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Intelligent Artificial Bee Colony Techniques to Solve Environment Emission and Economic Load Dispatch

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ABSTRACT: Economic load dispatch is an important optimization problem in power system. Due to the harmful effects of the emission released by fossil fueled electric power plants, Emission Dispatch plays an important role in power industry. This paper presents performances of an artificial bee colony algorithm; the proposed artificial bee colony is effective and reliable technique for obtaining the optimal solution of the combined economic and emission dispatch problem. The results have been demonstrated for combined economic and emission dispatch problem of standard 6-generator with and without consideration of the transmission losses.

KEYWORDS: Artificial bee colony, Economic Dispatch, Emission dispatch, Pareto optimal solution.

I. INTRODUCTION

In the present scenario electric power industry has to meet with subtle changes occurring worldwide. This has forced the utility engineers to plan the electric power generation system for efficient economic operation such that environmental pollution is reduced along with the minimization of generating cost. With the amendments in the clean air act in 1990 many efforts have been made to reduce the NOx, SOx and CO2 emissions into the atmosphere [1].In fossil-fired power plants, main sources of energy are coal, gas, oil and diesel. All of the above mentioned resources realize harmful gases in atmosphere. Coal Produces ash content, SOx, NOx, and CO2 in the atmosphere. The cooling water used in thermal power plant also rises the water temperature and affecting the marine life also. Nuclear power plants emit harmful radiation in the environment. Because of all above factors, emission control has become an important operational objective [2]. Emission control has received increasing attention owing to increased concern over environmental pollution caused by fossil based generating units and the enforcement of environmental regulations in recent years. Due to strict governmental regulations on environment protection, the conventional operation at absolute minimum fuel cost cannot be the only basis for dispatching electric power. There is a need from society for adequate and secure electricity at the cheapest possible price with minimum levels of pollution. It is compulsory for electric utilities to reduce pollution level by reducing CO2, SOx and NOx. Various methods available for reducing emissions are switching to low sulphur content coal, installing post-combustion cleaning system, allocation of generation to each generator unit with the objective to minimum emission dispatch [3]. The pollutants become an inescapable problem to control and govern emissions of power plants because, day by day energy conservation and pollution emissions reduction attains increasingly social attentions [4].

The Combined economic and emission dispatch has been proposed in the field of power generation dispatch, which simultaneously minimizes both fuel cost and pollutant emissions. When the emission is minimized the fuel cost may be unacceptably high or when the fuel cost is minimized the emission may be high. A number of methods have been presented to solve Combined economic and emission dispatch problems such as particle swarm optimization [5-7], Bat Algorithm [8-9], Differential Evolution Algorithm [10-11], Genetic algorithm [12] and simulated annealing [13].
Nowadays proposed artificial bee colony algorithm is a relatively new member of swarm intelligence. ABC tries to model natural behaviour of real honey bees in food foraging. Honey bees use several mechanisms like waggle dance to optimally locate food sources and to search new ones. This makes them a good candidate for developing new

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intelligent search algorithms. This paper uses artificial bee colony algorithm to solve combined economic and emission dispatch problem with equality and inequality constraints.

II. OVERVIEW OF THE ABC ALGORITHM

Artificial bee colony is one of the most recently defined algorithms by Karaboga in 2005, motivated by the intelligent behaviour of honey bees [14-15]. In the ABC system, artificial bees fly around in the search space, and some (employed and onlooker bees) choose food sources depending on the experience of themselves and their nest mates, and adjust their positions. Some (scouts) fly and choose the food sources randomly without using experience. If the nectar amount of a new source is higher than that of the previous one in their memory, they memorize the new position and forget the previous one .Thus; the ABC system combines local search methods, carried out by employed and onlooker bees, with global search methods, managed by onlookers and scouts, attempting to balance exploration and exploitation process In the ABC algorithm, the colony of artificial bees consists of three groups of bees: employed bees, onlooker bees, and scout bees. It is population-based search procedure and the foraging behavior of real bees in finding food sources is shown in Figure 1. The model consists of 3 essential components: employed bees, unemployed bees, and food sources. Figure 1A clearly shows the essential parts of the model: employed bees, unemployed bees, food sources, and a dancing area. Employed bees y around in a multidimensional search space and choose their food sources depending on their own experience, which is shown in Figure 1B. Once the employed bees complete their search

