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Solution to Optimization Problem Through Evolutionary Algorithm Using Weighting Function Method

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Abstract: The need for reduction in emission of harmful gases such as carbon dioxide, sulfur dioxide and nitrogen oxides from fossil fuel fired power plants has attracted our attention since it pollutes the atmosphere. So an attempt has been made to combine the concept of emission dispatch along with an economic dispatch problem with the help of the ABC algorithm using the weighting function method in power system operation. To apply this algorithm the original problem of optimization has been changed into the problem of identifying the best parameter that optimizes the objective function. This algorithm has shown its effectiveness in solving many real world problems with many constraints in different domains. The designed approach has been tested using Standard IEEE 30 bus system with incremental cost function along with emission coefficients valve opening and closing effects in the power plant. The result obtained shows that the designed approach was identified to be the best and most efficient in identifying the global minimum among the search space compared with other existing techniques.

Keywords: Combined Economic Emission Dispatch, Artificial Bee Colony, Optimization Techniques.

1 Introduction

In power system planning and operation the scheduling of the generated output power from various units become most important issue simultaneously meeting the system requirements [9]. The total operating cost of the generator includes the matching of load demand, both the side limits of power and also the stability of the power systems. Over the past few years the reduction of harmful gaseous emission has been combined along with minimization of operating cost. The harmful gases such as carbon dioxide, sulfur dioxide and nitrogen oxide has been causing pollution to the atmosphere. Though the main aim of the problem is minimizing the cost of operation and reduction of harmful gaseous emission subjected to different categories of physical and operating constraints convert the problem to more complicated nonlinear constrained optimization problem for huge power systems.

The input, output characteristics of the machine becomes a piecewise quadratic function due to valve point loading in the plants that uses fossil fuels. And also the units may have unavoidable operating zones due to the faults developed in the machineries or the auxiliaries associated with it such as the boilers, feed pumps, etc., and the operating range of online units may be constrained due to ramp rate limits of the generating units. Due to nonlinear characteristics of the problem with many numbers of constraints and more numbers of local optimum solutions the conventional methods such as a Lambda iteration method, participation factor method, Newton's method and gradient method cannot perform well. Even though the dynamic programming method is applied for solving this non linearity problem, it suffers due to large dimension.

Evolutionary algorithms like Genetic Algorithm and Evolutionary programming are very much faster than simulated annealing due to the process of parallel search technique. Ahmed Farag et al.(1995) [2] applies the linear programming method to solve the problem of Economic load dispatch with the help of restriction factor as a bi objective optimization problem. Harry Rughooputh et al.(2005) [4] implies two different approaches such as deterministic and stochastic methods to solve combined economic emission dispatch problem. Lakshmi A. Devi et al.(2008) [5] employs the soft computing technique to

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solve the environmental economic load dispatch problem. M. R. Airashidi et al.(2008) [6] discuss about the implementation of weighting function by considering the loading factors on both economic and emission dispatch problems.

Gaurav Prasad et al.(2011) [7] employs ABC approach to solve economic load dispatch problem and the result has been compared with other methods which has stable convergence, better computational efficiency and quality of solution. Sonmez et al.(2011) [8] explains about the implementation of the Bee Colony algorithm to solve the Bi-objective optimization problem using a penalty factor approach which is more efficient. Similarly Particle Swarm Optimization algorithm which imitates the food searching behavior of birds for solving the nonlinear constrained minimization or maximization problem. Jose et. al(2016) [11] discusses the implementation of the ABC approach for composing the medical crews by developing and demolishing operator in the algorithm. Gao Weifeng et al.(2016) [12] implies ABC in Elite guide search equations. Xiaoyu Song et al.(2017) [13] discusses the about involvement of ABC in solving function value information. Genghuili et al.(2017) [14] explains about the implementation of the ABC algorithm in gene recombination for numerical function. Fulizhong et al.(2017) [15] explains about the use of ABC in searching strategy for global optimization.

2 Problem Formulation

The motive of the CEED problem is to reduce the cost of the fuel $F(P_{gi})$ and emission factor $E(P_{gi})$ simultaneously by satisfying both equality and inequality constraints Wood et al.(1996) [1].

$$F(Pg_i) = c_i P_i^2 + b_i P_i + a_i. \tag{1}$$

The cost function has been changed due to the inclusion of valve point effect

$$F(Pg_i) = c_i P_i^2 + b_i P_i + a_i + e_i \sin\left(f_i(P_{i,\min} - P_i)\right) \tag{2}$$

The Emission objective function is given by

$$E(P_{gi}) = \alpha_i P_{gi}^2 + \beta_i P_{gi} + \gamma_i + \eta_i \times \exp(\delta_i \times P_{gi}) \text{ lb/hr} \tag{3}$$

2.1 Constraints

The Optimization of the Bi-objective function has to be satisfied by practical constraints.
Equality Constraints:
Limit of total power generated must satisfy the following equation

$$\sum P_{gi} - P_D - P_l = 0 \tag{4}$$

P_{gi}—Real Power generated by ith generator
P_D—Total Load Demand
The total loss P_l is given by

$$P_l = \sum_{i=1}^{NG} \sum_{j=1}^{NG} P_{gi} B_{ij} P_{gj} \tag{5}$$

Inequality Constraints: Limit of Active Power

$$P_{i,\min} \leqslant P_{it} \leqslant P_{i,\max} \tag{6}$$

where $P_{i,\min}$ is the lowest limit and $P_{i,\max}$ is the highest limit of the real power of the ith unit at time t in megawatts.

