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RESEARCH ARTICLE

Application of Modified Artificial Bee Colony Algorithm for Combined Economic Load and Emission Dispatch

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Abstract

The ELD problem in a power system is to determine the optimal combination of power outputs for all generating units which will minimize the total fuel cost while satisfying all practical constraints. Since optimum economic dispatch is not environmentally the best solution so it is required to reduce the pollution or emissions as well. Hence the classical economic dispatch problem is modified to economic-emission dispatch problem. Further, there are many inaccuracies and uncertainties in the input information which lead to deviations from optimal operation and cause an increase in the cost over the optimal value, therefore stochastic model is formed to solve the practical problem. Here, an attempt has been made to solve the stochastic economic-emission load dispatch problem using Modified Artificial Bee Colony Algorithm (MABC).Recently evolution search techniques are used to solve ELD problem. The technique used in this thesis is Modified Artificial Bee Colony Algorithm. There are number of applications of MABC. It has emerged as a useful tool for engineering optimization. In this paper, three and six unit test system has been considered for economic and emission dispatch. MABC search method is used to obtain the best optimal solution.

INTRODUCTION

This paper introduce the economic dispatch problem in a power system to determine the optimal combination of power output for all generating units which will minimize the total fuel cost while satisfying load and operational constraints. The economic dispatch problem is very complex to solve because of a non-linear objective function, and a large number of constraints.

Well known long-established techniques such as integer programming, dynamic programming (3), and lagarangian relaxation (4) have been used to solve the economic dispatch problem. Recently other optimization methods such as Simulated Annealing (K.P. wang et al, 1993), Genetic Algorithm (L.G. Damousis et al, 2003), Particle Swarm optimization (A. Immanuel et al,2003) and Tabu Search Algorithm (M. Sudhakaran et al, 2005) are presented to solve the economic dispatch problem.

Recently, various modern heuristics multi-objective evolutionary algorithms such as Non-dominated Sorting Genetic Algorithm- II (NSGA-II), Evolutionary Programming algorithm (EP), Strength Pareto Evolutionary Algorithm (SPEA) and Multi-Objective Particle Swam Optimization algorithm (MOPSO) may prove to be efficient in solving EED problem by tackling both two objectives of EED problem simultaneously as competing objectives. But all these methods seem to be lack of ability to find the Pareto-optimal front due to their drawbacks: NSGA-II and SPEA may obtain only near Pareto-optimal front with long simulation time when applied to solve EED problem because of the premature convergence of Genetic Algorithm (GA) which they are based on EP suffers from the oscillation of the solution and computational time may be too long when applying EP to solve EED problem, the

premature convergence of PSO may lead optimization progresses of MOPSO methods to the local Pareto-optimum front, which would degrade their performance in solving EED problem. In (M. Muslu,J N Chandra et al, 2004, 2014) including emission constrains to the economic dispatch and unit commitment problems have been presented, under cost- minimization environment.
In this paper a multi-objective optimization problem i.e., Modified Artificial Bee Colony Algorithm (karaboga et al, 2012) is proposed to solve combined economic and emissions dispatch problems is presented and the effectiveness of proposed algorithm is demonstrated using three and six generating unit test systems.

Combined Environmental Economic Dispatch

The traditional economic dispatch problem has been defined as minimizing of an objective function i.e., the generation cost function subject to equality constraints (total power generated should be equal to total system load plus losses for all solutions) and inequality constraints (generations should lie between their respective maximum and minimum specified values). The objective function (1) is minimized subjected to equality constraint (2) and inequality constraints (3).

$$\varphi(x,P)\varphi_t(P_i) = \sum_{i=1}^{n} \varphi_i(P_i) \quad (1)$$
$$g(x,P)\sum_{i=1}^{n} P_i - P_L - P_D = 0 \quad (2)$$
$$H(x,P) \leq 0 \quad P_{imin} \leq P_i \leq P_{imax} \quad (3)$$

Where x is a state variable, Pi is the control variable, i.e., real power setting of i_{th} generator and n is the number of units or generators.