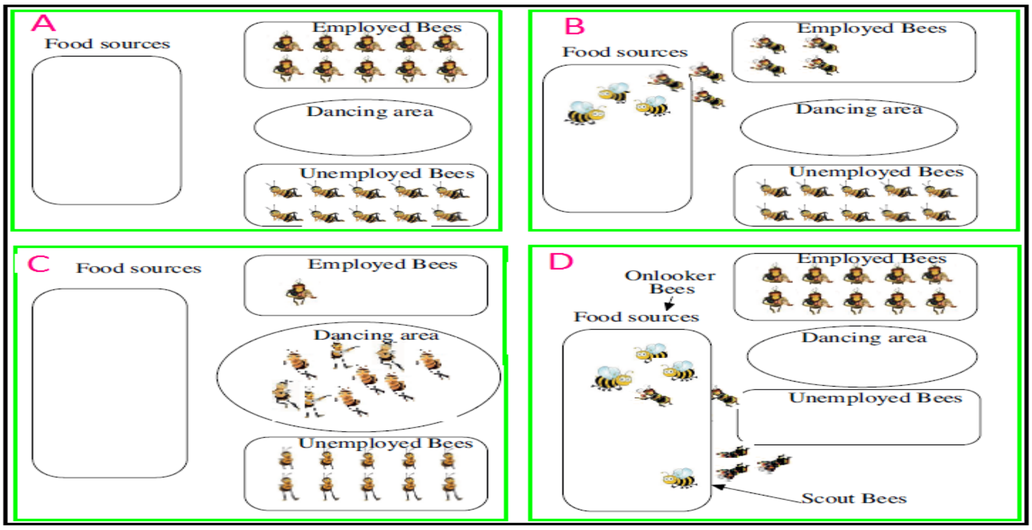

Fig 1 food sources finding

Process, they share their food source information with unemployed bees or onlooker bees waiting in the hive by dancing in the dancing area, which is shown in Figure 1C. Onlooker bees probabilistically choose their food sources depending on this information gained from the Employed bees, which is shown in Figure 1D. If there is no improvement in the food source (Fitness), then the scout bees y and choose the food sources randomly without using experience, which is also shown in Figure 1D [16].

III.ARTIFICIAL BEE COLONY (ABC) ALGORITHM

This model was introduced by Dervis Karaboga in 2005; ABC algorithm is based on the intelligent way of the bees Interacting with each other. Honey bees being social insects divide their work among themselves, Employed bees, Onlooker bees and Scout Bees. Their activities are categorized into four main phases: Initialization phase, Employed bee phase, Onlooker bee phase and Scout bee phase. In initialization phase, each employed bee is assigned with different food resources. In employed bee phase, each employed bee calculates the nectar amount of the food resource associated with it and the distance of it from the hive. After collecting the important information of the source the employed bee share the gathered information with the bees waiting in the hive. In onlooker bee phase, onlooker bees (the bees waiting in the hive) read information regarding different food resources and choose the best food resource. In

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scout bee phase, the employed bees whose food resource becomes abandoned turns into scout bee. The main job of scout bees is to search for new food resources.

IV. THE STEP BY STEP PROCEDURE FOR PROPOSED ARTIFICIAL BEE COLONY (ABC) ALGORITHM

Step I**:** Specify generator cost coefficients, emission coefficients, generation power limits for each unit and B-loss coefficients. Initialize the four control parameters of ABC algorithm and maximum cycle for termination process.

