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Optimization of Combined Economic Emission Dispatch Problem using Artificial Bee Colony Method

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Abstract **— Optimal system operation, in general, involves the consideration of economy of operation, system security, emissions at fossil-fuel plants, optimal release of water at hydro power plants etc. and aim at improving the efficiency of the power system. In this research work, consideration will be given to two aspects of the optimal system operation, emissions and economy of operation, also known as economic dispatch. Generally the heuristic methods like Genetic algorithm, Simulated annealing, Particle Swarm Optimization, Ant Colony techniques and their various modifications have shown marked improvement in the addressing of the economic dispatch problem as well as the combined economic and emission dispatch problem. However there is scope of improvement of the solution to the combined economic and emission dispatch problems, in terms of better convergence, lower losses, faster computation times, reduced fuel costs and reduced emissions. It is worthy of notice that Artificial Bee Colony Method applied in the present work, yielded superior solutions than the heuristic and traditional optimization techniques.**

Index Terms — Optimization, Economic Emission Dispatch, Artificial Bee Colony

1. Introduction

A power system is constructed by using interconnected structures for transporting electric energy from generating sites to load centers a shared amount of a total power to meet a load demand at a certain period time of operation. One purpose of this strategy is to reduce the total technical operating cost through the combination various types of power plants. A minimizing cost problem of power system operation can be expressed by using an Economic Load Dispatch (ELD) for obtaining a minimum total fuel cost of generating units. In general, ELD's primary objective is to schedule the committed generating unit outputs to meet a certain load demand at a certain time under some operational constraints [1-3]. Presently, since the public awareness of the environmental protection has increased to reduce atmospheric emissions, the ELD considers pollutant emissions in the air from combustions of fossil fuels at thermal power plants [4]. By considering an Emission Dispatch (EmD), the power system operation has to modify operational strategies of the thermal power plants for reducing pollutants in the air [5]. The ELD problem has become a crucial task to optimize a fuel cost with reducing a pollutant emission for scheduling the generating unit outputs based on a minimum total cost [6]. To avoid complexity problems of both dispatching types for determining solutions with difference targets, ELD and EmD are transformed into single objective function as a Combined Economic and Emission Dispatch (CEED).

Artificial bee colony (ABC) algorithm invented by Karaboga has shown to be more effective than other conventional biological-inspired algorithms like genetic algorithm (GA), differential evolution (DE) and particle swarm optimization (PSO).Though, ABC is superior at exploration but poor at exploitation. This paper presents a recently developed optimization method, where ABC algorithm is modified to guide the search of candidate solution towards the global optima. Bonabeau et al. [7] focused their viewpoint on social insects alone, such as termites, bees, wasps as well as different ant species. A few models have been developed to model the intelligent behaviours of honeybee swarms and applied for solving combinatorial type problems [8–18]. There is only one numerical optimization algorithm in the literature based on intelligent behaviour of honeybee swarms [19]. Yang developed a virtual bee algorithm (VBA) [19] to solve the numerical optimization problems. VBA has been introduced to optimize only the functions with two parameters. In VBA, a swarm of virtual bees are generated and started to move randomly in the phase space. These bees interact when they find some target nectar corresponding to the encoded values of the function. The solution for the optimization problem can be obtained from the intensity of bee interactions. For optimizing multivariable numerical functions, Karaboga has described a bee swarm algorithm called artificial bee colony (ABC) algorithm [20], which is different from the virtual bee algorithm. The Bees Algorithm is a newly developed population-based optimization algorithm which has been verified in many fields. However, it is limited to solving single optimization problems. To apply the Bees Algorithm to a Multi-Objective Optimization Problem, either the problem is converted to single objective optimization or the Bees Algorithm modified to function as a Multi-Objective solver. The novel computation method - Artificial Bee Colony (ABC) algorithm was proposed by Karaboga in 2005 based on foraging behaviors of honeybees in nature [21]. ABC has ability to overcome difficulties of evolutionary methods for solving real problems with multi-dimensional spaces and reducing time of computation [22-24]. These points are covered by using bee's interaction on the gathering and sharing information during searching the best solution. The ABC also has a powerful computation contrasted to other evolutionary methods, an ability to get out of a local and a global minimum, a capability of handling complex problems, and an effectiveness for solving optimizing problems [4, 6, 20-21].

