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Artificial Bee Colony Algorithm for an Optimal Solution for Combined Economic and Emission Dispatch Problem

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ABSTRACT

In India Electrical Energy is generated mainly Coal based Thermal Power stations and hydro Electric Power Stations. The main aim of power generating company is to provide good quality and reliable power to consumers at minimum cost. The problem of Combined Economic and Emission Dispatch deals with the minimization of both fuel cost and emission of pollutants such as oxides of Nitrogen and Oxides of Sulphur. In our power system the emission is major problem created that's why in now a days we move from green energy source or renewable energy such as Sunlight, Wind, Tides, Wave, and Geothermal Heat Energy. The Emission constrained Economic Dispatch problem treats the emission limit as an additional constraint and optimizes the fuel cost. In this paper we optimizes the Combined Economic and Emission Dispatch problem by using two different optimization method such as Artificial Bee Colony (ABC) and Genetic Algorithm (GA).The proposed ABC Algorithm has been successfully implemented is to IEEE 30 bus and Indian Utility sixty two Bus System The simulation result are compare and found the effective algorithm for Combined Economic and Emission Dispatch problem.

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1. INTRODUCTION

The aim of Economic Dispatch (ED) we schedule the generator output power in such manner the total load demand is achieved and the cost of the electrical power generation is less. In addition to the Economic dispatch problem we also consider environmental constraint that arises by the emission of fossil fuel. In India, two third of the electrical power generated is from coal based power stations. The use of fossil fuel for electrical energy generation its discharge several impurity, such as Sulphur Oxides (SOx), Nitrogen Oxides (NOx) and Carbon Dioxide (CO2) into atmosphere. This causes negative effects to human health and the quality of life. It also causes damage to vegetation, acid rain, reducing visibility and global warming [1, 2],these environmental effects can be minimizes by the proper load allocation and individual generator outputs is proper schedule. But In that case may be the total generator cost is increase. So it is find out optimum solution which gives balanced results in between Emission and Cost. This can be achieved by Combined Economic Emission Dispatch (CEED) problem.

In last years on solving ED problems have been applied classical mathematical programming techniques such as Interior Point Algorithm, Linear Programming and Dual Quadratic Programming [3,4]. In these mathematical techniques, the main consideration is that the fuel cost curve is considered as a monotonically increasing one because when the load demand is increasing so the generator output power is also increasing and the fuel requirement is also increasing. However, when the load demand is not fulfill by 1 generator so we increase the n. of generator so the problem is goes to nonlinear that's by the cost curve is also non smooth that's why these techniques is not applicable is gives correct solution.

Many Researchers have been done in Combined Economic Load Dispatch problem in power system like Provas Kumar Roy et al. [3] proposed a Biography based Optimization to solve the CEED problem with Valve Point discontinuities, Ramp Rate Limits and Prohibited Operation Zones are consider. K.Balamurugan et al.[5] utilized the differential Evolution Based solution for CEED with Valve Point Loading. A.Immanuel Selva Kumar et al. [6] used a Charlie Paul Particle Swarm Optimization solution to Emission and Economic Dispatch Problem. A.El-Keib et al [7] study Economic Dispatch in view of the Clean Air Act of 1990, Hooshmand R el al[8] Proposed Economic and Emission dispatch and reverse dispatch with frequency constraints in competitive power market.

Artificial Bee Colony is a new swarm intelligence algorithm proposed by Karaboga [9, 10] which is motivated from the intelligent food foraging behavior of Honey Bee. Since the development of ABC it has been applied to solve different kinds of problems. The ABC algorithm is developed based on inspection the behaviors of real bees on finding nectar and sharing the information of food sources to the bees in their hive. The main advantages of the ABC algorithm over other optimization methods for solving optimization are simplicity, high flexibility, strog robustness, few control parameter, ease of combination with other methods, ability to handle the objective with stochastic nature, fast convergence.

Many application of ABC algorithm in Real World problem is available in the literature Hadidi el al[11] employed an ABC algorithm based approach for structural optimization, Y.Zhang et al [12] employed the ABC for various tasks including multi-level thresholding MR Brain image classification and face pose estimation.

