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Multi-Objective Environmental/Economic Dispatch Solution Using ABC_PSO Hybrid Algorithm

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Abstract- The problem of power system optimization has become a deciding factor in current power system engineering practice with emphasis on cost and emission reduction. The economic and emission dispatch problem has been addressed in this paper using two efficient optimization methods, Artificial Bee Colony (ABC) and Particle Swarm Optimization (PSO). A hybrid produced from these two algorithms is used on the 30-bus 6 generator IEEE test system. The results are compared with ABC, Fuzzy Controlled Genetic Algorithm (FCGA) and Non Sorting Genetic Algorithm (NSGA-II) and found to be effective on the combined economic and emission dispatch problem.

Index Terms- Economic and Emission Dispatch, Artificial Bee Colony, Particle Swarm Optimization, 6-Generator test system.

I. INTRODUCTION

Economic Dispatch (ED) optimization problem is the most important issue which is to be taken into consideration in power systems. The problem of ED in power systems is to plan the power output for each devoted generator unit in such a way that the operating cost is minimized and simultaneously, matching load demand, power operating limits and maintaining stability. The total generator operating cost includes fuel, labor, supplies and maintenance costs. For simplicity we consider fuel cost as the only variable cost since generally the costs of labor, supplies and maintenance are fixed percentages of the fuel cost. Hence only thermal plants are considered in this research. Over the recent years there has been much research in the area of the combined economic and emission dispatch problem. Gopala Krishnan et al, 2011 [1] outlines a summary of techniques that have been applied so far to the combined economic and emission dispatch problem. The paper highlights new techniques which have been applied the CEED problem from 2000-2010. It also highlights challenges faced by the use of traditional methods due to the non linearity of cost functions. It generally encourages the use of PSO. Biswajit Purkayasha et al, 2010 [2] aims at non dominated solutions in considering the multi-objective optimization problem of economic and emission dispatch using Non-dominated Sorting GA II. The results demonstrate the effectiveness in solving the multi-objective problem. It considers the cost of fuel, SOx and NOx. Celal Yasar et al, 2005 [3] uses the first order gradient method in solving the Combined Economic and Emission Dispatch problem. It has the advantage of easy control of constraints. Also all intermediate solutions are feasible for application to the power system. Anurag Gupta et al, 2012 [4] uses PSO on the combined economic and emission dispatch problem. It combines the two objectives into one using the price penalty function. It shows a better advantage in terms of cost, fast convergence, and less computational time than other heuristic methods like GA and dynamic programming. Also PSO gives efficiently high quality solutions with more stable convergence characteristics than the other heuristic methods afore mentioned. Lakshmi A. Devi et al, 2008 [5] uses the evolutionary programming method on the combined economic and emission dispatch problem. This paper proposes the use of the lambda in the evolutionary algorithm with the reason being that it makes the coding of the chromosomes independent on the number of units. Notably PSO generates a lower fuel cost and emission release but sometimes has a higher computational time than GA. Harry Rughooputh et al, 2005 [6] applies both deterministic and stochastic methods to the economic environmental problem. Ahmed Farag, 1995 [7] uses linear programming in addressing the multi-objective problem of the economic dispatch. It uses the constriction factor approach to handle the CEED problem. M. R. Alrashidi et al, 2008 [8] on the impact of loading conditions on the emission and economic dispatch problem uses weighting functions on the double objective of emission and fuel cost. It provides a simple way of addressing the equality constraint. The rule guiding the application of the weights to the objectives is not explicitly shown. Also this method is not applied to the CEED rather it optimizes the objectives independently. Gaurav Prasad et al, 2011 [9] applies a new technique called Artificial Bee Colony method (ABC) the economic load dispatch problem. In comparison to other heuristic methods it shows highly superior features like quality of solution, stable convergence characteristics and good computational efficiency. It does not consider the environmental or emission dispatch problem. Y. Sonmez et al, 2011 [10] applies the Artificial Bee Colony method to solve the multi-objective economic and environmental dispatch problem using the penalty factor approach. It is superior in comparison to the other heuristic methods and more efficient. In this research work, exploration of the area of hybridizing PSO and the Artificial Bee Colony method and studies of its behavior in comparison with the other methods using the combined emission and economic dispatch problem was be done.

II. FORMULATION

MULTI OBJECTIVE DISPATCH PROBLEM

Here the main objective of the CEED problem is to minimize the two objectives given as fuel cost $F(P_{gi})$ and emission $E(P_{gi})$ simultaneously to ensure optimal output of generated power whilst satisfying the equality and inequality constraints.