2. Artificial Bee Colony Method and CEED Optimization Method

This paper presents the ABC approach for obtaining the best solution to the CEED problems. The objective function of the CEED is subjected to some operational constraints. A problem of Economic Load Dispatch (ELD) is related to a nonlinear equation. The ELD's objective function is expressed by a total cost for providing a total power from generation stations and it can be computed by using equation. Presently, an ELD includes a pollutant emission as a constraint as well. Various pollutants are emitted by burning of fossil fuels in the thermal power plants. The total pollutant emission is formulated by equations of the Emission Dispatch (EmD). The ELD and EmD are composed into single objective function of CEED problem with considering a price penalty and a weighting factor as a compromised factor as formed in equation. The penalty factor shows the rate coefficient of each generating unit at its maximum output for the given load. The compromised factor shows a sharing contribution of ELD and EmD. Several limitations for performing CEED are given by equation. Specifically, a total transmission loss is not constant and it depends on the power outputs of generating units. The transmission loss can be derived from a load flow analysis. In general, the CEED problem can be formulated by using expressions as follows:

EmD minimize:-

$$E = \sum_{I=1}^{N} (\alpha_i + \beta_i P_i + \gamma_i P_i^2 + \zeta_i exp(d_i p_i)) \; ton$$

ELD minimize:-

$$F_c = \sum_{i=1}^{N} (a_i + b_i P_i + c_i P_i^2)$$

CEED minimize:-

$$\emptyset = w.Ftc + (1-w).h.Et$$

$$\sum_{i=1}^{n} Pi = P_d + P_l$$

$$P_{gp} = P_{dp} + V_p \sum_{q=1}^{nBus} Vq \left(G_{pq}.\cos\theta_{pq} + B_{pq}.\sin\theta_{pq}\right)$$

$$Q_{gp} = Q_{dp} + V_p \sum_{q=1}^{nBus} V_q \left(G_{pq}.\sin\theta_{pq} - B_{pq}.\cos\theta_{pq}\right)$$

$$P_{i\,min} \le P_i \le P_{i\,max}$$

$$Q_{i\,min} \le Q_i \le Q_{i\,max}$$

$$V_{p\,min} \le V_p \le V_{p\,max}$$

where P_i is output power of i^{th} generating unit (MW), a_i, b_i, c_i are fuel cost coefficients of i^{th} generating unit, F_{tc} is total fuel cost ($/hr), α_i, β_i, γ_i are emission coefficients of i^{th} generating unit, E_t is total emission of generating units (kg/hr), h_i is individual penalty factor of i^{th} generating unit, P_{imax} is maximum output power of i^{th} generating unit, E_i is total emission of i^{th} generating unit (kg/hr), F_i is fuel cost of i^{th} generating unit ($/hr), Φ is CEED ($/hr), w is compromised factor, n_g is number of generator, h is penalty factor of ascending order selection of h_i, P_d is power load demand, P_l is transmission loss, P_{gp} and Q_{gp} are power injections of load flow at bus p, P_{dp} and Q_{dp} are load demands of load flow at bus p, V_p and V_q are voltages at bus p and q, P_{imin} is minimum power of i^{th} generating unit, Q_{imax} and Q_{imin} are maximum and mini-mum reactive powers of i^{th} generating unit, V_{pmax} and V_{pmin} are maximum and minimum voltages at bus p.The challenges being faced by the above are high computational time, convergence to local optima, not feasible solutions and malfunctioning of algorithm for large and medium sized systems.

Artificial Bee Colony (ABC) is a swarm based a stochastic search algorithm which imitates the scrounging behaviour of honeybees. In ABC algorithm, the colony of artificial bees consists of three groups of bees: employed bees, onlookers and scouts. Some of the bee of colony consists of employed artificial bees and the some includes the on lookers. In other words, the number of employed bees is equal to the number of food sources around the hive. The employed bee whose food source has been abandoned becomes a scout. In ABC algorithm the position of food source determines the solution and the amount of nectar represents the fitness of the respective solution.