3 Combined Economic Emission Dispatch

There are numbers of methods implemented for combining the single objective function into a multi objective optimization problem. The methods are as follows:

1. Price penalty factor method:
   The objective function is written as
   $G(P_{gi}) = F(P_{gi}) + p_f E(P_{gi})$
   where p_f is the price penalty factor calculated based on the maximum values of fuel cost and emission rate.
   $$p_f = \frac{F(P_{gi\max})}{E(P_{gi\max})}$$
2. Weighting Function Method:
   The two single objective has been combined with the help of weighting function
   $$G = w_1 F(P_{gi}) + w_2 E(P_{gi}) \tag{7}$$
   where $\sum_{i=1}^{n} w_i = 1$; n—number of objectives
3. Cardinal Priority Ranking Method:
   In this method the value is chosen based on Fuzzy set. Whatever the method may be the value will always lie between 0 and 1 based on the values of fuel cost and emission rate.
   Among the above three methods in this paper, the second method is implemented in this work.

4 Artificial Bee Colony

The algorithm developed by Dervis Karaboga [3] based on the concept of food searching behavior of the bees. This algorithm starts initially with population, i.e. group of solutions which is randomly generated instead of a single solution. The solution is represented by location of food and the suitability is indicated by the nectar value of the source. Three different sets of bees are involved in this algorithm such as working bee, monitoring bee and marching bee. The bee that is performing the action of identifying the location of food is called working bee. The bee that is staying in the nest for taking the next decision is called the monitoring bee. The bee that search randomly for new location of a food source is called the marching bee [11].

The location of food sources is assigned rank depending upon the quantity as well as the quality of their nectar. Similarly the suitability, value is designated to each individual solution that indicates the better ness of the solution

$$Fitness(i) = 1/(1+\sum F_i) \quad (8)$$

$\forall i \in (1,2,3,\ldots,NG)$.
$\sum F_i$ represents the total generation cost.

1. The phase of Working Bee(Employee Bee):
   In this stage the working bee searches the food source in the neighborhood and if it identifies the best food source it disconnects the previous source and starts with the new food source and travels to identify the best source of food.
2. The Phase of Monitoring Bee(Onlooker Bee):
   In this stage the monitoring bee identifies the location of the food source from the data's given by the working bee. The food source is selected such that it has better quality of food.

   $$Probability(i) = fitness(i)/sum(fitness)$$

   A number is chosen randomly that indicates the required value of the monitoring bee which is matched with the probability of the food source. If the solution achieves the required value, then it moves to search the location of a food source and this becomes a working bee, then the new working bee starts searching the nearby location and repeats the same procedure. If the required value is not met, then the monitoring bee choose the next food source with another value of the requirement. The location of food sources with high quality will be given best priority and the one which is discarded many times will be the least priority.
3. The Phase of Marching Bee(Scout Bee):
   This phase is to enlighten the area of search and is usually indicated represented by solution of random generation. The solution of better quality and the best suitability values are stored in the memory for each cycle. This is repeated for largest number of iterations and ends with result of global maximum or minimum.

The step by step procedure of the artificial bee colony algorithm has been depicted in the flowchart which is shown in Fig. 1. Initially the algorithm starts working by assuming the population initially and the evaluation process is performed in each stage.

5 Pseudocode for ABC algorithm

The steps in our ABC algorithm are given below.

1. Population initialization.
2. Population Evaluation.
3. cycle = 1
4. Repeat.
5. Generate new solutions for the employee bee for evaluation process.
6. Apply greedy selection method for employ bee.
7. Determine the probability value for each solution
8. Generate the new solution for monitoring bee from the selected solutions of working bee and evaluate them.
9. Implement the selection process for the monitoring bees.
10. Identify the abandoned solution for the marching bee if it exists or change with new random solution.
11. cycle = cycle + 1
12. Repeated till the value of cycle = Maximum Cycle Number.

6 Numerical Results

To test the feasibility of the proposed method it has been tested using Standard IEEE 30 bus system using MATLAB software. The considered system comprises a total of six generators connected through forty one line with thirty buses. The input data's for the cost coefficient, power generating limits, emission coefficients have been given in Tables 1 and 2. The load demand has been chosen to be 283.4 MW and the population size is decided such that the total count of employee bees must match with a count of both monitoring and marching bees (onlooker and scout bees).