Economy objectives

$$F(P_{gi}) = a_i P_i^2 + b_i P_{gi} + c_i + e_i * \sin(f_i * (P_{imin} - P_i)) \text{ \$/hr} \quad - (1)$$

Environmental Objectives

$$E(P_{gi}) = \alpha_i P_i^2 + \beta_i P_{gi} + \gamma_i + \eta_i * \exp(\delta_i * P_{gi}) \text{ kg/hr} \quad – (2)$$

Subject to equality and inequality constraints

Equality constraint

$$\sum P_{gi} - P_D - P_l = 0 \quad - (3)$$

Where P_{gi} is real power by the i^{th} generator , P_D is total demanded load and P_l is losses, where

$$P_l = \sum_{i=1}^{NG} \sum_{j=1}^{NG} P_{gi} B_{ij} P_{gj} \quad - (4)$$

Inequality constraints

$$P_{gi\,(min)} \le P_{gi} \le P_{gi\,(max)} \quad - (5)$$

The multi-objective economic and emission dispatch problem can be defined as

$$\text{Min}\{G = [F(P_{gi}), E(P_{gi})]\} \quad - (6)$$

FORMULATION BY THE WEIGHTING FUNCTION METHOD AND CARDINAL PRIORITY RANKING METHOD

The weighting function method is applied in this research. The weighting function converts the multi-objective problem into a scalar optimization one [12]. Hence by the usage of the weighting function the objective function can be reformulated as:

$$G = w_1 F(P_{gi}) + w_2 E(P_{gi}) \quad - (7)$$

, where: $\sum_{i=1}^{n} w_i = 1$; n = number of objectives.

The best combined objective will be determined by the usage of the cardinal priority ranking method. The purpose of the cardinal priority ranking will be to generate non- inferior solutions through the normalized weights.

CARDINAL PRIORITY RANKING

The fuzzy sets are defined by equations called membership functions, which represent the goals of each objective function. The membership function represents the degree of achievement of the original objective function as a value between 0 and 1 with $\mu(F_i)$ =1 as completely satisfactory and $\mu(F_i)$= 0 as unsatisfactory. Such a linear membership function represents the decision maker's fuzzy goal of achievement, and at the same time scales the original objective functions with different physical units into measure of 0-1. By taking account of the minimum and maximum values of each objective function together with the rate of increase of membership satisfaction, the decision maker must determine the membership function $\mu(F_i)$ in a subjective manner given by:

$$\{1 \; ; F_i \le F_{imin}\}$$

$$\mu(F_i) - \left\{\frac{(F_{imax} - F_i)}{(F_{imax} - F_{min})}; F_{imin} \le F_i \le F_{imax}\right\} \quad - (8)$$

$$\{0 \; ; F_{imax} \le F_i\}$$

The value of the membership function indicates how much (in the scale from 0 to 1) a non–inferior solution has satisfied the i_{th} objective. The sum of the membership function values $\mu(F_i)$, i= 1, 2, … l, where l is the number of objectives, for all the objectives can be computed in order to measure the 'accomplishment' of each solution in satisfying the objectives. The 'accomplishment' of each non-dominated solution can be rated with respect to all the M non-dominated solutions by normalizing its 'accomplishment' over the sum of the 'accomplishment' of the M non-dominated solutions as follows:

$$\mu_D^k = \frac{\sum_{i=1}^{L} \mu(F_i)^k}{\sum_{k=1}^{M} \sum_{i=1}^{L} \mu(F_i)^k} \quad - (9)$$

Hence from the accomplishments given by μ_D^k , a set of non dominated solutions will be arrived at, from which the maximum value was chosen as the best suited result [12].

PARTICLE SWARM OPTIMIZATION

The algorithm of PSO emulates from behavior of animals societies that don't have any leader in their group or swarm, such as bird flocking and fish schooling. Typically, a flock of animal that have no leaders will find food by randomly, following one of the members of the group that has the closest position with a food source (potential solution). The flocks achieve their best condition simultaneously through communication among members who already have a better situation. This would happen repeatedly until the best conditions or a food source discovered. The process of PSO algorithm in finding optimal values follows the work of this animal society. Particle swarm optimization consists of a swarm of particles, where particle represent a potential solution. [11]