In this paper the ABC algorithm is proposed to solve the CEED problem with and without losses the proposed ABC Algorithm has been applied in IEEE-30 Bus system and Indian Utility sixty two bus systems. The results obtained with the proposed ABC algorithm is compared with the results obtained by GA algorithm.

All these techniques are implemented for a CEED problem with linear constraints. The non-linear constraints such as prohibited operating zones, ramp rate limits and valve point loading effects were neglected.

2. PROBLEM FORMULATION

2.1. Objective function

The ELD problem is having an objective function so as to minimize the total generation cost F_T , when supplying the required load demand of a power system. The total generation cost is the arithmetic sum of the individual generators cost function

The objective function is,

$$\min(F_T) = \min\left(\sum_{i=1}^{n} F_i(P_{Gi})\right) \tag{1}$$

Where P_{Gi} the output power is generated by the i^{th} generator; $F_i(P_{Gi})$ is the generation cost function of i^{th} generator and *n* is the number of generators

$$F_T = \sum_{i=1}^{n} A_i P_{Gi}^2 + B_i P_{Gi} + C_i \tag{2}$$

Where, A_i , B_i and C_i are the cost coefficients of the i^{th} generator.

Equality Constraint- In equality constraint the total power demand P_D is meet with the transmission losses P_L by the total power generation. This relation can be expressed as

$$\sum_{i=1}^{n} P_{Gi} = P_D + P_L \tag{3}$$

Over long distances, the transmission loss is significant and it is function of generators output power through Kron's loss coefficients.
The Kron's loss formula can be expressed as follows,

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} P_{Gi} B_{ij} P_{Gj} + \sum_{i=1}^{n} B_{0i} P_{Gi} + B_{00} \tag{4}$$

Where B_{ij}, B_{0i} and B_{00} are the transmission network power loss B -coefficients, which are assumed to be constant

2.2. Generation capacity constraint

This is an inequality constraint for each generator. For normal system operations, real power output of each generator is within its lower and upper limits as follows, [2]

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \tag{5}$$

Where $P_{Gi}^{\min}$ and $P_{Gi}^{\max}$ are the lower and upper limit of power generated by i^{th} generator

2.3. Multi-objective Economic/Environmental Dispatch Formulation

Minimization of Emission: The total emission of atmospheric pollutants from a fossil based generating units depend on the
Amount of power generated by that unit, the total pollution level can be expressed by Abido (2001) in the following form,

$$E = \sum_{I=1}^{N} \alpha_I + \beta_I P_{Gi} + \gamma_I P_{Gi}^2 \tag{6}$$

Where

α_i, β_i, χ = generation unit emission rate coefficients

E=Total emission

N= Number of Generators

The nature of cost and emission production allows the economic and emission dispatch problem which is constructed as a dual objective optimization problem.

2.4. Objective function for penalty factor [5, 13]

The combination of economic and emission dispatch problem is to reduce the cost function and the emission function including penalty factor as in equations (7) and (8).

$$h = \frac{F_T(P_{i\max})}{E(P_{i\max})} \tag{7}$$

Where $P_{i\max}$ is maximum power constraint for i_{th} unit in MW Price penalty factor h ($\$/lb$)

Minimize $\phi_T = F_T(P) + h.E_T(P)$ (8)

2.5. Artificial Bee Colony Algorithm

Inspired by the intelligent foraging behavior of honeybee swarms [9], the ABC algorithm was introduced to handle unconstrained benchmark optimization functions similar to other well-known meta-heuristic algorithms. An extended version of the ABC algorithm was then offered to handle constrained optimization problems [15].

In ABC the colony of artificial bees contains three groups of bees. Employed bees associated with specific food source, onlooker bees watching the dance of employed bee within the hive to choose a food source and scout bees searching for food source randomly. Both onlookers and scouts are also called unemployed bees. Initially all food source positions are discovered by scout bees. Thereafter, the nectar of

food sources are exploited by employed bees and onlooker bees and this continual exploitation will ultimately cause them to become exhausted then the employed bee which was exploiting the exhausted food sources once again. In other words the employed bee whose food source has been exhausted becomes a scout bee. In ABC the position of food source represented a possible solution to the problem and the nectar amount of food source corresponding to the quality of the associated solution. The number of employed bees is equal to the number of food source since each employed bee is associated with and only one food source [21].
The total numbers of bee is called colony size. The total number of employed bees is represents by the one half of the colony size and the number of onlooker is represented by other one half of the colony size. The one employed bee is assigned by one food source position. It means the number of employed bee is equal to number of food source positions [13].