Step II: *Initialization of the ABC algorithm parameters.* In this step, the parameters of the ABC algorithm, such as the colony dimension, maximum cycle number (MCN), number of variables, and limit parameter, are initialized.

Step II: *Initialization of the population with a random solution.* In this step, a set of food sources (initial population of S solutions xi (i = 1, 2,......S)) is generated randomly by the bees and their nectar amounts are determined, where S corresponds to size of the employed bees. Each solution xi is represented by a D-dimensional vector, where D corresponds to the number of parameters to be optimized.

Step IV: *Evaluation of the fitness.*
In this step, evaluation of the fitness function of each food source position corresponding to the employed bee in the colony.

Step V: Modification of the food source position and local selection by the employed bee. In this step, an employed bee modifies the food source position, finds a new position (solution) using her visual information belonging to that source in her memory, and tests the nectar amount of the new source. In the ABC algorithm, the new food source found by the employed bee is described as follows:

$$v_{ij} = x_{ij} + \phi_{ij}\left(x_{ij} - x_{kj}\right) \quad \text{.............................. (1)}$$

Where, k (1, 2, 3…..S) and j (1, 2…..D) are randomly chosen indices and ϕ is a random number in the interval of [-1, 1]. In fact ϕij gives a comparison between 2 sources found, the new and the old. After vij is produced and its fitness is evaluated, the comparison is done by the employed bees. According to the comparison, if the fitness value of the new food source is better than that of the old one, the new food source is kept in the memory and the old one is discarded; otherwise, the new one is discarded from the memory and the old one is kept. This selection is called local searching or greedy selection process in the ABC algorithm. In this process, if the new food source is selected instead of the old one, a limit count is set.

Step VI: *Employ the onlookers for the selected sources and evaluate the fitness.* After completion of the local search process in Step 5 by the employed bees, they come back into the hive and share the nectar amount information of the sources with the onlooker bees waiting at the dancing area. In fact, these onlooker bees were called employed bees before going to the food source that they visited. In this step, onlooker bees make a new food source choice according to the information they took from the employed bees and the nectar amount is calculated. This process of choosing a food source depends on the probability value Pi associated with the fitness of that food source and is formulated as follows:

$$\boldsymbol{P_i} = \frac{\boldsymbol{f_i t_i}}{\sum_{n=1}^{N} \boldsymbol{f_i t_n}} \quad \text{.................................... (2)}$$

Where, $\boldsymbol{f_i t_i}$ is the fitness value of the *i* th solution and *N* is the total number of food sources which is equal to the number of employed bees.
Step VII: *Modification of the food source position by the onlookers.* In this step, the onlookers modify the food source position to find a new position (solution) using the visual information belonging to that source in their memory and check the nectar amount of the new source, just as in the case of the employed bee in Step 5. The greedy selection process is done again for the onlookers in this step. That is, if the fitness value of the new food source is better than that of the old one, the new food source is kept in the memory and old one is discarded; otherwise, the new one is discarded from the memory and the old one is kept.

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Step VIII: *Abandon the exploited food sources.*
This step is done according to the `limit' parameter, which is a predetermined number of cycles for releasing the food source. In the ABC algorithm, a solution is abandoned when that solution can not improve further for the determined limit value. In this step, when the nectar amount is abandoned in this way, one of the employer bees is determined randomly as a scout bee to find a new food source. This process is described as follows:

$$\boldsymbol{x_{ij} = x_{jmin} + \delta\,(0,1) * (x_{jmax} - x_{jmin})}\text{......................... (3)}$$

j (1,2………D)

Where, δ is a random value in the interval of [0,1], and x_{jmax} and x_{jmin} are the minimum and maximum limits of the parameter to be optimized and *Keep the position achieved so far and increase the counter of the cycle*.
Step IX: *Stopping of the global searching process.* In the ABC algorithm, steps V through IX are repeated until the criterion is met. Next, this global searching process stops.

