Combined Emission and Economic Dispatch Problems using Hybrid of Particle Swarm and Teaching Learning Based Optimizations

Rajanish Kumar Kaushal, Praveen Saini, Tilak Thakur

Abstract: with day by day increasing population and standard of human being increases the consumption of electrical energy and this increasing in the consumption of electrical energy, increases the number of generators, transmission lines to full fill the daily needs of the electrical energy. So the power system has become more complex and main source of gaseous emission. So arranging and the task of intensity framework of power system must be done in such a way that energy and emission arising due to power generation, the retribution paid by the power plant because of emission and cost paid in generation need to tackle all the while. This paper shows a reliable and effective hybrid of particle swarm optimization (PSO) algorithm and teaching learning based optimization (TLBO) for combined emission and economic dispatch (CEED) problems. The outcomes have been shown for combined emission and economic dispatch issues of standard 3 and 6-generators frameworks with consideration of transmission losses.

Index Terms*: *Economic dispatch, Emission dispatch, PSO, TLBO, PSO-TLBO

I. INTRODUCTION

With the consideration of CEED dispatch problems of a thermal power plant, the basic or primary objective is to schedule the generating units' outputs is such manners that satisfy all the system constraints that may be equality or inequality constraints and meet the load demand at minimum generating power, minimum emission, minimum environmental cost and operating cost. In recent years, emission and environmental limitation started to be considered as part of electric system planning and operation. So consideration of emission and environmental constraint with economic is very important in the case of power generation from thermal power plant. However, it became necessary for power utilities to count this. So this emission and environmental must be considered together with the economic. If we considered emission and environmental together CEED dispatch problems acts as multi-objective problem with highly linear and nonlinear constraints.For economic, reduction in emission, reduction in environment cost and power management lot of researches have been carried out till the date. Different derivative approaches applied to solve for the significant benefits in economic, reduction in emission, reduction in environment cost and power management including Lagrangian multiplier method [1].

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These methods only considered the incremental fuel cost curves that's nature are monotonically increasing but actual curve is different from the monotonically increasing nature [2,3]. An ELD issue can be resolved with valve-point discontinuities by dynamic programming [4]. The issue of dimensionality, however, is the DP technique which imposes huge calculation burdens. Many population-based optimization methods like CASO (Caotic Ant Swarm Optimization) [5], evolutionary programming [6], hybrid evolutionary programming (HEP) [7], genetic algorithms [8–10], Simulated annealing [11], PSO [12-15], and have been used to solve complicated ELD-related issues in latest years.

II. PARTICLE SWARM OPTIMIZATION (PSO)

Behavior of swarms motivated the main concept of the PSO. To better understand the PSO we can assume that a swarm of birds of fishes searching for the food randomly in a specific region. We can assume that all the birds or fishes are searching the same food in the search space. During the searching of food, each bird or fish has a position and velocity. Swarm of birds or fish schooling moves in such a way that they have the knowledge of distance of food but not the knowledge of the exact location of food. Best plan to get the food by birds or fishes to follow a bird or fish nearest to the food. In PSO each bird or fish acts as a particle and may be the solution within the ask for area, so the number of particle in the problem is equal to total numbers of birds and fishes and the total number of the particle shows the population size. Each particle within ask for area has its hold own velocity and fitness value. The fitness of any particle is determined by the objective function of the problem.

Steps to be taken to implement PSO algorithm:

1. Start with a swarm /population decision that depends on problem complexity.
2. For the position and velocity of the particles, initialized
   randomly
   the particles.
3. The position of an ith particle is an array of 1X N in an N dimensional optimization problem.