There are several ways to include emission into the problem of economic dispatch. (JN Chandra et al, 2014) summarizes the various algorithms for solving environmental dispatch problem with different constraints. One approach is to include the reduction of emission as an objective. In this work, only NO_x reduction is considered because it is a significant issue at the global level. A price penalty factor (h) is used in the objective function to combine the fuel cost, Rs/hr and emission functions, kg/hr of quadric form.
The combined economic and emission dispatch problem can be formulated as to minimize

$$\varphi_i = \sum_{i=1}^{n} E_i(P_i)\ Rs/hr \quad (4)$$
$$\varphi_i = \sum_{i=1}^{n}(a_i\,{P_i}^2 + b_iP_i + c_i) + h\sum_{i=1}^{n}(d_i\,{P_i}^2 + e_iP_i + f_i)Rs/hr \quad (5)$$

Subject to equality and inequality constraint defined by equations (2), (3). Once price penalty factor (h) is known, equation (5) can be rewritten as

$$\varphi_i = \sum_{i=1}^{n}\{(a_i + h\,d_i){P_i}^2 + (b_i + he_i)P_i + (c_i + f_i)\}\ Rs/hr \quad (6)$$

This has the resemblance of the familiar fuel cost equation, once h is determined. A practical way of determining h is discussed by (JN Chandra et al, 2014) Consider that the system is operating with a load of PD MW, it is necessary to evaluate the maximum cost of each generator at its maximum output, i.e.,

(i) Evaluate the maximum cost of each generator at its maximum output, i.e.,

$$F_i(P_{imax}) = (a_i\,{P_{imax}}^2 + b_{imax}\,P_i + c_{imax})\ Rs/hr \quad (7)$$

(ii) Evaluate the maximum NO_x emission of each generator at its maximum output, ie,

$$E_i(P_{imax}) = (d_i\,{P_{imax}}^2 + e_{imax}\,P_i + f_{imax})\ \ kg/hr \quad (8)$$

(iii) Divide the maximum cost of each generator by its maximum NO_x emission, i.e.,

$$\frac{F_i(P_{imax})}{E_i(P_{imax})} = \frac{(a_i\,{P_{imax}}^2 + b_{imax}\,P_i + c_{imax})}{(d_i\,{P_{imax}}^2 + e_{imax}\,P_i + f_{imax})} Rs/kg \quad (9)$$

Recalling that

$$\frac{F_i(P_{imax})}{E_i(P_{imax})} = h_i \ \text{Rs/kg} \quad (10)$$

(iv) Arrange hi (I = 1,2,......,n) in ascending order.

(v) Add the maximum capacity of each unit, one at a time, starting from the smallest h_i unit until total demand is met as shown below.

$$\sum_{i=1}^{n} P_{imax} \geq P_D \tag{11}$$

At this stage, hi associated with the last unit in the process is the price penalty factor h Rs/Kg for the given load.

Arrange hi in ascending order. Let ‘h’ be a vector having ‘h’ values in ascending order.

$$h = [h_1, h_2, h_3, \ldots., h_n] \tag{12}$$

For a load of PD starting from the lowest hi value unit, maximum capacity of unit is added one by one and when this total equals or exceeds the load, hi associated with the last unit in the process is the price penalty factor for the given PD. Then equation (6) can be solved to obtain environmental economic dispatch using lambda iteration method.

Modified ABC Algorithm

The MABC algorithm (karaboga et al, 2012) is a population-based metaheuristics algorithm that mimics the foraging behavior of honey bee swarms. The MABC algorithm classifies bees in a colony into three main groups: employed bees, onlooker bees, and scout bees. Employed bees are responsible for exploiting the food sources and sharing the information about these food sources. Onlooker bees wait in the hive and take the food source information from employed bees to make a decision on further exploiting the food source. Scout bees randomly search the environment to find a new food source. In the MABC algorithm, each candidate solution to the problem is associated with a food source and is represented by a n-dimensional real-coded vector. The quality of a solution corresponds to the nectar amount on that food source, and one employed bee explores each food source. In other words, the number of the employed bees is equal to the number of food sources. The colony is equally divided into employed and onlooker bees. A food source, which cannot be improved for a predetermined number of tries, is abandoned and the employed bee associated with that food source becomes a scout. In the MABC algorithm, the employed and onlooker bees are responsible for exploiting, whereas the scout bees handle exploring. The main steps of the MABC algorithm are as follows

(1) Initialization,
(2) Evaluating the population,
(3) Repeat,
(4) Employed bee phase,
(5) Onlooker bee phase,
(6) scout bee phase,
(7) Until (termination criteria are satisfied).