The ABC algorithm consist of four main steps initialization, employed bee phase, onlooker bee phase , and scout bee phase, after the initialization step, other three main steps of the algorithm are carried out repeatedly loop until the termination condition is met. The main steps of the ABC algorithm are as follow

Step 1 (initialization): in the initialization step, the ABC generates a randomly distributed population of food source solution. It is represented by swarm size.

$$Y_i = \{Y_1, Y_2 \ldots\ldots\ldots\ldots\ldots Y_n\} \tag{9}$$

Represent the i^{th} solution in the swarm, where n is the dimension size.

Step 2 (employed bee phase): In employed bee phase each employed bee visits a food source and generate a neighboring food source in the vicinity of the selected food source. Employed bees search a new solution by performing a local search around each food source as follow

$$L_{ik} = Y_{ik} + u(Y_{ik} - Y_{jk}) \tag{10}$$

Where Y_j is randomly selected candidate solution ($i \neq j$), k is a random dimension index selected from the set (1, 2, 3, 4………n) and u is a random number within range [-1, 1]

Step 3 (onlooker bee phase): unlike the employed bees onlooker bee selected a food source depending on the probability value and that is determine as follow
The probability *pi* of selecting a food source by onlooker bees is calculated as follows:

$$p_i = \frac{fitness_i}{\sum_{i=1}^{E_b} fitness_i} \tag{11}$$

Where, *fitnessi* is the fitness value of a solution *i*, and *Eb* is the total number of foodsource positions or, in other words, half of the *CS*. Clearly, resulting from using (11), a good food source will attract more onlooker bees than a bad one.

Step 4 (scout bee phase): a trial counter is associated with each food source, which depict the number of trail that the food source cannot be improved. If a food source cannot be improved for predetermine number of trail during the onlooker and employed bee phase the employed bee associated with that food source become scout bee then the scout bee finds a new food source.
Steps involved in the ABC algorithm are as follows:
1. Initialize the population
2. Modify position
3. Apply selection criterion
4. Repeat (cycle)
5. Allow the employed bees to share the food information with onlooker bee
6. Allow the onlooker bees to choose the best food source based on the probability calculation
7. Apply selection criterion.

8. Check for an abundant solution, and (if exists) initate a new food source position. Otherwise follow the next step
9. Retain best solution so far
Until stopping rule

3. TEST SYSTEMS

3.1. IEEE 30 Bus Systems

The IEEE 30 Bus System that comprises of six generator, 43 branches and 21 Load Buses. The typical IEEE 30 bus system as shown in fig.1 is considered for the proposed approach. The system load is 450MW. The Fuel Cost and Emission Coefficient Data's are shown below.

Table 1. Cost coefficient [5]

Gen n.	$P_i^{\min}$ (MW)	$P_i^{\max}$ (MW)	a_i	b_i	c_i
1	5	150	10	200	100
2	5	150	10	150	120
3	5	150	20	180	40
4	5	150	10	100	60
5	5	150	20	180	40
6	5	150	10	150	100

Table 2. Emission coefficient [5]

Gen n.	$P_i^{\min}$ (MW)	$P_i^{\max}$ (MW)	σ_i	β_i	γ_i
1	5	150	4.091	-5.55	6.49
2	5	150	2.543	-6.04	5.638
3	5	150	4.258	-5.09	4.586
4	5	150	5.426	-3.55	3.380
5	5	150	4.258	-5.09	4.586
6	5	150	6.131	-5.55	5.151

3.2. Indian Utility Sixty Two Bus System

The Indian utility sixty two bus system that comprises of nineteen generators, 33 load buses. The typical Indian utility sixty two bus systemas shown in figure 2 is considered for the proposed approach. The systemload is 2912 MW. The fuel cost and emission coefficient data's are shown below.

