers wait at the dancing area in order to decide which food source should be chosen. Scout is responsible for the discovery of new food sources (Karaboga and Basturk, 2007, 2008; Karaboga and Akay, 2009; Singh, 2009).

In ABC algorithm, the solution of the optimization problem is represented by the location of a food source and the quality of the solution is represented by the nectar amount of the source (fitness). In the first step of ABC, the locations for the food source are produced randomly. In other words, for SN (the number of employed or onlooker bees) solutions, a randomly distributed initial population is produced. In the solution space, each solution $(X_i = (X_{i1}, X_{i2}, ...X_{iSN}))$ is a vector on the scale of its number of optimization parameters.

After initializing, the population of the solutions is repeated through the cycles which represent the searching process of the employed, onlooker and scout bees. In ABC, each cycle was formed by 3 steps (Karaboga and Akay, 2009):

1. Sending the employed bees to food sources and assessing the nectar amounts: At this stage, the employed bees that return to hive again share the information, including the nectar amounts of the sources with onlooker bees that are waiting at the dancing area. Then each employed bee, by means of its visual knowledge, chooses a new food source adjacent to other food sources that it has visited before and kept in her memory, after which it assesses its nectar amount.
2. Selection of the food source area by onlooker bees and assessing the nectar amount of the food sources: At this stage, one onlooker chooses a food source area (P_i) depending on the nectar information given by the employed at the dancing area. This process can be formulized as shown in (9).

$$P_i = \frac{F(X_i)}{\sum_{j=1}^{SN} F(X_j)} \quad (9)$$

where $F(X_i)$ is the fitness value of solution *i* which is proportional to the nectar amount of the food source in position *i* and SN is the number of food sources which is equal to the number of employed bees or onlooker bees. Depending on the old sources in the memory, the following formula is used for the production of a new food position (v_{ij});

$$v_{ij} = x_{ij} + \varphi_{ij}(x_{ij} - x_{kj}) \quad (10)$$

Here, $k \in \{1,2,...,SN\}$ and $j \in \{1,2,...,D\}$ are randomly chosen indexes and they have to be $k \ne i$. Moreover, ϕ_{ij} is a random number which is in between the interval [-1 and 1].

3. Determining scout bees and sending them to possible food sources randomly: In ABC algorithm, one of the employed bees is chosen according to "limit" parameter and she is converted into a scout bee. The source is

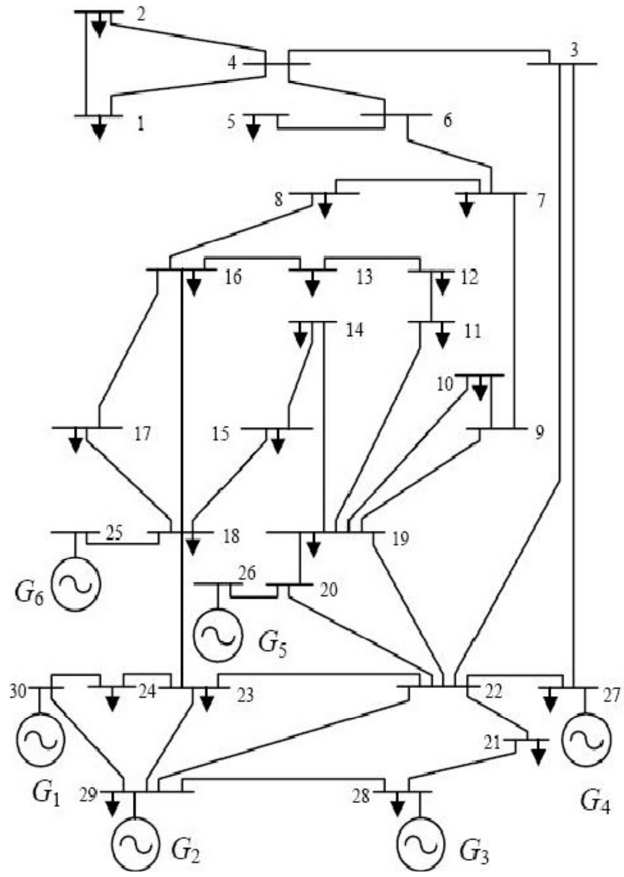

Figure 1. Single-line diagram of IEEE 30-bus test system (Lee and Darwish, 2008).

abandoned unless the solution which implies the source is not improved by a specific number of trials. The employed bee that goes to that source becomes a scout bee in the end. The trial number for abandoning the source is determined by the "limit" parameter.