- **Movement of Employed Bees**

Probability of selecting a nectar source:

$$P_i = \frac{F(\theta_i)}{\sum_{k=1}^{s} F(\theta_k)}$$

P_i: The probability of selecting the ith employed bee
S : The number of employed bees
θ_i : The position of the ith employed bee
F(θ) : The fitness value

- **Movement of The Onlookers**

Calculation of the new position

$$x_{ij}(t+1) = \theta_{ij}(t) + \emptyset(\theta_{ji}(t) - \theta_{kj}(t))$$

x_i : The position of the onlooker bee.
t : The iteration number
θ_k : The randomly chosen employed bee.
j : The dimension of the solution
$\emptyset(\blacksquare)$ A series of random variable in the range

- **Movement of The Scouts**

The movement of the scout bees follows equation

$$\theta_{ij} = \theta_{jmin} + r.(\theta_{jmax} - \theta_{jmin})$$

r: A random number

3. Methodology

1. Objective Functions of Economic and Emission Dispatch Problem

Traditionally, solutions of the classical economic dispatch problem have focused on minimizing the total fuel cost only. However, due to rising public concerns about the environmental impact of fossil-fuelled electric power stations, a solution based only on the minimization of the economic cost is no longer acceptable and need to consider minimization of emissions as well. There are several strategies to reduce harmful atmospheric emissions such as installing pollution control equipment, switching to low-emission fuels, replacing aged fuel burners and generators with more efficient ones, and emission dispatching. The first three strategies can involve considerable costs. Moreover, due to the time-consuming procedures for the installation and modification of equipment, they can be regarded only as long term solutions. For these reasons, the emission dispatching strategy has represented an attractive short-term alternative in recent years. In this case, the economic dispatch problem is re-stated, taking into account emissions as well as the fuel costs. As a result, the problem is treated as a Multi-Objective optimization task with non-commensurable and conflicting goals.

The traditional way of solving a Multi-Objective optimization problem consists of representing the goals via a single-objective (SO) function, and minimizing this function whilst maintaining the physical constraints of the system. The evaluation result for the candidate solutions is thus expressed as a single value reflecting a compromise between the various conflicting goals. In the case of the economic dispatch problem, the SO function takes the form:

$$F(x)= w_1.f_c(x) + w_2.f_e(x)$$

where $x = \{x_1,...,x_n\}$ is an n-dimensional vector of decision variables representing a feasible solution. fc and fe are respectively the fuel cost and emissions and w_1 and w_2 are user-defined weights. Although this technique is relatively simple to implement, it is not suitable for Multi-Objective applications because engineers may need to evaluate the detailed fitness of a solution for all the optimization goals (f_c and f_e in the economic dispatch problem). In general, the set of solutions of a Multi-Objective optimization problem lies on a hyper surface formed by the best trade-offs (or Pareto front) which satisfy the multiple conflicting goals. In contrast to aggregation-based methods, intelligent techniques such as population-based algorithms are naturally suited to the direct generation of a Pareto front. This is because these methods work simultaneously to achieve solutions for the individual search objectives, and also evaluate multiple potential solutions in a single iteration. Therefore this generated Pareto front can help a Decision Maker (DM)/Engineer to know all possible solutions throughout the various ranges. However, the challenge for intelligent techniques is to guide the search towards the Pareto optimal set whilst maintaining population diversity to prevent premature convergence. In this paper, test runs, utilizing the proposed Bees Algorithm, were performed on the standard IEEE 30-bus 6 - generator test system using the proposed Bees Algorithm. Fig. 1 shows the test system layout.