The obtained result shown in Table 3 has been compared with another swarm intelligence algorithm called Particle Swarm Optimization which shows that the fuel cost has been reduced by 7 Rs/hr, i.e. from 908.136 Rs/hr to 901.45 Rs/hr. Fig. 2 shows the convergence characteristics for 500 iterations. In the graph (Fig. 2) fitness value gets converge at 2205.2 and it is constantly up to last iteration.

It shows that this proposed method algorithm is the better one to identify the near global optimum solution with high computational efficiency.

Table 4 shows the comparison of results with various algorithms using two lkmbhjcdifferent approaches for combining the two different objectives into a single multi objective optimization problem. Fig. 3 depicts the results obtained in three different algorithm with two different methods.

Simulation Parameters:

1.Colony size employee +(onlooker + scout)) bees = 20
2.Location of Food = 10
3.Range = 100
4.Maximum Iterations = 500
5.Load Demand = 283.4 MW

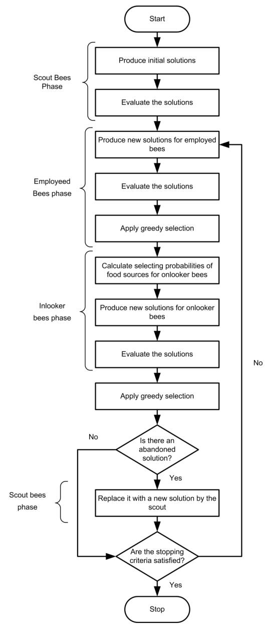

Fig. 1: Flow process of artificial bee colony optimization algorithm.

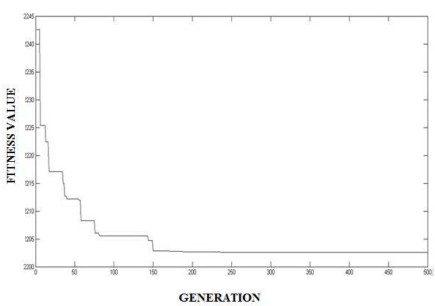

Fig. 2: Convergence characteristics for 500 iterations of artificial bee colony optimization.

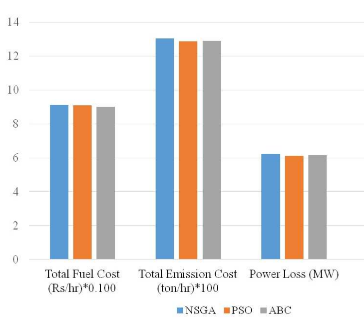

Fig. 3: Comparison of result for three different algorithm of combined economic emission dispatch.

Table 1: Fuel Cost coefficient with valve point effect.

Unit	a	b	c	d	e	P_{max}	P_{min}
	$/MW^{2}hr	$/MWhr	$/hr	$/hr	rad/MW	MW	MW
1	0.0037	2	0	0	0	200	50
2	0.0175	1.75	0	0	0	80	20
3	0.0625	1	0	40	0.08	50	15
4	0.0083	3.25	0	50	0.09	35	10
5	0.025	3	0	0	0	30	10
6	0.025	3	0	0	0	40	12

Table 2: Economic Cost coefficient.

Unit	α	β	γ
	lb/MW^{2}hr	lb/MWhr	lb/hr
1	0.0126	-1.1	22.983
2	0.02	-0.1	25.313
3	0.027	-0.01	25.505
4	0.0291	-0.005	24.9
5	0.029	-0.004	24.7
6	0.0271	-0.0055	25.3

Table 3: Comparison of output for IEEE 30 bus system with the use of weighting function method.

Particulars	PSO	ABC
P_{G1}(MW)	121.512	120.884
P_{G2}(MW)	47.370	49.381
P_{G3}(MW)	25.564	24.176
P_{G4}(MW)	34.106	34.999
P_{G5}(MW)	28.722	29.450
P_{G6}(MW)	32.218	30.640
Total P_G(MW)	289.49	289.532
Total Fuel Cost(Rs/hr)	908.136	901.453
Total Emission Cost(ton/hr)	0.12875	0.12911
Power Loss(MW)	6.1025	6.1416

Table 4: Result Comparison of various algorithm for IEEE 30 bus system.

Particulars	NSGA (Price Penalty Factor)	PSO (weighting Function)	ABC (weighting Function)
Total Fuel Cost Rs/hr)	910.564	908.136	901.453
Total Emission Cost(ton/hr)	0.13015	0.12875	0.12911
Power Loss(MW)	6.2105	6.1025	6.1416

7 Conclusion

The motive of reduction of harmful gaseous emission from fossil fuel fired power plants which pollute the atmosphere has attracted our attention. So in this paper, ABC algorithm has been successfully implemented to solve the Bi-objective, non-convex Combined Economic Emission dispatch problem to obtain the global optimum solution. The Efficiency of the proposed approach has been verified using the IEEE 30 bus system that shows the capability of achieving the global minimum solution with stable dynamic convergence characteristics and reduced fuel cost along with harmful gaseous emission.

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