On that step, when the nectar of a food source is abandoned, a scout randomly defines a food source and it takes the place of the abandoned one. The following formula is used for this process:

$$x_{ij} = x_j^{min} + (x_j^{max} - x_j^{min}) * rand \quad j \in \{1,2,...,D\} \tag{11}$$

In ABC, each candidate is compared to the older version in the memory by the artificial bee after the source position is produced and assessed. If the nectar amount in the new source is higher than the older one, then it changes place with the older one in the memory. Otherwise, the older one remains its place in the memory. This is called choosing operation.

In ABC, the aforementioned cycle process continues till all the necessities determined for the solution of the process are fulfilled. Therefore, the most suitable value for the optimization problem is produced. Besides, while employed and onlooker bees are explored in ABC, the scout bees exploit the explored sources at the same time so that the algorithm gives results quickly and becomes powerful. The detailed psuedo-code of ABC (Karaboga and Akay, 2009) is shown as follows.

Detailed psuedo-code of ABC algorithm:

1. Initialize the population of solutions x_i; i = 1,2,. . . , SN.
2. Evaluate the population.
3. Cycle = 1.
4. Repeat
5. Produce new solutions v_i for the employed bees by using (10) and evaluating them.
6. Apply the greedy selection process for the employed bees.
7. Calculate the probability values of P_i for the solutions of x_i by Equation (9).
8. Produce the new solutions of v_i for the onlookers from the solutions of x_i selected depending on P_i and evaluating them.
9. Apply the selection process for the onlookers.
10. Determine the abandoned solution for the scout, if it exists, and replace it with a new randomly produced solution x_i by (11).
11. Memorize the best solution achieved so far.
12. Cycle = cycle + 1.
13. Until the cycle = MCN.

DESCRIPTION OF THE TEST SYSTEM

Here, the experimental study performed for the effectiveness of ABC algorithm over solving EED problem is described. The results for the different load demands have been examined in the experiment. The results obtained from ABC are compared to the results of the algorithm shown in Rughooputh and King (2003). The problem formulations and ABC algorithm is implemented using M-file in Matlab.

In the experimental study, ABC algorithm is tested over standard IEEE 30-bus power system with six generators which are shown in Figure 1. The algorithm is separately tested for 500, 700 and 900 MW of load demands. The coefficients of EED problem and the transmission loss coefficients matrix are taken from Rughooputh and King (2003). The coefficients of fuel cost, emission and the capacities of the generating units are shown in Table 1. However, the transmission loss coefficients matrix is specified in Equation (12).

$$B_{ij} = \begin{bmatrix} 0.002022 & -0.000286 & -0.000534 & -0.000565 & -0.000454 & -0.000103 \\ -0.000286 & 0.003243 & 0.000016 & -0.000307 & -0.000422 & -0.000147 \\ -0.000534 & 0.000016 & 0.002085 & 0.000831 & 0.000023 & -0.000270 \\ -0.000565 & -0.000307 & 0.000831 & 0.001129 & 0.000113 & -0.000295 \\ -0.000454 & -0.000422 & 0.000023 & 0.000113 & 0.000460 & -0.000153 \\ -0.000103 & -0.000147 & -0.000270 & -0.000295 & -0.000153 & 0.000898 \end{bmatrix} \tag{12}$$

RESULTS AND DISCUSSION

The multi-objective EED problem is solved by the ABC algorithm for the standard IEEE 30-bus system. In the study's problem, the variables given in Table 1 refer to

Table 1. Coefficients of fuel cost, emission and capacities of the six generating units.

Gen.	a_i (\$/MW2h)	b_i (\$/MWh)	c_i (\$/h)	d_i (kg/MW^{2}h)	e_i (kg/MWh)	f_i (kg/h)	P_{imin} (MW)	P_{imax} (MW)
1	0.15247	38.53973	756.79886	0.00419	0.32767	13.85932	10	125
2	0.10587	46.15916	451.32513	0.00419	0.32767	13.85932	10	150
3	0.02803	40.39655	1049.32513	0.00683	0.54551	40.2669	40	250
4	0.03546	38.30553	1243.5311	0.00683	0.54551	40.2669	35	210
5	0.02111	36.32782	1658.5696	0.00461	0.51116	42.89553	130	325
6	0.01799	38.27041	1356.27041	0.00461	0.51116	42.89553	125	315

Table 2. Best fuel cost solutions for the test power system.