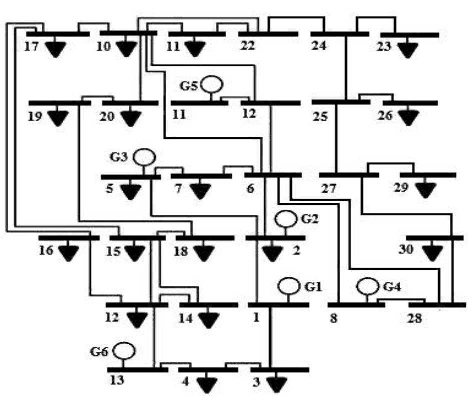

Fig. 1 One-line diagram of IEEE 30 bus system

1.1 Objective Function

The EEDP for power generation requires the simultaneous achievement of two objectives:

- **Fuel Cost Objective**

The requirement is to minimize the total fuel cost while satisfying the total demand. The equation used to determine the optimal combination for this problem is

$$F_c = \sum_{i=1}^{N} (a_i + b_i * P_{Gi} + c_i * P_{Gi}^2)$$

where:-
f : total fuel cost (\$/hr),
a_i, b_i, c_i : fuel cost coefficients of generator
P_{Gi}: power output by generator
n : number of generator

- **N_{Ox} Emission Objective**

This objective is necessary to minimize the total NOx emission. The total N_{Ox} emission created by burning fossil fuels is expressed as:

$$F_e = \sum_{i=1}^{N} (a_{iN} + b_{iN} * P_{Gi} + c_{iN} * P_{Gi}^2 + d_{iN} * exp(e_{iN} * P_{Gi}))\ kg/hr$$

where:-
Fe: total N_{Ox} emission (kg/hr),
a_{iN}, b_{iN}, c_{iN}, d_{iN}, and e_{iN} are N_{Ox} coefficients of the I^{th} generator emission characteristics.

1.2 Constraints

Two constraints need to be satisfied:

- **Power balance constraint**

The total power generated must supply the total load demand plus the transmission losses expressed as:

$$\sum_{i=1}^{n} Pgi = P_d + P_l$$

where
P_d : total load demand and
P_l : transmission losses.
For this work, P_l was assumed to be 0.

- **Generation limits constraint**

The power generated P a by each generator is constrained between its minimum and maximum limits stated as:

$$P_{Gi\ min} \leq P_{Gi} \leq P_{Gi\ max}$$

where
P_{Gimin}: minimum power generated by generator
P_{Gimax}: maximum power generated by generator

The transmission losses are given by:-

$$P_l = \sum_{i=1}^{N} \sum_{j=1}^{N} (r_l/v_i v_j)cos(\delta_i - \delta_j)(P_i P_j + Q_i Q_j) + (r_l/v_i v_j)sin(\delta_i -$$

where
N : number of buses
r_{ij} : series resistance connecting buses i and j
V_i : voltage magnitude at bus i
δ_i : voltage angle at bus i
P_i : real power injection at bus i
Q_i : reactive power injection at bus i

1.3 Multi-Objective formulation

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The Multi-Objective Environmental/Economic Dispatch optimization problem is therefore formulated as:

Minimize {f_c, f_e}

subject to:

$\sum_{i=1}^{n} P_{gi} = P_d$ (power balance), and

$P_{Gi\,min} \leq P_{Gi} \leq P_{Gi\,max}$ (generation limits).

Designed programs of application ABC for solving CEED problems are created by considering several steps of ABC's procedures. The listing programs are categorized into three programs. The data input program is consisted by a set data of parameters for generating units, transmission lines, loads, constraints, CEED's parameters and HSABC's parameters. The CEED program is designed for an objective function to compute a minimum total cost based on the CEED problem, compromised factors and constraints. The ABC program is developed by using HSABC's steps for searching the best solution of the CEED problem.

2. Artificial Bee Colony Algorithm

To calculate the values for given data, here is the algorithm which has to be follow during code generation through matlab software. The coding steps are as follows:-

- Generate n random solutions with in boundaries of the system.
  $P = P_{min} + rand*(P_{max} - P_{min})$
- Calculate the objective function and fitness of each solution.
- Store the best fit as P_{best} solution.
- A mutant solution is formed using a randomly selected neighbour.
  $P_{k\,mutant} = P_k(i) + (P_j(i) - P_k(i))*(2*rand - 1))$
  where j is the randomly selected neighbour and i is a random parameter
- Replace $P_{k\,mutant}$ by P_k, if the mutant has higher fitness or lower fuel cost of generation.
- Repeat the above procedure for all the solutions.
- Probability of each solution is calculated as:-
  Probability (i) =a*fitness (i)/max (fitness) + b
  where { a+b =1 }
- The solution P is selected if its Probability is greater than a random number
  If (rand<probability (i))
  solution is accepted for mutation
  else
  go for next solution
  counter is incremented
  While (Counter = population/2)
- Again the best P is determined.
- Replace a P by random P if its trial counter exceeds threshold.
- Repeat the above for max number of iterations.
- The P_{best} and $F(P_{best})$ are the best solution and Global min of the objective function.