<u>Detailed pseudo-code of PSO algorithm:</u>

1. A population of agents is created randomly.

$x_i = (P_1, P_2, P_3 \ldots\ldots\ldots\ldots, \ldots P_N)$

2. Evaluate each particle's position according to the objective function. In this case it is the total operational cost given by C for each particle and evaluate their fitness (i.e minimization of the objective function)
3. Cycle =1
4. Repeat
5. Update the velocity of the particles according to the formula

$$V_i(t) = V_i(t-1) + c_1 r_1 (Pbest(t) - x_i(t-1)) + c_2 r_2 (gbest(t) - x_i(t-1)) \quad - (10)$$

c = acceleration factor. r = random values between 1 and 0

6. Evaluate the velocity to ascertain if it is the range of

$$v_{max} \le v_i \le v_{min} \qquad - (11)$$

7. Move particles to their new position

$$x_i(t) = x_i(t-1) + V_i(t) \qquad - (12)$$

8. Evaluate to ensure that limits have not been exceeded.
9. Compare the particle's fitness evaluation with its previous pbest. If the current value is better than the previous pbest, then set the pbest value equal to the current value and the pbest location equal to the current location in the N dimensional search space.
10. Compare the best current fitness evaluation with the population gbest. If the current value is better than the population gbest, then reset the gbest to the current best position and the fitness value to current fitness value.
11. Check if stopping criterion had been met. If not update the cycle and go back to step (5).
12. End when the stopping criterion, which here is the number of iterations, has been met.

ARTIFICIAL BEE COLONY

In ABC algorithm, the solution of the optimization problem is represented by the location of a food source and the quality of the solution is represented by the nectar amount of the source (fitness). In the first step of ABC, the locations for the food source are produced randomly. In other words, for SN (the number of employed or onlooker bees) solutions, a randomly distributed initial population is produced. In the solution space, each solution ($X_i = (X_{i1}, X_{i2}, \dots \dots X_{iSN})$) is a vector on the scale of its number of optimization parameters [10].

Detailed pseudo-code of ABC algorithm:

1. Initialize the population of solutions X_i; i = 1, 2, . . . , SN.
2. Evaluate the population.
3. Cycle = 1.
4. Repeat
5. Produce new solutions v_i for the employed bees by using (13) for evaluation.

$$v_{ij} = x_{ij} + \emptyset_{ij}(x_{ij} - x_{kj}) \qquad - (13)$$

6. Apply the greedy selection process for the employed bees.
7. Calculate the probability values of P_i for the solutions of x_i by:

$$P_i = \frac{F(X_j)}{\sum_{j=1}^{SN} F(X_j)} \qquad - (14)$$

8. Produce the new solutions of $v_i$for the onlookers from the solutions of x_i selected depending on P_i and evaluating them.
9. Apply the selection process for the onlookers.
10. Determine the abandoned solution for the scout, if it exists, and replace it with a new randomly produced solution x_i by:

$$x_{ij} = x_j^{min} + (x_j^{max} - x_j^{min}) * rand \quad j \in \{1,2 \dots . D\}$$

\- - (15)

11. Memorize the best solution achieved so far.
12. Cycle = cycle + 1.
13. Until the cycle = MCN (maximum cycle number)

ABC-PSO HYBRID ALGORITHM FOR COMBINED ECONOMIC AND EMISSION DISPATCH PROBLEM

In this method of hybridization, ABC runs till its stopping criterion, which in this case is the maximum number of iterations, is met. Then the optimal values of individuals generated by the ABC are given to the PSO as its starting point. Ordinarily the PSO randomly generates its first individual sets, but in this case of hybridization that is taken care of by providing the starting point for the Particle Swarm Optimization who are the final values for individuals generated by the Artificial Bee Colony.