Load demand (MW)	500			700			900		
Generating unit	FCGA (Rughooputh and King, 2003)	NSGA-II (Rughooputh and King, 2003)	ABC	FCGA (Rughooputh and King, 2003)	NSGA-II (Rughooputh and King ,2003)	ABC	FCGA (Rughooputh and King, 2003)	NSGA-II (Rughooputh and King, 2003)	ABC
P1 (MW)	49.47	50.836	52.532	72.14	76.179	77.017	101.11	102.963	103.351
P2 (MW)	29.40	31.806	29.079	50.02	51.81	48.542	67.64	74.235	72.426
P3 (MW)	35.31	35.12	35.000	46.47	49.82	44.568	50.39	66.003	61.324
P4 (MW)	70.42	73.44	70.871	99.33	103.407	103.892	158.80	140.316	138.847
P5 (MW)	199.03	191.988	191.627	264.60	267.984	264.642	324.08	324.888	324.998
P6 (MW)	135.22	135.019	137.616	203.58	184.734	192.146	256.56	248.416	249.154
Fuel cost (\$/h)	28150.80	28150.834	28078.994	38384.09	38370.746	38208.214	49655.40	49620.824	49300.313
Emission (kg/h)	314.53	309.04	309.102	543.48	534.924	535.787	877.61	849.326	846.160
Power loss (MW)	18.86	18.208	16.734	36.15	33.934	30.809	58.58	56.822	50.101
Total capacity (MW)	518.86	518.208	516.725	736.14	733.934	730.809	958.57	956.822	950.102

the nectar position and the best comprise solutions that refer to the nectar amount.

The values of the ABC algorithm for solving EED problem in this paper are designated as follow:

Colony dimension: 20; maximum number of cycles: 500; number of variables: 6; and limit parameter: 3000.

Table 2 gives the minimum fuel cost solutions for EED problem using ABC, FCGA and NSGA-II with load demands of 500, 700 and 900 MW for six-generator system. As seen in Table 2, when the minimum fuel cost solutions for test power system with all load demands are considered, it is observed that the proposed ABC method can reduce the fuel cost by about 71.84 \$/h when compared with NSGA-II and FCGA for 500 MW load demand, 175.876 \$/h when compared with FCGA and162.5 \$/h when compared with NSGA-II for 700 MW load demand, and 355.087 \$/h when compared with FCGA and 320.51 \$/h when compared with NSGA-II for 900 MW load demand, respectively. However, NSGA-II produces lower emission (NO_x) effects as compared to ABC for 500 and 700 MW load demands in the best fuel cost solution. Table 3 gives the minimum NO_x emission effects for EED problem using ABC and NSGA-II with load demands of 500, 700 and 900 MW for six-generator system. As seen in Table 3, when the minimum emission effects solutions for the test power

Table 3. Best emission effects (NO_x) for the test power system.

Load demand (MW)	500			700			900		
Generating unit	FCGA (Rughooputh and King, 2003)	NSGA-II (Rughooputh and King, 2003)	ABC	FCGA (Rughooputh and King, 2003)	NSGA-II (Rughooputh and King, 2003)	ABC	FCGA (Rughooputh and King, 2003)	NSGA-II (Rughooputh and King, 2003)	ABC
P1 (MW)	81.08	56.931	54.088	120.16	103.078	101.018	133.31	124.998	124.989
P2 (MW)	13.93	41.542	37.518	21.36	73.505	73.163	110.00	109.893	109.856
P3 (MW)	66.37	73.896	72.925	62.09	91.556	92.687	100.38	111.081	109.884
P4 (MW)	85.59	84.931	83.530	128.05	110.787	110.254	119.27	141.961	141.711
P5 (MW)	141.70	136.502	139.690	209.65	187.869	185.937	250.79	254.36	250.734
P6 (MW)	135.93	131.328	136.024	201.12	174.289	174.769	251.25	226.578	225.065
Power loss (MW)	24.61	25.129	23.777	42.44	41.083	37.83	65.00	68.87	62.24
Total capacity (MW)	524.60	525.129	523.777	742.44	741.083	737.83	964.99	968.87	962.24
Fuel cost ($/h)	28756.71	28641.078	28495.572	39455.00	39473.422	39271.868	53299.64	51254.195	50942.660
Emission (kg/h)	286.59	275.544	275.165	516.55	467.388	463.109	785.64	760.052	749.529

Table 4. Best comprise solutions for the test power system with 500 MW.