3.1. Initialization. In the initialization step, the MABC algorithm generates a randomly distributed population of SN solutions (food sources), where SN denotes the number of employed or onlooker bees. Let xi= {xi,1, xi,2,..., xi,n} represent the ith food source, where $D$is the problem size. Each food source is generated within the range of the boundaries of the parameters by

$$x_{i,j} = x_j^{\min} + \text{rand}\,(0,1)\left(x_j^{\max} - x_j^{\min}\right), \tag{13}$$

Where $i = 1, \ldots, \text{SN}$, $j = 1 \ldots D$. $x^{\min}$, and $x^{\max}{}_j$ are the lower and upper bound for the dimension j, respectively.

3.2. Employed Bee Phase. In the employed bee phase, employed bees generate a neighboring food source Vi,j by performing a local search around each food source i∈{1, 2,..., SN} as follows:

$$v_{i,j} = x_{i,j} + \Phi_{i,j}\left(x_{i,j} - x_{k,j}\right) + \Psi_{i,j}\left(y_j - x_{i,j}\right) \tag{14}$$

where $yj$is the jth element of global best solution, Ψi,j is a uniform random number in [0, C] where C is a nonnegative constant and is suggested to be 1.5, Φi,j is a random number in the range [−1, 1], and j∈ {1, 2,..., n} is a randomly chosen index.

3.3. Onlooker Bee Phase. Onlooker bees select a food source depending on the probability value prob associated with that food source. The value $p$is calculated as follows:

$$\text{prob}_i = \frac{f_i}{\sum_{j=1}^{\text{SN}} f_j}, \tag{15}$$

Where $f_i$is the objective function value of solution i. By using this mechanism, food sources having better fitness values will be more likely to be selected. Once the onlooker bee has chosen the food source, she generates a new solution using (13). As in the employed bee phase, a greedy selection is carried out between $xi$and Vi.

In the employed bee phase, a local search is applied to every food source, whereas only the selected food sources will be updated in the onlooker bee phase.

3.4 Scout Bee Phase. If a food source cannot be improved for a predetermined number of tries, then the employed bee associated with that food source becomes a scout bee. Then, the scout bee finds a new food source using (14). After the scout bee finds a new source, she becomes an employed bee again. Scout again.

Results

The applicability and efficiency of MABC algorithm for practical applications has been tested on two test cases. The programs are developed using MATLAB 7.9.

Test system I: Three generator system

The system consists of three thermal units. The parameters of all thermal units are adapted from (Gaurav Prasad et al 2011).

Table 1: Fuel cost Coefficients

Unit	Fuel cost coefficients			$P_{G\,min}$ (MW)	$P_{G\,max}$ (MW)
	a_i	b_i	c_i		
G1	0.03546	38.30553	1243.53110	35	210
G2	0.02111	36.32782	1658.56960	130	325
G3	0.01799	38.27041	1356.65920	125	315

Table 2: emission cost Coefficients

Unit	Emission coefficients			$P_{G\,min}$ (MW)	$P_{G\,max}$ (MW)
	d_i	e_i	f_i		
G1	0.00683	-0.5455	40.26690	35	210
G2	0.00461	-0.5116	42.89553	130	325
G3	0.00461	-0.5116	42.89553	125	315