$$P_i = [Pi1, Pi2, \ldots\ldots P_{iN}] \quad (1)$$

Similarly velocity is presented by,

$$V_i = [Vi1, Vi2, \ldots\ldots V_{iN}] \quad (2)$$

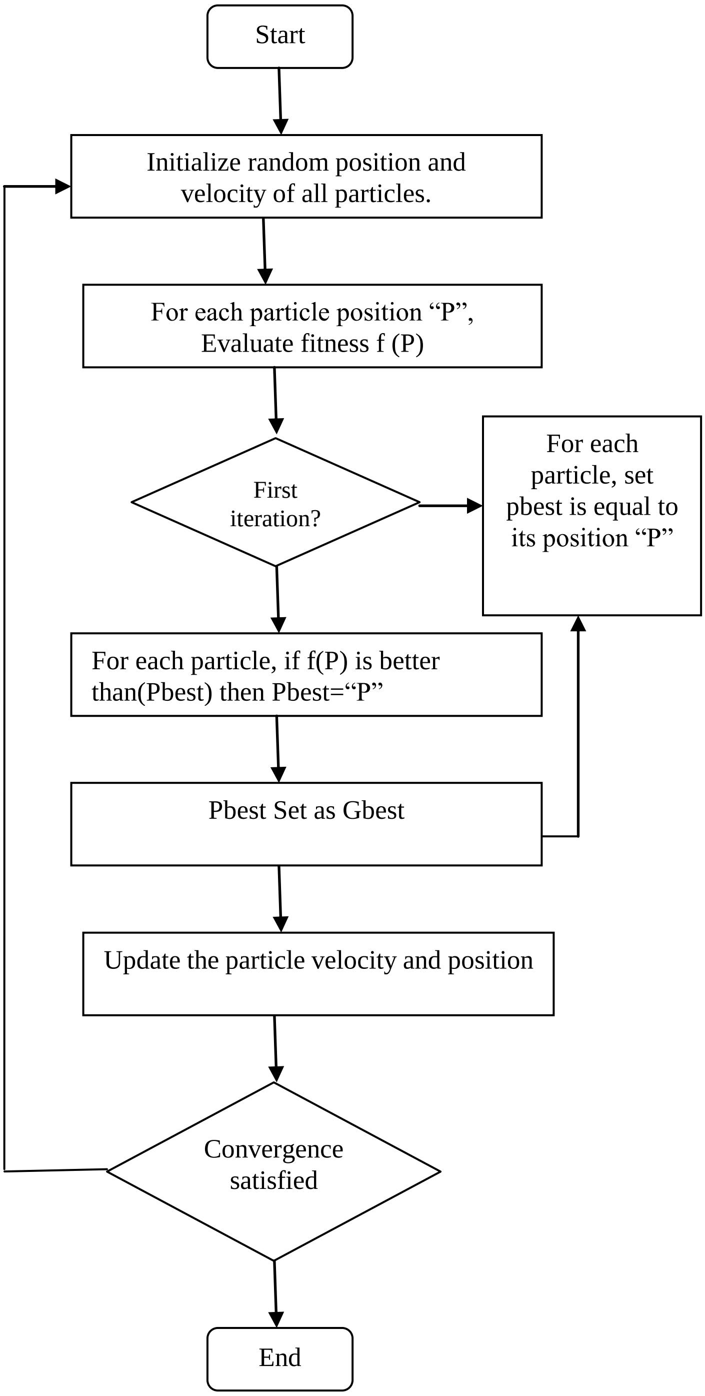

Figure1 Flow chart of PSO algorithm

4. The objective function given is to assess fitness for e ach particle:

   $F_i = f\,(Pi1,\ldots\ldots\ldots\ldots Pi2,\ldots\ldots P_{iN})$ (3)

5. Two best positions are chosen for the next iteration, known as pbest and gbest.

   Pbest: best personal position ever obtained by a Particle.gbest: best position in all pbests globally.

In the case of a first iteration, pbest is the same as a random initial part, whereas in the case of subsequent iterations, pbest is the most appropriate for that particular iteration

6. Each particle's velocity is updated with the following equation

$$v_i^{k+1} = \omega^k v_i^k + c_1 r_1\left(pbest_i^k - p_i^k\right) + c_2 r_2\left(gbest_i^k - p_i^k\right) \quad (4)$$

Where:

v_i^k : i_{th} particle velocity at k iteration.

ω_i^k : Weight of inertia at iteration k.

c_1 and c_2: acceleration coefficients.

r_1 and r_2: random numbers between (0, 1).