Generating unit	FCGA (Rughooputh and King (2003)	NSGA-II (Rughooputh and King (2003)	ABC
P1 (MW)	65.23	54.048	54.2622
P2 (MW)	24.29	34.25	35.9799
P3 (MW)	40.44	54.497	51.4078
P4 (MW)	74.22	80.413	76.5267
P5 (MW)	187.75	161.874	162.6180
P6 (MW)	125.48	135.426	137.0864
Power loss (MW)	17.41	20.508	17.88
Total capacity (MW)	517.41	520.508	517.88
Fuel cost ($/h)	28231.06	28291.119	28194.988
Emission (kg/h)	304.90	284.362	284.980

system with all the load demands are considered, it is observed that the proposed ABC method can reduce the NO_x emission levels by about 11.425 kg/h when compared with FCGA and 0.379 kg/h when compared with NSGA-II for 500 MW load demand, 53.441 kg/h when compared with FCGA and 4.279 kg/h when compared with NSGA-II for 700 MW load demand, and 36.111 kg/h when compared with FCGA and 10.523 kg/h when compared with NSGA-II for 900 MW load demand, respectively. Moreover, ABC produces lower fuel cost as compared to FCGA and NSGA-II for all load demands in the best emission effect solution.

Tables 4 to 6 give the best comprise solutions for EED problem using ABC, FCGA and NSGA-II with

Table 5. Best comprise solutions for the test power system with 700 MW.

Generating unit	FCGA (Rughooputh and King, 2003)	NSGA-II (Rughooputh and King, 2003)	ABC
P1 (MW)	80.16	86.286	87.128
P2 (MW)	53.71	60.288	59.978
P3 (MW)	40.93	73.064	74.182
P4 (MW)	116.23	109.036	110.862
P5 (MW)	251.20	223.448	211.442
P6 (MW)	190.62	184.111	190.202
Power loss (MW)	32.85	36.234	33.792
Total capacity (MW)	732.85	736.234	733.793
Fuel cost ($/h)	38408.82	38671.813	38570.017
Emission (kg/h)	527.46	484.931	477.286

Table 6. Best comprise solutions for the test power system with 900 MW.

Generating unit	FCGA (Rughooputh and King, 2003)	NSGA-II (Rughooputh and King, 2003)	ABC
P1 (MW)	111.40	120.058	119.946
P2 (MW)	69.33	85.202	82.309
P3 (MW)	59.43	89.565	87.103
P4 (MW)	143.26	140.278	136.515
P5 (MW)	319.40	288.614	290.055
P6 (MW)	252.11	233.687	233.953
Power loss (MW)	54.92	57.405	49.873
Total capacity (MW)	954.92	957.405	949.880
Fuel cost ($/h)	49674.28	50126.059	49722.424
Emission (kg/h)	850.29	784.696	778.423

load demands of 500, 700 and 900 MW for six-generator system. As seen in Table 4, when the best comprise solutions are considered, ABC reduced the fuel cost by about 36.072 $/h when compared with FCGA and 96.31 $/h when compared with NSGA-II. Moreover, ABC can reduce the NO_x emission by about 19.92 kg/h when compared with FCGA, whereas NSGA-II can produce lower NO_x emission than ABC by about 0.618 kg/h for 500 MW load demand. As seen in Table 5, ABC can reduce both the fuel cost by about 101.796 $/h when compared with NSGA-II, whereas FCGA can produce lower fuel cost than ABC by about 161.197 for 700 MW load demand. Furthermore, ABC can reduce NO_x emission by about 50.174 kg/h when compared with FCGA and 7.645 kg/h when compared with NSGA-II for 700 MW load demand. As seen in Table 6, ABC can reduce both the fuel cost by about 48.144 $/h when compared with FCGA and 403.635 $/h when compared with NSGA-II, and NO_x emission by about 71.867 kg/h when compared with FCGA and 6.273 kg/h when compared with NSGA-II for 900 MW load demand, respectively.