Table 3: results

Load demand	h, Rs/kg	Performance	Conventional Method [8]	MABC
400	44.788	Fuel cost, Rs/hr	20898.83	20838.729
		Emission, kg/hr	201.5	200.198
		Power loss, MW	7.41	7.403120
		Total cost, Rs/hr	29922	29805.615
500	44.788	Fuel cost, Rs/hr	25486.64	25494.904
		Emission, kg/hr	312.0	311.125
		Power loss, MW	11.88	11.679210
		Total cost, Rs/hr	39458	39429.646
700	47.82	Fuel cost, Rs/hr	35485.05	35462.826
		Emission, kg/hr	652.55	354.628
		Power loss, MW	23.37	23.334221
		Total cost, Rs/hr	66690	66617.903

Table: 3 shows the summarized result of CEED problem for load demand of 400MW, 500MW and 700MW are obtained by the proposed MABC algorithm with stopping criteria based on maximum-generation=100.

Form Table: 3, it is clear that MABC algorithm gives optimum result in terms of minimum fuel cost, emission level and the total operating cost compared to other algorithms. Table: 4 gives the best optimum power output of generators for CEED problem using MABC algorithm for load demand 400MW, 500MW and 700MW.

Table 4: output of generators

Load demand, MW	**Algorithm**	**P1**	**P2**	**P3**
400	MABC	102.5546	152.7996	152.0485
500	MABC	128.8494	191.4610	191.3687
700	MABC	182.6259	270.3542	270.3541

The convergence tendency of proposed MABC algorithm based strategy for power demand of 400MW, 500MW and 700 MW is plotted in figure: 1. It shows that the technique converges in relatively fewer cycles thereby possessing good convergence property.

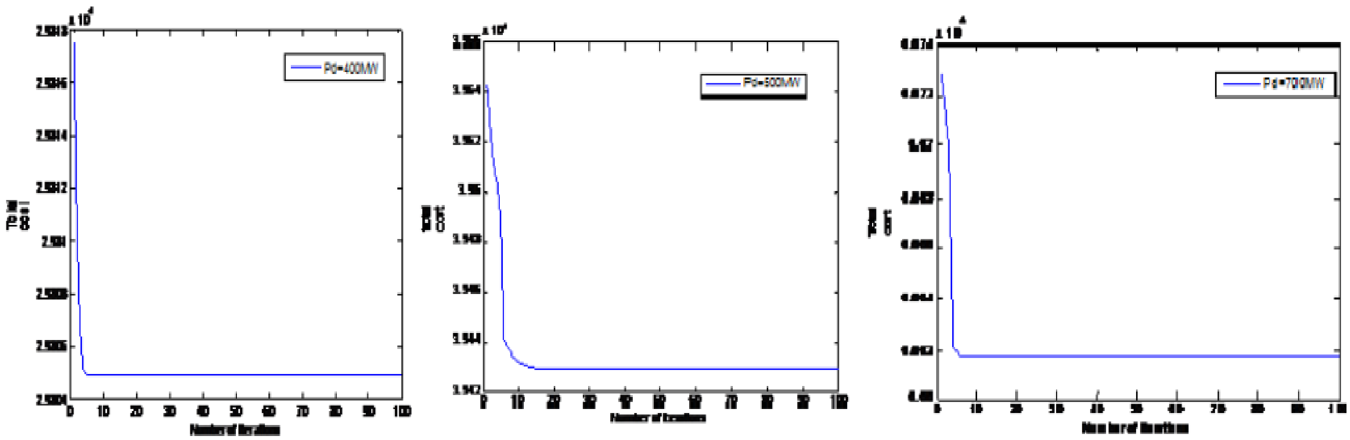

Figure: 1 convergence of three generating units system for load demand values 400MW, 500MW & 700MW

Test system II: Six generator system

The system consists of six thermal units. The parameters of all thermal units are adapted from (Gaurav Prasad et al 2011). The summarized result of CEED problem for load demand of 500MW and 900MW are obtained by the proposed MABC algorithm with stopping criteria based on maximum-generation=100 is presented in Table: 5.