$pbest_i^k$: ith particle best position at iteration k.

p_i^k : ith particle position at iteration k.

$gbest_i^k$: Global best position at iteration k

v_i^{k+1} : Updated velocity at iteration k+1

At the kth iteration the velocity v_i^k of ith particle should be within its minimum and maximum range:

$$v_{i\min} \le v_i^k \le v_{i\max} \quad (5)$$

At each iteration, the inertia weight is modified by the next equation:

$$\omega^k = \omega_{\max} - \frac{\omega_{\max} - \omega_{\min}}{iter_{\max}} \times k \quad (6)$$

Where:

$\omega_{\max}$: Maximum inertia weight value

$\omega_{\min}$: Minimum inertia weight value

$iter_{\max}$: Maximum iteration number

7. The After an updated velocity, the position of every particle is updated with the next equation.

$$p_i^k = p_i^{k+1} + v_i^k \quad (7)$$

8. Fitness is assessed for each particle's updated locatin; pbest and gbest for the next iteration are achieved The process shall be repeated until a criterion of convergence is met.

Figure1 shows the step-by step process to implement the particle swarm optimization algorithm.

III. TEACHING LEARNING BASED OPTIMIZATION (TLBO)

TLBO is a one of the most effective and reliable intelligence algorithm for non convex optimization problems proposed by Rao etc in 2010 [5]. TLBO works in two important phases for optimizing a problem. The first important phase is instructor phase and second important phase is student or learner Phase.