4. Results and Discussion

The proposed ABC algorithm is tested on standard IEEE-30 bus system with six generating units. All the results shown are for 283.4 MW of load demand. The program of ABC algorithm is implemented on Matlab software. Here the adopted simulation parameters are:

Colony size=20
Limit=100
No. of iterations=200
Load demand=283.4

Here the term 'Price Penalty Factor' is represented by 'h' and it is given as:

h = (Quadratic equation of fuel cost) / (Quadratic equation of gas emission)

and overall combined economic emission dispatch (CEED) is written as:

F = (Fuelcost) + min(h) * Emission

Table I and Table II shows the cost and NO_x emission coefficients of six generating units [57]. Table3 shows the loss coefficients of IEEE-30 bus system.

TABLE I
GENERATOR COSTS AND COEFFICIENTS

Generator	a $/MW2hr	b_i $/MWhr	c_i $/hr	P_{min} MW	P_{max} MW
G1	0.0037	2.0000	0	50	200
G2	0.0157	1.7500	0	20	80
G3	0.0625	1.0000	0	15	50
G4	0.0083	3.2500	0	10	35
G5	0.0250	3.0000	0	10	30
G6	0.0250	3.0000	0	12	40

TABLE II
GENERATOR EMISSION COEFFICIENTS

Generator	α Kg/MWhr^2	β Kg/MWhr	γ Kg/hr	Q_{min} Mvar	Q_{max} Mvar
G1	0.0126	-1.1000	22.9830	100	-100
G2	0.0200	-0.1000	25.3130	60	-60
G3	0.0270	-0.0100	25.5050	65	-15
G4	0.0291	-0.0050	24.9000	50	-15
G5	0.0290	-0.0040	24.7000	40	-10
G6	0.0271	-0.0055	25.3000	15	-15

TABLE III
LOSS COEFFICIENTS FOR IEEE 30 BUS SYSTEM (B-MATRIX)

0.000218	0.000102	0.000010	0.000010	0.000001	0.000027
0.000102	0.000187	0.000004	0.000015	0.000003	0.000031
0.000010	0.000004	0.000430	0.000134	0.000160	0.000108
0.000010	0.000015	0.000134	0.000097	0.000097	0.000051
0.000001	0.000003	0.000160	0.000256	0.000256	0.000000

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0.000027	0.000031	0.000108	0.000000	0.000000	0.000359

Table IV gives the result of comparison between the Evolutionary Programming method [58] and ABC method. In this comparison we can see that the EP method gives the local minimum optimized value whereas proposed ABC algorithm shows the nature of global minima. Here we can say that we can save 23.22 $/hr in fuel cost. Likewise in Table V, ABC method is compared with PSO method [59] and proposed algorithm is superior to PSO. We save 18.56 $/hr in fuel cost and 20.59 kg/hr of gas emission. The total operating cost is also very low as compared to PSO to 1052 $/hr.

TABLE IV
THE BEST SOLUTION FOR FUEL COST AND EMISSION GAS OPTIMIZED SIMULTANEOUS FOR ABC METHOD

Generator unit (MW)	**EP method**	**ABC method**
P1	118.770	141.9103
P2	62.246	50.8288
P3	34.462	24.3045
P4	24.289	30.5851
P5	21.621	21.9017
P6	28.072	22.0773
Fuel Cost ($/hr)	840.219	816.9996
Emission (Kg/hr)	350.509	356.6430

TABLE V
BEST OPTIMIZED VALUES FOR ABC IS COMPARED WITH PSO METHOD

Method	**Price Penalty Factor - h ($/kg)**	**Fuel Cost ($/hr)**	**Emission Output (kg/hr)**	**Total Operating Cost ($/hr)**	**Total Loss (MW)**
PSO	2.3340	835.5655	377.2407	1624	5.664
ABC	2.3340	816.9996	356.6430	1052.20	8.2087

From Fig. 1 to Fig. 8, the realization of simulation result is been shown. Fig. 2, Fig. 3, Fig. 4 and Fig. 5 are scaled between no. of iterations and objective value, fitness value, fuel cost and emission respectively. The Fig. 1 is 3-D diagram and drawn between emission, cost and no of iterations. Fig. 6 is realization of fuel cost per generator unit with no of generators.