PSEUDO-CODE

```
Run ABC
Generate optimal values for all individuals
Pass these individuals to the PSO as starting points
Run the PSO till stopping criterion is met
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III. 6-GENERATOR TEST SYSTEM

The above method was implemented in Matlab 2009. The test system used was the IEEE 30 bus system with 6 generators under various load conditions. **Particle Swarm Optimization control settings**: c_1, c_2=2, r_1, r_2 : randomly generated values between 0 and 1, Maximum number of iterations = 1000, Population number= 15 individuals. **Artificial Bee Colony control settings**: Colony size = 30,Food Number =15, Limit of trials = 90,Maximum cycle Number = 500

Data for test system showing cost coefficients (a to c), emission coefficients (α to γ), P_{min} in MW and P_{max} in MW. Data was taken from Y. Sonmez [10].

Table 1: Coefficients of fuel cost and capacities of the 6 generating units.

No.	a $/MW²hr	b $/MWhr	c $/hr	$Pmin$ MW	$Pmax$ MW
1	0.15247	38.53973	756.79886	10	125
2	0.10587	46.15916	451.32513	10	150
3	0.02803	40.39655	1049.32513	40	250
4	0.03546	38.30553	1243.5311	35	210
5	0.02111	36.32782	1658.5696	130	325
6	0.01799	38.27041	1356.27041	125	315

Table 2: Coefficients of emission of the 6 generating unit

Unit	α kg/MW²hr	β kg/MWhr	γ kg/hr
1	0.00419	0.32767	13.85932
2	0.00419	0.32767	13.85932
3	0.00683	-0.54551	40.2669
4	0.00683	-0.54551	40.2669

5	0.00461	-0.51116	42.89553
6	0.00461	-0.5116	42.89553

Table 3: loss coefficient matrix of the 6 generating units

B coefficients ($\times 10^{-6}$)					
2022	-286	-534	-565	-454	-103
-286	3243	16	-307	-422	-147
-535	16	2085	831	23	-270
-565	-307	831	1129	113	-295
-454	-422	23	113	460	-153
-103	-147	-270	-295	-153	898

IV. RESULTS AND DISCUSSIONS

The results from the hybrid ABC_PSO are compared with the results obtained by other methods used by other authors under various loading conditions.

Economic Dispatch comparison

Table 4: Economic dispatch comparison for 6 generator test system at 500MW demand

Load demand of 500 MW				
	ABC_PSO	ABC [10]	FCGA [13]	NSGA-II [13]
P1 (MW)	52.081	52.532	49.47	50.836
P2 (MW)	29.077	29.4	29.4	31.806
P3 (MW)	40	35	35.31	35.12
P4 (MW)	68.074	70.871	70.42	73.44
P5 (MW)	191.46	191.63	199.03	191.99
P6 (MW)	136.4	137.02	135.22	135.02
Loss MW	17.097	16.734	18.86	18.208
Fuel cost $/hr	28086	28078	28150	28150
Emission kg/hr	306.28	309.1	314.53	309.04

Table 5: Economic dispatch comparison for 6 generator test system at 700MW demand

Load demand of 700MW				
	ABC_PSO	ABC [10]	FCGA [13]	NSGA-II [13]
P1 (MW)	76.061	77.017	72.14	76.179
P2 (MW)	49.087	48.542	50.02	51.81
P3 (MW)	45.421	44.568	46.47	49.82
P4 (MW)	102.73	103.89	99.33	103.41
P5 (MW)	266.3	264.64	264.6	267.98
P6 (MW)	191.34	192.15	203.58	184.73
Loss MW	30.943	30.809	36.15	33.934
Fuel cost $/hr	38206	38208	38384	38371
Emission kg/hr	536.43	535.79	543.48	534.92

Table 6: Economic dispatch comparison for 6 generator test system at 900MW demand

Load demand of 900 MW				
	ABC_PSO	ABC [10]	FCGA [13]	NSGA-II [13]
P1 (MW)	103.45	103.35	101.11	102.96
P2 (MW)	70.143	72.426	67.64	74.235
P3 (MW)	60.892	61.426	50.39	66.003
P4 (MW)	139.38	138.85	158.8	140.32
P5 (MW)	325	325	324.08	324.89
P6 (MW)	251.71	249.15	256.56	248.42
Loss MW	50.563	50.101	58.58	56.822
Fuel cost $/hr	49294	49300	49655	49620
Emission kg/hr	849.23	846.16	877.61	849.33

Comparing results yielded by ABC-PSO hybrid compared with ABC, FCGA and NSGA-II at demand levels of 500, 700 and 900 MW considering economic dispatch only.

At demand level of 500MW with only economic dispatch the hybrid produces a fuel cost of 8$/hr lower than ABC, 64$/hr lower than FCGA and NSGA-II. Also its emission is lower by 2.822kg/hr than ABC, 8.25kg/hr than FCGA and 2.76kg/hr than NSGA-II. Its losses are higher by 0.30634MW than ABC but better than FCGA and NSGA-II.