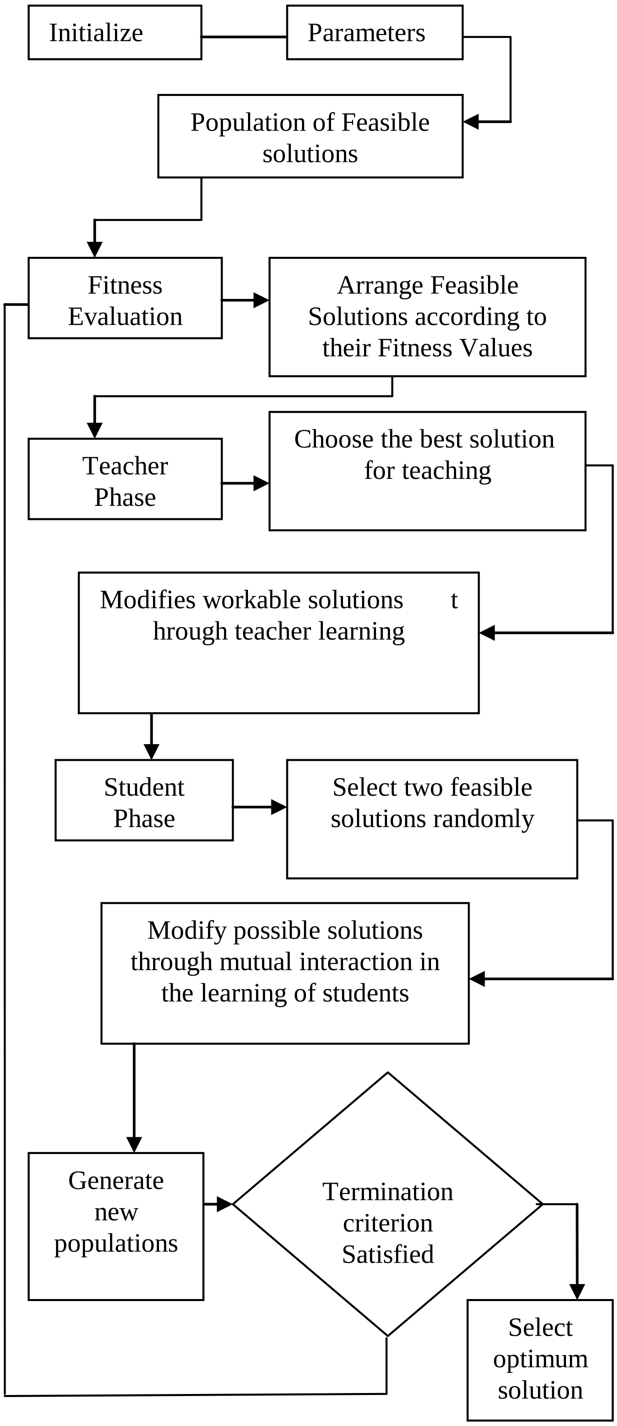

Figure2 Flow chart of TLBO algorithm

By simulating the teaching and learning method it achieves improvement. This technique is incredibly easy as a result of having just one parameter that's the amount of learners and having the good performance and less optimization time because of single depending parameter. Because of its unique nature it is widely used in different practical problems and engineering problems. Researchers adopt varied improvement techniques to accurately simulate the teaching and learning method to urge improves performance. At each iteration the best technique is the greatest learners are selected since the best solutions in order to replace the least students also to increase the ability associated with global search also to keep up with the diversity of search the feedback process is launched after learning process.

TLBO has two fundamental amounts. The first is "Instructor Phase" as well as the second the single is "learner Phase".

The point by point process is depicted as pursues:

Stage 1: Define the enhancement issue and introduce the advancement parameters.

Stage 2: Initialize the populace

Stage 3: Instructor stage

Stage 4: Learner stage

Stage5: Terminate the calculation if the most extreme age number is accomplished, generally rehash from Step 3.

The population of TBO alternatives is regarded to be one class of learners and the fitness of the alternatives is deemed to be results and grades. Through teacher learning and learning through the interaction between learners algorithm adeptly each class learner's grade updates. For the teacher group in its entirety, a teacher is the best solution. Teacher exchanges his / her experience with learners in order to improve median school performance. If xi = *(xi1……….....xid…………...xiD)* is the position of the learner, the learner with the best fitness is identified as the teacher, and the mean position of a class with the NP learner is presented as:

$$x_{mean} = 1/NP\left(\sum_{i=1}^{NP} x_i\right) \qquad (8)$$

Every learner's position is updated with the following equation:

$$x_{i,new} = x_{i,old} + rand.(x_{teacher} - T_F.x_{mean})$$

if the learner new and old positions are $x_{i,new}=(x_{i,new}^{1}\ldots\ldots x_{i,new}^{d}\ldots\ldots x_{i,new}^{D})$ and $x_{i,old} = (x_{i,old}^{1}\ldots\ldots x_{i,old}^{d}\ldots\ldots x_{i,old}^{D})$, respectively, then a random vector distributed uniformly inside [0, 1] is the teacher's factor T (F).otherwise $x_{i,new}$, is recognized unaffected when $x_{i,new}$ better than $x_{i,old}$.

In the student stage, a student interacts randomly with other students in order to improve his/her efficiency. Learner x_i selects another student x_j randomly and the following equation can be used to express:

$$x_{i,new} = \begin{cases} x_i^{old} + rand.(x_i - x_j), \ldots\ldots f(x_i) \le f(x_j) \\ x_i^{old} - rand.(x_j - x_i), \ldots\ldots f(x_i) > f(x_j) \end{cases} \quad (9)$$

if f(x) is the objective function ,the ancient situation of the jth student is with D-dimensional variables is used in the replacement of $x_{i,\,old,}$ if $x_{i,\,new}$ is better than $x_{i,\,old}$

IV. HYBRID PSO-TLBO OPTIMIZATION TECHNIQUE

For making the hybrid of the PSO and TLBO the concepts of the PSO and TLBO are used. At the first step generate the population as per problem and based on the population calculate the fitness for each and set the best of pbest as gbest on next apply teacher phase of TLBO in teacher phase choose the best solution for teaching and modified working solutions through teacher learning then apply PSO and update pbest as gbest and then apply student phase or learner phase of TLBO. When results are compared with the PSO and TLBO the hybrid of PSO-TLBO gives the improved results because it optimizes three times one in teaching phase second by PSO and third in student phase.