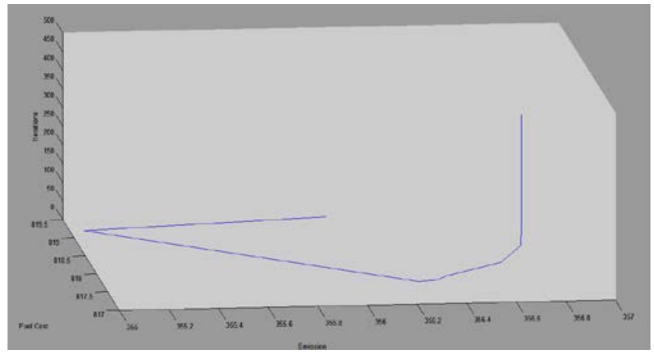
Fig. 1. Graph between emission, cost and iterations

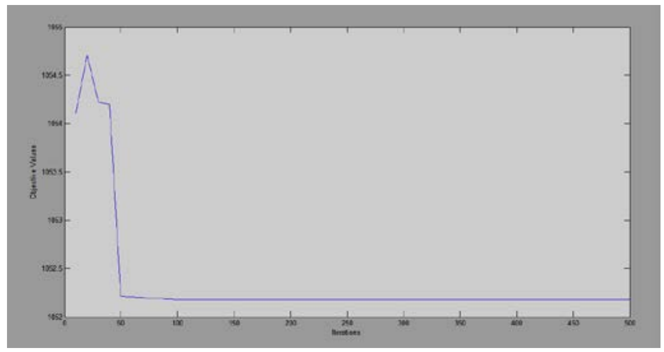
Fig. 2. Graph between total objective values and no. of iterations

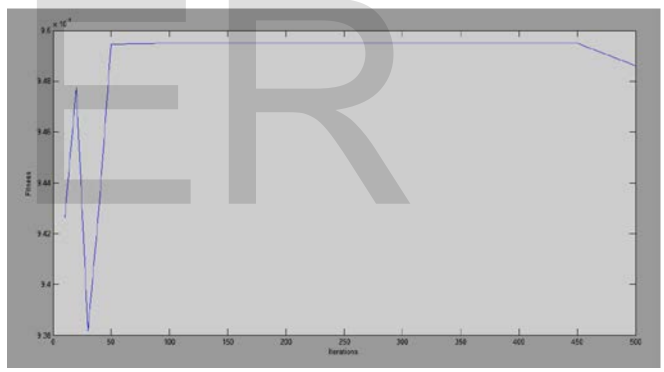
Fig. 3. Graph between fitness and no. of iterations