At demand level of 700MW the hybrid produces a fuel cost of 2.21$/hr lower that ABC, 178$/hr lower that FCGA and 164.75$/hr lower than NSGA-II. Its emission is greater by 0.6462kg/hr than ABC, but lower than FCGA by 7.0468kg/hr and lower than NSGA-II by 7.4908kg/hr. Its losses are higher by 0.1342MW than ABC but lower than FCGA and NSGA-II.

At demand level of 900MW the hybrid produces a lower fuel cost of 6$/hr than ABC, 361.4$/hr lower than FCGA and 316$/hr lower that NSGA-II. Its emission is slightly higher that ABC by 3kg/hr and lower than FCGA and NSGA-II by 28.3779kg/hr and 0.0939kg/hr respectively. Its losses are 0.46MW higher that ABC but lower than the other methods.

Emission Dispatch comparison

Table 7: Emission dispatch comparison for 6 generator test system at 500MW demand

Load demand of 500 MW				
	ABC_ PSO	ABC [10]	FCGA [13]	NSGA-II [13]
P1 (MW)	58.026	54.088	81.08	56.931
P2 (MW)	43.752	37.518	13.93	41.542
P3 (MW)	75.741	72.925	66.37	73.896
P4 (MW)	83.939	83.53	85.59	84.931
P5 (MW)	133.42	139.69	141.7	136.5
P6 (MW)	128.79	136.02	135.93	131.33
Loss MW	23.677	23.777	24.61	25.129
Fuel cost $/hr	28625	28496	28757	28641
Emission kg/hr	274.16	275.17	286.59	275.54

Table 8: Emission dispatch comparison for 6 generator test system at 700MW demand

Load demand of 700 MW				
	ABC_ PSO	ABC [10]	FCGA [13]	NSGA-II [13]
P1 (MW)	105.27	101.02	120.16	103.08
P2 (MW)	76.462	73.163	21.36	73.505
P3 (MW)	92.967	92.687	62.09	91.556
P4 (MW)	109.79	110.25	128.05	110.79
P5 (MW)	183.13	185.94	209.65	187.87
P6 (MW)	170	174.77	201.12	174.29
Loss MW	37.617	37.83	42.44	41.083
Fuel cost $/hr	39429	39271	39455	39473
Emission kg/hr	462.52	463.11	516.55	467.39

Table 9: Emission dispatch comparison for 6 generator test system at 900MW demand

Load demand of 900 MW.				
	ABC_ PSO	ABC [10]	FCGA [13]	NSGA-II [13]
P1 (MW)	125	124.99	133.31	124.99
P2 (MW)	111.72	109.86	110	109.86
P3 (MW)	109.53	109.88	100.38	109.88
P4 (MW)	143.32	141.71	119.27	141.71
P5 (MW)	248.63	250.73	250.79	250.73
P6 (MW)	224.54	225.07	251.25	226.58
Loss MW	62.74	62.24	65	68.87
Fuel cost $/hr	51014	50943	53300	51254
Emission kg/hr	749.07	749.53	785.64	760.05

Comparing results for the emission dispatch at various demand levels amongst the various methods.

At 500MW demand level, the hybrid yields a higher fuel cost of 129$/hr than ABC, lower cost of 131$/hr than FCGA and 16$/hr than NSGA-II. Its emission levels are better than ABC by 1.008kg/hr, 12.4268kg/hr than FCGA and 1.3808kg/hr than NSGA-II. Its losses are better than ABC by 0.1MW and better than the other algorithms by 0.9329MW and 1.4519MW for FCGA and NSGA-II respectively.

At demand level of 700MW, the hybrid yields a higher fuel cost of 158$/hr than ABC, 26$/hr less than FCGA and 44.42$ less than NSGA-II. Its emission levels are better than ABC by 0.939kg/hr, 54kg/hr than FCGA and 4.8646kg/hr than NSGA-II. Its losses are better than ABC by 1.2128MW, by 4.8228MW than FCGA and 3.4658MW than NSGA-II.

At demand level of 900MW, the hybrid yields a higher fuel cost of 71$/hr than the ABC, 2,285.6$/hr than FCGA and 240.2 $/hr than NSGA-II. Its emission is lower than ABC by 0.4554kg/hr, 36.5664kg/hr than FCGA and 10.978kg/hr than NSGA-II. Its losses are slightly higher that ABC by 0.5MW and lower than FCGA and NSGA-II by 2.2MW and 6.1296MW respectively.

Combined Economic and Emission Dispatch comparison

Table 10: CEED comparison for 6 generator test system at 500MW demand

Load demand of 500 MW				
	ABC_ PSO	ABC [10]	FCGA [13]	NSGA-II [13]
P1 (MW)	54.6	54.262	65.23	54.048
P2 (MW)	32.484	35.98	24.29	34.25
P3 (MW)	48.548	51.408	40.44	54.497
P4 (MW)	77.517	76.527	74.22	80.413
P5 (MW)	167.28	162.62	187.75	161.87
P6 (MW)	137.29	137.09	125.48	135.43
Loss MW	17.718	17.88	17.41	20.508
Fuel cost $/hr	28157	28194	28231	28291
Emission kg/hr	288.01	284.98	304.9	284.36

Table 11: CEED comparison for 6 generator test system at 700MW demand