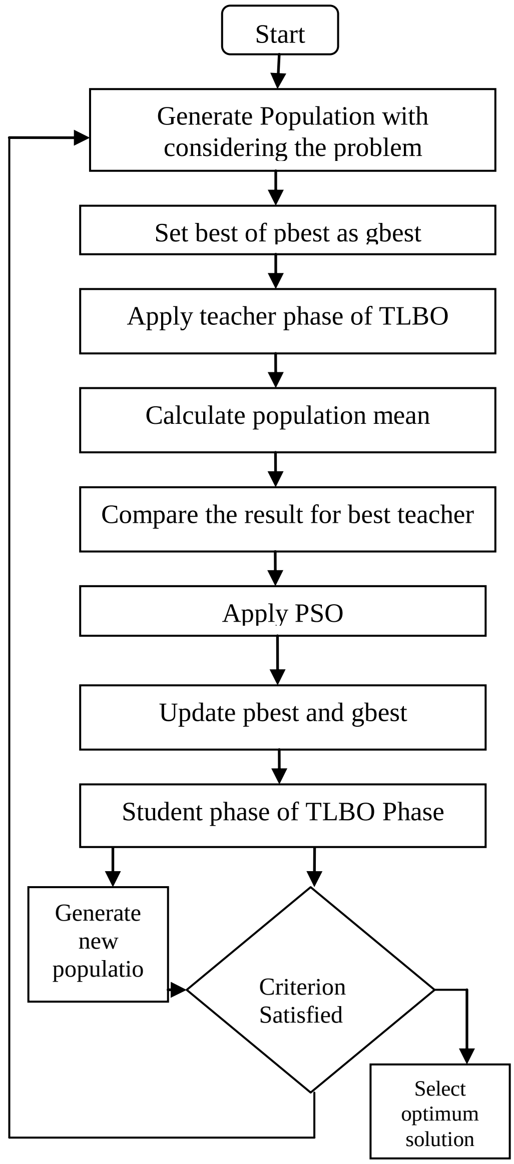

Figure3 Flow chart of hybrid (PSO-TLBO) algorithm

V. MATHEMATICAL PROBLEM FORMULATION

The formulation of CEED dispatch of a Thermal Power system summarized as:
Problem includes –

- **Economic optimization**
- **Emission optimization**
- **Environmental Cost optimization**

For CEED dispatch problems, the following objectives and limitations are considered:

A) Economic optimization

i) Economic load dispatch for convex system

$$F_T\left(P_{gi}\right)=\sum_{i=1}^{N_T}\left(a_i P_{gi}^2+b_i P_{gi}+c_i\right)\$/h \qquad (10)$$

(ii) For non-convex system

$$F_C=\sum_{i=1}^{N_T} a_i P_{gi}^2+b_i P_{gi}+c_i+\left|e_i * \sin\left(f_i *\left(P_{i\min}-P_i\right)\right)\right| \$/h \qquad (11)$$

Where:

F_C (P_{gi}): is the total cost of fuel required for generation in (\$/hr), a_i, b_i, and c_i are cost coefficients of the i_{th} generating unit and Pi represents the to the power generated by the i_{th} unit.N_T is the total number of units.

B) Emission Dispatch

$F_E(P_{gi})$: Represents the total emission of the thermal units in kg/h.

$$F_E\left(P_{gi}\right)=\sum_{i=1}^{N_T}\left(d_i P_{gi}^2+e_i P_{gi}+f_i\right) kg/h \qquad (12)$$

d_i,e_i,,f_i,: are the emission coefficients of the i_{th} generator

N_T : Represents the total available committed thermal generating units.

C) Environmental Dispatch

F_{HE} (Pgi): spoken to as the all out expense as a result of health and environmental harm.

$$F_{H\&E}(P_{gi})=\sum_{i=1}^{N_T}(P_{gi}) \qquad (13)$$

D) Real power balance constraint

$$\sum_{i=1}^{N_T} P_{gi}=P_D+P_L \qquad (14)$$

P_L: represents the total transmission losses in the network and the total transmission losses can be represented by using B-coefficients as given below:

$$P_L=\sum_{i=1}^{N_T}\sum_{j=1}^{N_T} P_{gi} B_{ij} P_{gj}+\sum_{i=1}^{N_T} B_{io} P_{gi}+B_{00} \qquad (15)$$

Here B_{ij}, B_{i0} and B_{00} are loss coefficients.