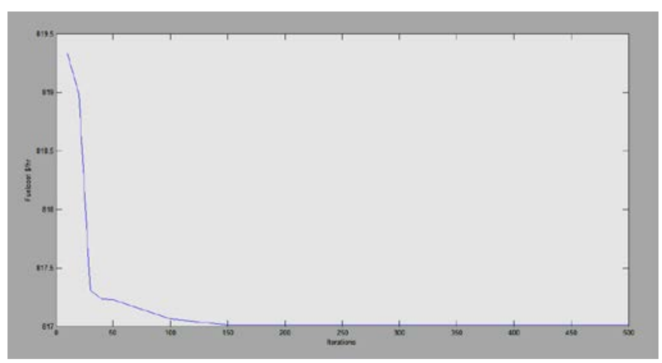

Fig. 4. Graph b/t fuel cost and no of iterations

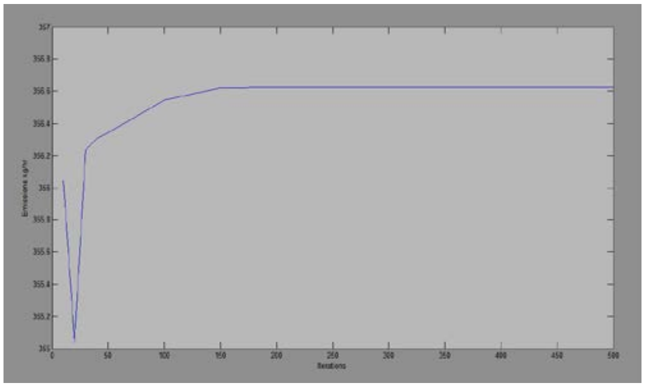

Fig. 5. Graph between emission and no. of iterations

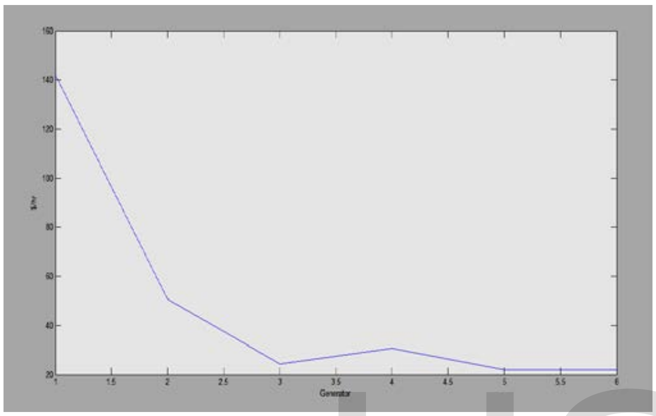

Fig. 6. Graph between fuel cost/unit and no. of generators

5. Conclusion

The application of the ABC method in the field of Power Flow studies to optimize Combined Economic Emission Dispatch Problem has been demonstrated in this paper. The test results for the problem brings out several advantages of the ABC method: In the ABC method, there is only one population in each iteration, that moves towards the global optimal point. The convergence abilities of the ABC method are better than that of the evolutionary and PSO methods. The price penalty factor for solving the CEED problem has been demonstrated on the IEEE 30 bus test system in order to obtain the exact total operating cost. The better efficiency and convergence property of the proposed PSO approach shows that it can be applied to a wide range of optimization problems. The computational time is high for convergences.

ABC algorithm can further be improved, which would make it most effective and efficient method for optimization. ABC can be modified using operators of fast computational algorithms to get a hybrid fast computational ABC. The effect of weighted sum method and valve point effect with the use of penalty factor can much improve the ABC optimization method for CEED problems. Hybridization of this algorithm with some other optimization techniques could make it more effective in achieving the global optimum.

6. References

[1] H. Chahkandi Nejad, 1R. Jahani, 1M. Mohammad Abadi, "GAPSO-based Economic Load Dispatch of Power Sys-tem", Australian Journal of Basic and Applied Sciences, Vol. 5, No.7, 2011, pp. 606-611.

[2] M. A. Abido, "Multiobjective Evolutionary Algorithms for Electric Power Dispatch Problem," IEEE Transac-tions on Evolutionary Computation, Vol. 10, No. 3, 2006, pp. 315-329.

[3] S. Sayah, K. Zehar, "Economic Load Dispatch with Secu-rity Constraints of the Algerian Power System Using Successive Linear Programming Method," Leonardo Journal of Science, No. 9, 2006, pp. 73-86

[4] Y. Z. Cheng, W. P. Xiao, W.-J. Lee and M. Yang, "A New Approach for Missions and Security Constrained Economic Dispatch", Proc. NAPS, IEEE Conference Publication, Starkville USA, 4-6 Oct 2009, pp. 1-5.

[5] M. A. Abido, "Environmental/economic Power Dispatch Using Multi objective Evolutionary Algorithm," IEEE Transactions Power Systems, Vol. 18, No. 4, 2003, pp. 1529-1537.

[6] F. S. Abu-Mouti and M. E. El-Hawary, "Optimal Distributed Generation Allocation and Sizing in Distribution System via Artificial Bee Colony Algorithm," IEEE Journal & Magazines, Vol. 26, No. 4, 2011, pp. 2090-2101.