Load demand of 700 MW				
	ABC_ PSO	ABC [10]	FCGA [13]	NSGA-II [13]
P1 (MW)	83.741	87.128	80.16	86.286
P2 (MW)	55.373	59.978	53.71	60.288
P3 (MW)	65.306	74.184	40.93	73.064
P4 (MW)	107.05	110.86	116.23	109.04
P5 (MW)	232.19	211.44	251.2	223.45
P6 (MW)	187.88	190.2	190.62	184.11
Loss MW	31.54	33.792	32.85	36.324
Fuel cost $/hr	38357	38570	38409	38672
Emission kg/hr	491.69	477.29	527.46	484.93

Table 12: CEED comparison for 6 generator test system at 900MW demand

Load demand of 900 MW				
	ABC_ PSO	ABC [10]	FCGA [13]	NSGA-II [13]
P1 (MW)	114.59	119.95	111.4	120.06
P2 (MW)	78.395	82.309	69.33	85.202
P3 (MW)	80.693	87.103	59.43	89.565
P4 (MW)	137.13	136.52	143.26	140.28
P5 (MW)	300.2	290.06	319.4	288.61
P6 (MW)	238.55	233.95	252.11	233.69
Loss MW	49.559	49.873	54.92	57.405
Fuel cost $/hr	49528	49722	49674	50126
Emission kg/hr	794.44	778.42	850.29	784.7

The strength of the hybrid is evidenced in the combined economic and emission dispatch phase.

At 500MW demand level the hybrid produces a lower fuel cost of 37$/hr than ABC, 74.06$/hr than FCGA and 134$/hr than NSGA-II. Its emission is higher that ABC by 3kg/hr, lower by 16.8943kg/hr than FCGA and 3.6437kg/hr than NSGA-II. It also has lower losses than ABC by 0.16MW, 0.307MW lower than FCGA and 2.79MW lower than NSGA-II.

At 700MW demand level, the hybrid produces a far lower fuel cost of 213$/hr than ABC, 51.82$/hr than FCGA and 314.81$/hr than NSGA-II. Its emission is higher than ABC by 14.4kg/hr and lower by 35.77kg/hr and 6.7577kg/hr than FCGA and NSGA-II respectively. It possesses a lower loss than ABC by 2.251MW, 1.3101MW lower than FCGA and 4.7841MW lower than NSGA-II.

At 900MW demand level, the hybrid produces a lower fuel cost of 194$/hr than ABC, 146.28$/hr lower than FCGA and 598$/hr than NSGA-II. Its emission is higher than ABC by 16kg/hr, lower by 55.8549kg/hr than FCGA and higher by 9.7391kg/hr than NSGA-II. It has better losses than ABC by 0.1342MW, than FCGA by 5.3612MW and NSGA-II by 7.8462MW.

Generally the hybrid performs well under the combined economic and emission dispatch problem than other optimization methods. It yields overall lower generation cost for optimum emission and fuel costs. It is evident that the proposed hybrid yield better overall combined economic and emission dispatch results in all instances tested. With the aim of this thesis being the area of the combined economic and emission dispatch, the hybrid satisfies the intended objective of better efficiency of the power system in general.

The method was subjected to different loading conditions and different test systems to ascertain its strength in the CEED problem. In all cases it can be said to be comparable in terms of results obtained and better in the multi-objective optimization problem than all other methods compared with.

The hybrid so proposed makes use of the faster computational time of the PSO coupled with its convergence strength to implement the results yielded by the ABC in getting better near global solution. Hence the hybrid shows the following strengths:

- Better ability to reach near global optimal solution
- Quality solution
- Stable convergence characteristics
- Modeling flexibility.

It however shows the following weakness:

- High computational time.

These traits accounts for the results exhibited by the hybrid algorithm for the test cases implemented.

V. CONCLUSION

In conclusion this paper has formulated and implemented a hybridized PSO and ABC algorithm and has been shown to improve the optimization of the combined economic and emission dispatch problem. Though the proposed method shows efficiency than the algorithms it was compared with, its speed can be improved with the inclusion of mutation operators from other algorithms to improve its real time benefit.

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