V.COMBINED ECONOMIC AND EMISSION DISPATCH PROBLEM FORMULATION

The Combined economic and emission dispatch problems is formulated as an optimization problem in which fuel cost and emission are minimized simultaneously for the prescribed schedule of load. In electric power system, there are mainly four objectives to be minimized which include the economy and environmental impacts because of NOx, SO2 and CO2 gaseous pollution.

A. Economic Dispatch

The objective of solving the economic dispatch problem in electric power system is to determine the generation levels for all units which minimize the total fuel cost and minimizing the emission level of the system, while satisfying a set of constraints. It can be formulated as follows:

$$F(P) = \sum_{i=1}^{n} F_i(P_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$F_i(P_i) = \sum_{i=1}^{n} a_i + b_i P_i + C_i P_i^2 \quad Rs/hr \ldots\ldots\ldots\ldots\ldots (5)$$

The economic dispatch problem can be modeled by Where, $F_i(P_i)$ -Total fuel cost $(Rs\ /hr)$
Pi - generating unit i^{th} a_i, b_i, c_i Fuel cost coefficients of i^{th} unit
n- Number of generating units

B. Emission Equation

The fuel cost objective function is replaced by an emissions objective function. The constraints are the same but the optimal solution will produce the lowest total emissions as opposed to the lowest total cost.
The total (kg/hr) emission can be expressed as

$$E(P) = \sum_{i=1}^{n} E_i(P_i) \ldots\ldots (6)$$

$$E_i(P_i) = \sum_{i=1}^{n} d_i + e_i P_i + f_i P_i^2 \quad Rs/hr \ldots (7)$$

Where, $E_i(P_i)$ -Total fuel cost $(Kg\ /hr)$,Pi - generating unit i^{th}
d_i, e_i, f_i Emission coefficients of i^{th} unit, n- Number of generating units

C. ***Power balance constraint*** The total power generated must supply total load demand and transmission losses.

$$\sum_{i=1}^{n} P_i = P_d + P_l \ldots\ldots \text{MW} \ldots. (8)$$

Where, P_d - total load demand (MW), P_l - Total transmission losses (MW)

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D. Unit capacity constraint

The power generated, Pi by each generator is constrained between its minimum and maximum limits, i.e.

$$P_i^{min} \leq P_i \leq P_i^{max} \quad \ldots\ldots(9)$$

Where, P_i^{min} - minimum generation limit, P_i^{max} - Maximum generation limit.

VI. RESULT AND DISCUSSION

The applicability and validity of the ABC algorithm for practical applications has been two test Case study emissions and cost for 900 MW and 1170 MW. The Programs are developed using MATLAB 2012 and the system configuration is core i3with 2.40 GHz speed and 2 GB RAM. The system has the 6- units [20].The plant 1 consists of three generating units, plant 2 consists of two generators and plant 3 consists of one unit ,The Fuel cost coefficients show in table 1, Emission Coefficients show in table 2 and loss Coefficients show in table 3.
Data are show in the table 1, as follows.

Table 1: Fuel cost Coefficients of 6 units [20]

PLANT NAME	Fuel cost coefficients				Pi(min) MW	Pi(max) MW
	Unit	ai	bi	ci		
A	G1	756.79886	38.53973	0.15247	10	125
	G2	451.32513	46.15916	0.10587	10	150
	G3	1049.32513	40.39655	0.02803	40	250
B	G4	1243.5311	38.30553	0.03546	35	210
	G5	1658.5696	36.32782	0.02111	130	325
C	G6	1356.65920	38.27041	0.01799	125	315

Table 2: Emission Cost Coefficients of 6 units [20]

PLANT NAME	Emission Coefficients				Pi(min) MW	Pi(max) MW
	Unit	di	ei	fi		
A	G1	13.85932	0.32767	0.00419	10	125
	G2	13.85932	0.32767	0.00419	10	150
	G3	40.2669	-0.54551	0.00683	40	250
B	G4	40.2669	-0.54551	0.00683	35	210
	G5	42.89553	-0.51116	0.00461	130	325
C	G6	42.89553	-0.51116	0.00461	125	315