Table 3. Cost coefficient for Indian utility sixty two bus system

Gen n.	$P_i^{\min}$ (MW)	$P_i^{\max}$ (MW)	a_i	b_i	c_i
1	50	300	.007	6.8	95
2	50	450	.0055	4.0	30
3	50	450	.0055	4.0	45
4	0	100	.0025	.85	10
5	50	300	.0025	4.6	20
6	50	450	.006	4.0	90
7	50	200	.0065	4.7	42
8	50	500	.0075	5	46
9	0	600	.0085	6	55
10	0	100	.0029	.5	58
11	50	150	.0045	1.6	65
12	0	50	.0025	.85	78
13	50	300	.005	1.8	75
14	0	150	.0045	1.6	85
15	0	500	.0065	4.7	80
16	50	150	.0045	1.4	90
17	0	100	.0025	.85	10
18	50	300	.0045	1.6	25
19	100	600	.008	5.5	90

Table 4. Emission coefficient [5]

Gen n.	$P_i^{\min}$ (MW)	$P_i^{\max}$ (MW)	σ_i	β_i	γ_i
1	50	300	.018	-1.8	24.3
2	50	450	.033	-2.5	27.023
3	50	450	.033	-2.5	27.023
4	0	100	.0136	-1.3	22.07
5	50	300	.018	-1.81	24.327
6	50	450	.033	-2.5	27.023
7	50	200	.0126	-1.36	23.04
8	50	500	.036	-3.0	29.03
9	0	600	.04	-3.2	27.05
10	0	100	.0136	-1.3	22.07
11	50	150	.0139	-1.25	23.01
12	0	50	.0121	-1.27	21.09
13	50	300	.018	-1.81	24.3
14	0	150	.014	-1.2	23.06
15	0	500	.036	-3.0	29
16	50	150	.0139	-1.25	23.02
17	0	100	.0136	-1.3	22.07
18	50	300	.018	-1.81	24.3
19	100	600	.04	-3.0	27.010

4. SIMULATION RESULTS

Two different cases we have consider first case is without losses consideration and second is with losses in two different systems first is IEEE 30 Bus system and second is Indian utility sixty two bus systems
CASE1: Without loss:
For comparison purpose in the first case the systems is considered as lossless the corresponding cost and iteration is

Table 5. Individual generator output (without losses)

Unit output	ABC	GA
P1 (MW)	87.8435	87.7893
P2 (MW)	90.2941	90.3240
P3 (MW)	44.5801	44.4105
P4 (MW)	92.8025	92.7594
P5 (MW)	44.2786	44.4012
P6 (MW)	90.2786	90.3156
TOTAL POWER (MW)	450	450
TOTAL COST	475518	475529

CASE 2: With losses
For comparison purpose in the first case the systems is considered as lossless the corresponding cost and iteration is plotted as below

Table 6. Individual Generator Output (With Losses)

UNIT OUTPUT	ABC	GA
P1 (MW)	79.5476	79.4535
P2 (MW)	94.0585	93.6744
P3 (MW)	49.4885	49.4737
P4 (MW)	98.6445	98.6302
P5 (MW)	47.9760	47.9550
P6 (MW)	93.0345	93.5549
TOTAL POWER	462.75	462.781
LOSSES	12.75	12.781
TOTAL COST	502468	502472

Table 7 Price penalty factor in ascending order

P (MAX)	150	300	450	600	750	900
PANALTY FACTOR	1.8057	3.7805	6.577	10.973	15.947	20.966

Table 8 Results For IEEE 30 Bus Systems

CASES	MATH OD	ELD COST	EMISSION	COMBINED COST h=6.577	MODIFIED COMBINED COST
WITHOUT LOSSES	ABC	475518	163398.4	1550189.2	1550189.2
	GA	475529	163396.8	1550189.7	1550189.7
WITH LOSSES	ABC	502468	17231.91	1634579.5	1634579.5
	GA	502472	172455.8	1636714.1	1636714.1

From the table no. 8 it is clear that the results obtained by ABC algorithm are superior in both the cases (with or without losses) then the results obtained by GA algorithm.
For Indian utility sixty two bus system

CASE 1Without losses

For comparison purpose in the first case the systems is considered as lossless the corresponding cost and iteration is plotted as below

Table 9. Individual Generator Output (Without Losses)