Table: 5 Results for six generating unit system

Load demand	h, Rs/kg	Performance	Conventional Method [10]	MABC
500	43.89	Fuel cost, Rs/hr	27638.300	27613.247
		Emission, kg/hr	262.454	263.013
		Power loss, MW	8.830	8.934145
		Total cost, Rs/hr	39159.500	39158.9
900	47.82	Fuel cost, Rs/hr	48892.900	48350.683
		Emission, kg/hr	701.428	693.788
		Power loss, MW	35.230	28.009673
		Total cost, Rs/hr	82436.580	81529.00

Form Table: 5, it is clear that MABC algorithm gives the optimum result in terms of minimum fuel cost, emission level and the total operating cost compared to other algorithms.

Table: 6 gives the best optimum power output of generators for CEED problem using MABC algorithms for load demand 500MW and 900MW.

Table: 6 Optimum Power dispatch results by MABC Approach for six unit system

Load demand, MW	Algorithm	P1	P2	P3	P4	P5	P6
500	MABC	33.2733	26.8554	89.9135	90.4852	135.6435	132.7631
	BAT	33.2703	26.85061	89.91347	90.48638	135.6411	132.762
900	MABC	92.3297	98.3912	150.1948	148.5588	220.4043	218.1307
	BAT	92.3288	98.3910	150.1132	148.5586	220.4007	218.1267

The convergence tendency of proposed MABC algorithm based strategy for power demand of 500MW and 900 MW is plotted in figure:2. It shows that the technique converges in relatively fewer cycles there by possessing good convergence property.

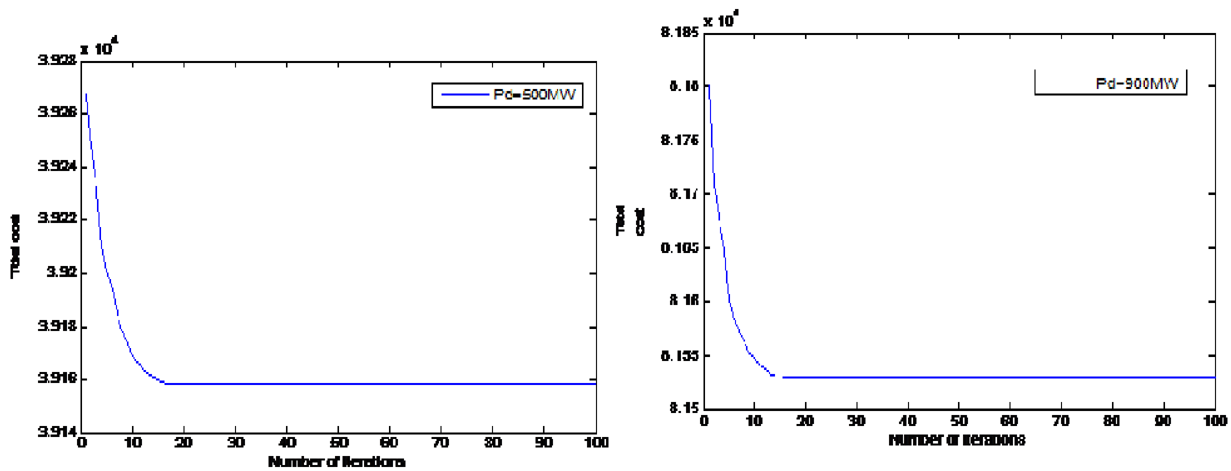

Figure: 2 convergence of six generating unit system for load demand values of 500MW and 900MW.

Conclusion

The public attitude towards environmental issues necessitates the optimal economic- environmental power dispatch. In the traditional power dispatch problems, all the variables involved are treated as deterministic ones and the inaccuracies and uncertainties inherent in the practical power system operations are ignored. In this thesis, a new optimization of MABC algorithm has been proposed. In order to prove the effectiveness of algorithm it is applied to CEED problem with three and six generating unit. The results obtained by proposed method were compared to those obtained conventional method. The comparison shows that MABC algorithm performs better than above mentioned method. The MABC algorithm has superior features, including quality of solution, stable convergence characteristics and good computational efficiency. Therefore, this results shows that MABC optimization is a promising technique for solving complicated problems in power system.

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*h values are considered based on literature.