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Table 3 loss Coefficients of 6 units [20]

Bij	1	2	3	4	5	6
1	0.000091	0.000031	0.000029	0.000028	0.000031	0.000029
2	0.000031	0.000091	0.000028	0.000031	0.000029	0.000029
3	0.000029	0.000028	0.000091	0.000028	0.000031	0.000029
4	0.000028	0.000031	0.000028	0.000062	0.000029	0.000031
5	0.000031	0.000029	0.000031	0.000029	0.000062	0.000028
6	0.000029	0.000029	0.000029	0.000031	0.000028	0.000072

Case Study I – Without Loss (Cost and Emission)

In this case cost and emission without loss constraint are considered, here, the ABC algorithm implements as a single-objective optimization problem. The power load used 900 MW and 1170 MW and Parameter of ABC algorithm considered here are: N=30; Food-Number=N/2; and limit=100 and max Cycle 500. The result using the proposed ABC algorithm is in comparison with the recently reported methods is given in Table 4 and fig 2.

PLANT NAME		**Economic/Emission Dispatch Without loss**			
		Pareto optimal solution [20]	ABC **solution**	**Pareto optimal solution [20]**	ABC **solution**
	POWER LOAD	**900 MW**	**900 MW**	**1170 MW**	**1170 MW**
A	G1	32.4969	67.2006	49.3809	77.0295
	G2	10.8160	69.4331	35.1316	86.8251
B	G3	143.6467	240.1016	235.4875	199.*4061*
	G4	143.0317	205.7478	210.0000	204.2118
C	G5	287.1036	317.6183	325.0000	296.4383
	G6	282.9051	170.690052	315.0000	306.0892
Total fuel cost (Rs/hr)		45464	45456	59096	59010.0
Total emission (Kg/h)		795.0169	**649.7982**	1291.3	**11811.0**

Case study II – With loss (cost and Emission)

In this case cost and emission with loss constraint are considered, here, the ABC algorithm implements as a single-objective optimization problem. The power load used 900 MW and 1170 MW and Parameter of ABC algorithm considered here are: N=30; Food-Number=N/2; and limit=100 and max Cycle 500. The result using the proposed ABC algorithm is in comparison with the recently reported methods is given in Table 4 and fig 2.

PLANT NAME		Economic/Emission Dispatch With loss			
		Pareto optimal solution **[20]**	**ABC solution**	Pareto optimal solution **[20]**	**ABC solution**
	POWER LOAD	900 MW	**900 MW**	1170 MW	**1170 MW**
A	G1	33.8724	**19.3734**	71.2939	**70.2718**
	G2	12.7969	**19.2234**	66.6899	**69.6181**
B	G3	151.1287	**104.4038**	250.0000	**239.1193**
	G4	148.9459	**159.9865**	210.0000	**198.7708**
C	G5	297.0382	**302.1505**	325.0000	**281.1708**
	G6	294.5627	**294.8624**	315.0000	**310.9881**
Total fuel cost (Rs/hr)		47330	**47175**	62924	**62319**
Total emission (Kg/h)		862.9949	**698.6139**	1373.5	**1211.6**
Transmission loss (MW)		38.3448	**33.8123**	67.9838	**54.5365**

VI. CONCLUSION

The Emission and Economic Load dispatch problem being attempted using ABC algorithm for 6 generator test system evaluates the performance of the proposed approach of artificial bee colony; ABC is the best algorithm to reach the near Global optimal solution. However good choice of the number of iterations, population size, Employed and unemployed bees results in fast computation. The comparison shows that ABC solution performs better than Pareto optimal solution. The ABC solution algorithm has superior features, including stable convergence characteristic, quality of solution and better computational efficiency.

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