[7] E. Bonabeau, M. Dorigo, G. Theraulaz, "Swarm Intelligence: From Natural to Artificial Intelligence", NY: Oxford University Press, New York, 1999.

[8] L.N. De Castro, F.J. Von Zuben, "Artificial Immune Systems, Part I. Basic Theory And Applications", Technical Report No. Rt Dca 01/99, Feec/ Unicamp, Brazil, 1999.

[9] J. Vesterstrøm, J. Riget, "Particle swarms extensions for improved local, multimodal and dynamic search in numerical optimization", M.Sc. Thesis, May 2002.

[10] J. Kennedy, R.C. Eberhart, "Particle swarm optimization", Proceedings of the 1995 IEEE International Conference on Neural Networks, vol. 4, 1995, pp. 1942–1948.

[11] V. Tereshko, "Reaction-diffusion model of a honeybee colony's foraging behaviour", M. Schoenauer, et al. (Eds.), Parallel Problem Solving from Nature VI, Lecture Notes in Computer Science, vol. 1917, Springer- Verlag, Berlin, 2000, pp. 807–816.

[12] V. Tereshko, T. Lee, "How information mapping patterns determine foraging behaviour of a honey bee colony", Open Syst. Inf. Dyn. 9 (2002) 181–193.

[13] V. Tereshko, A. Loengarov, "Collective decision-making in honey bee foraging dynamics", Comput. Inf. Syst. J. 1352-94049 (2005).

[14] D. Teodorovicˇ, "Transport modeling by multi-agent systems: a swarm intellgence approach", Transport. Plann. Technol. 26-4 (August) (2003) 289–312.

[15] P. Lucic, D. Teodorovicˇ, "Transportation Modeling: An Artificial Life Approach", ICTAI, 2002, pp. 216–223.

[16] D. Teodorovicˇ, M. Dell'orco, "Bee colony optimisation—a cooperative learning approach to complex transportation problems", 10th EWGT Meeting, Poznan, 13–16 September, 2005.

[17] K. Benatchba, L. Admane, M. Koudıl, "Using bees to solve data-mining problem expressed as a max-sat one, artificial intelligence and knowledge engineering applications: a bioinspired approach", First International Work-Conference on the Interplay Between Natural and Artificial Computation, IWINAC 2005, Las Palmas, Canary Islands, Spain,

ISSN 2229-5518
June 15–18, 2005.

[18] H.F. Wedde, M. Farooq, Y. Zhang, "BeeHive: an efficient fault-tolerant routing algorithm inspired by honey bee behavior, ant colony, optimization and swarm intelligence", 4th International Workshop, ANTS 2004, Brussels, Belgium, September 5–8, 2004.

[19] X.S. Yang, "Engineering Optimizations via Nature-Inspired Virtual Bee Algorithms", Lecture Notes in Computer Science, 3562, Springer-Verlag GmbH, 2005,, p. 317.

[20] D. Karaboga and B. Basturk, "A Powerful and Efficient Algorithm for Numerical Function Optimization: ABC Algorithm," Journal of Global Optimization, Vol. 39, No. 0925-5001, 2007, pp. 459-471.

[21] D. Karaboga, "An Idea Based on Honey Bee Swarm for Numerical Optimization", Technical Report-TR06, Erciyes University, Turkey, 2005.

[22] M. Subotic, "Artificial Bee Colony Algorithm for Con-strained Optimization Problems Modified with Multiple Onlookers," International Journal and Mathematical Models and Methods in Applied Sciences, Vol. 6, No. 2, 2012, pp.314-322.

[23] N. Stanarevic, M. Tuba and N. Bacanin, "Modified Ar-tificial Bee Colony Algorithm for Constrained Problems Optimization", International Journal of Mathematical Models and Methods in Applied Science, Vol. 5, No. 3, 2011, pp. 644-651.

[24] E. M. Montes, M. D. Araoz and O. C. Dominges, "Smart Flight and Dynamic Tolerances in the Artificial Bee Colony for Constrained Optimization," Proc. IEEE Congress on Evolutionary Computation CEC , Barcelona, 18-23 July 2010, pp. 1-8.