Conclusions

In thermal power plants, multi-objective EED problem requires the optimum processing states of the generators to be determined while synchronously holding the fuel cost and NO_x emission effect at minimum level. In this paper, this difficult optimization problem is solved by using ABC algorithm. The multi-objective problem is converted into single-objective form by means of price penalty factor, and the problem constraints are also considered. Numerical simulation for different load demands is done on a testing system in order to observe the efficiency and feasibility of ABC algorithm. After comparing the simulation results with the other algorithms, it is obviously seen that ABC gives more powerful results than other algorithms so that both fuel cost and emission effect are reduced for different load demands. This situation shows that ABC algorithm can easily be applied to other optimization problems, and as such, effective results can be obtained.

REFERENCES

Balamurugan R, Subramanian S (2008). A simplified recursive approach to combined economic emission dispatch. Elec. Power Comp. Sys., 36(1): 17-27.

Cetinkaya N (2009). Optimization algorithm for combined economic and emission dispatch with security constraints. Int. Conf. Comp. Sci. Appl. ICCSA, pp. 150-153.

Cobanli S, Ozturk A, Guvenç U, Tosun S (2010). Active power loss minimization in electric power systems through artificial bee colony algorithm. Int. Rev. Elect. Eng., 5(5): 2217-2223.

Gaing ZL (2003). Particle swarm optimization to solving the economic dispatch considering the generator constraints. IEEE Trans. Power

Sys., 18(3). 1187-1195.
Güvenç U (2010). Combined economic emission dispatch solution using genetic algorithm based on similarity crossover. Sci. Res. Essay, 5(17): 2451-2456.
Hemamalini S, Simon SP (2010). Economic/emission load dispatch using artificial bee colony algorithm. Int. Conf. Cont., Comm. Power Eng., pp 338-343.
Karaboga D, Basturk B (2007). A powerful and efficient algorithm for numerical function optimization: artificial bee colony (abc) algorithm. J. Global Opt., 39(3): 459-471.
Karaboga D, Bastürk B (2008). On the performance of artificial bee colony (ABC) algorithm. Appl. Soft Comp., 8: 687-697.
Karaboğa D, Akay B (2009). A comparative study of artificial bee colony algorithm. Appl. Math. Comp. 214: 108-32.
Kumarappan N, Mohan MR, Murugappan S (2002). ANN approach applied to combined economic and emission dispatch for large-scale system. Int. Joint Conf. Neural Nets., 1: 323-327.
Lee JL, Darwish AH (2008). Multi-objective environmental/economic dispatch using the bees algorithm with weighted sum. EU-Korea Conf. Sci. Tech., pp. 267-274.
Lim SY, Montakhab M, Nouri H (2009). Economic dispatch of power system using particle swarm optimization with constriction factor. Int. J. Innov. Energy Syst. Power, 4(2): 29-34.
Nayak SK, Krishnanand KR, Panigrahi BK, Rout PK (2009). Application of artificial bee colony to economic load dispatch problem with ramp rate limits and prohibited operating zones. World Congr. Nat. Biolog. Insp. Comp. pp. 1237-1242.
Palanichamy C, Babu NS (2008). Analytical solution for combined economic and emissions dispatch. Elect. Power Systs. Res., 78: 1129-1137.
Prasanna TS, Somasundaram P (2008). Fuzzy-tabu search algorithm for combined economic and emission dispatch. XXXII Natl. Syst. Conf., pp. 542-547.
Purkayastha B., Sinha N (2010). Optimal combined economic and emission load dispatch using modified NSGA-II with adaptive crowding distance. Int. J. Inform. Tech. Know. Man., 2(2): 553-559.
Ratniyomchai T, Oonsivilai A, Pao-La-Or P, Kulworawanichpong T (2010). Particle swarm optimization for solving combined economic and emission dispatch problems. 5th IASME/WSEAS Int. Conf. Energy Environ., pp 211-216.
Roy PK, Ghoshal SP, Thakur SS (2010). Combined economic and emission dispatch problems using biogeography-based optimization. Electr. Eng., 92(4-5): 173-184.
Rughooputh HCS, King RTFA (2003). Environmental/economic dispatch of thermal units using an elitist multiobjective evolutionary algorithm. IEEE Int. Conf. Ind. Tech., pp. 48-53.
Sasikala J, Ramaswamy M (2010). Optimal λ based economic emission dispatch using simulated annealing. Int. J. Comp. Appl., 1(10): 55-63.
Singh A (2009). An artificial bee colony algorithm for the leaf-constrained minimum spanning tree problem. Appl. Soft Comp., 9:625-631.
Walters DC, Sheble, GB (1993). Genetic algorithm solution of economic dispatch with valve point loading. IEEE Trans. Power Syst., 8(3): 1325-1332.