UNIT POWER	ABC	GA
P1 (MW)	110.6655	74.6013
P2 (MW)	286.6217	145.2539
P3 (MW)	211.3904	186.9798
P4 (MW)	117.0396	109.2386
P5 (MW)	93.1075	99.8178
P6 (MW)	165.8865	209.4452
P7 (MW)	119.054	145.8607
P8 (MW)	180.1773	204.8583
P9 (MW)	35.4465	28.2791
P10 (MW)	117.0396	116.8404
P11 (MW)	167.0396	166.8404
P12 (MW)	67.0396	61.9833
P13 (MW)	283.1211	316.8404
P14 (MW)	167.0396	166.8404
P15 (MW)	53.9347	173.5422
P16(MW)	167.0396	153.2202
P17(MW)	117.0396	116.8404
P18(MW)	317.0396	308.5104
P19(MW)	136.2782	126.2071
TOTAL POWER	2912	2912
TOTAL COST	12790.0	12814.2

CASE 2 with losses

For comparison purpose in the first case the systems is considered as lossless the corresponding cost and iteration is plotted as below

Table 10. Individual Generators Output (Withlosses)

UNIT POWER	ABC	GA
P1 (MW)	164.7064	165.4502
P2 (MW)	237.1719	235.4251
P3 (MW)	232.3953	247.3509
P4 (MW)	100.7110	101.0552
P5 (MW)	168.8156	156.0241
P6 (MW)	218.2790	222.7024
P7 (MW)	200.7110	201.0652
P8 (MW)	155.3321	153.6312
P9 (MW)	103.4167	99.6341
P10 (MW)	.7997	1.221
P11 (MW)	150.7110	151.0652
P12 (MW)	50.7110	51.0651
P13 (MW)	300.7110	301.0652
P14 (MW)	150.7110	151.0652
P15 (MW)	136.9887	133.8824
P16 (MW)	150.7110	151.0652
P17 (MW)	100.7110	101.4028

P18 (MW)	300.7110	301.0652
P19 (MW)	101.4517	101.4028
TOTAL POWER OUTPUT(MW)	3025.756	3026.312
TOTAL COST	14990.8	15012.1
POWER LOSSES(MW)	113.756	114.312

Table 11. Price penalty factor in ascending order

P(MAX)	PANALTY FACTOR
600	.4889
1200	.9854
1650	1.51255
2100	2.04235
2550	2.58015
3150	3.11865

Table 12. Results for Indian Utility Sixty two Bus System

CASES	Algorithm	ELD COST	EMISSION	COMBINED COST
WITHOUT LOSSES	ABC	12791.2	6747.033	33832.844
	GA	12815.3	6803.84	34034.09
WITH LOSSES	ABC	14990.8	8167.235	40461.63
	GA	15012.2	8405.166	41224.98

From the results it is clear that the results obtained by ABC algorithm are superior in both the cases (with or without losses) then the results obtained by GA algorithm respectively. Hence the results obtained by ABC are better than the results obtained by GA.

From the table No. 13 the developed ABC Algorithm gives less combined cost which includes ELD cost plus Emission as compared to GA Algorithm. Execution time of ABC algorithm is also less as compared to GA Algorithm.

5. CONCLUSION

The aim of the present research work has been the development of reliable optimization techniques to solve the combined economic and emission power dispatch problem (CEED). The ELD is a significant problem in order to schedule the generation among the units in a power system to overcome the required demand. The main objective of ELD problem is to minimize the total generation cost subjected to constraints. Such as Generator constraints and Power constraints. In addition to the total generation cost, the transmission loss is to be minimized. A study has been made of the existing techniques and the ABC is show better optimization technique in which the objective function is to be optimized to get a better solution. To evaluate the performance of proposed ABC Algorithm, two test systems are used IEEE 30 bus, and Indian utility sixty two bus system with different power demands for 6 unit systems with 450 MW and 19 unit system OR Indian utility sixty bus system with 2912 MW demand. The total loss and total generation cost and are small in ABC algorithm. The NOx emission is also less in ABC algorithm. The time taken for execution of program ABC algorithm is less as compare to GA algorithm. An attempt has been done in order to compare the proposed ABC Algorithm with GA for the solution of CEED.

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