E) Generation unit capacity limits

$$P_{gi}^{\min}\le P_{gi}\le P_{gi}^{\max} \qquad (16)$$

P_{gi}^{min} Represents the Minimum loading limit and on the other hand P_{gi}^{max} represents the upper limit.

F) Ramp Rate Limits

Ramp rate limit such a limit, to the point that decide the range inside this generation may increment or decline. The thermal unit generation limited by the ramp rate is limited by:

$$P_i^t-P_i^{t-1}\le UPR_i$$
$$P_i^{t-1}-P_i^t\le DPR_i \qquad (17)$$

Where UPRi represents upper limit of the ith unit and DPRi represents the down limits of the ith unit individually. Due to the limits of ramp rate generating units are expressed as:

$$\max(P_{i\min}, UPR_i-P_i^t)\le P_i^t\le\min(P_{i\max}, P_i^{t-1}-DPR_i) \qquad (18)$$

F) Prohibited zones Limits

During the power generation each unit must be avoid operation in prohibited zones. The operating zones of the ith unit may be described as follows:

$$P_{gi}^{\min}\le P_{gi}\le P_{gi,1}^{l}$$

$$P^{u}_{gi,j-1} \le P_{gi} \le P^{l}_{gi,j}, j = 2,3,......n_i \qquad (19)$$
$$P^{u}_{gi,n_i} \le P_{gi} \le P^{max}_{gi}$$

Where:

n_j: number of prohibited zones of ith generating unit;

$P^{l}_{gi,j}$: lower active power limit of prohibited zone of j of ith generating unit, MW;

$P^{u}_{gi,j-1}$: upper active power limit of prohibited zone of j-1 of ith generating unit, MW.

VI. OPTIMIZATION PROBLEMS

CEED dispatch issue of a Thermal Power Plant can be characterized as,

Minimize

$$([(F_C(P_{gi}) + F_{H\&E}(P_{gi})), F_E(P_{gi})] \qquad (20)$$

Considering the constraints given in (14) to (19)

Mathematically, the fitness function of CEED can be described by introducing a price penalty factor as follows:

$$TC = (F_C(P_{gi}) + F_{H\&E}(P_{gi})) + h * F_E(P_{gi}) \qquad (21)$$

VII. SIMULATION AND RESULT

The algorithm proposed is used in four various samples and contrasts with the demographic optimization methods used by past scholars such as NR, Tabu search, GA, NSGA, FCGA, DE and PSO. The performance of each system has been judged out of 50 trials. The programming was written in MATLAB language, using MATLAB 7.1 on Intel's earlier Core Duo processor, 1.6 GHz with 3GB RAM.

Case-I: To take a look at the adequacy of the PSO-TLBO algorithm first, three- units of a generating plant to meet total load of 850 MW is considered for this example. The framework information is the indistinguishable as [16].Here solely targets mainly emission & fuel fee is used for this situation. The performance of PSO-TLBO is compared to that of Tabu search [24] and non dominated sorting genetic algorithm-II (NSGA-II) [17].

Table 1 Generating unit capacity and coefficients for case-I

Unit	P_i^{min}	P_i^{max}	a_i ($)	b_i ($/MW)	c_i ($/MW^2)
1	150	600	0.001562	7.92	561
2	100	400	0.00194	7.85	310
3	50	200	0.00482	7.97	78

Table2 Emission coefficients for case-I

Units	*f* (lb/h)	e (lb/MW/h)	d (lb/MW^2/h)
1	13.85932	0.32767	0.00419
2	13.85932	0.32767	0.00419
3	40.26690	-0.54551	0.00683

Table3 Best compromise solution for case-I

Unit	Tabu search [16]	NSGA-II [17]	BBO [21]	**PSO-TLBO**
P1(MW)	435.69	435.88	435.195	436.07
P2(MW)	298.82	299.98	299.972	223.46
P3(MW)	131.28	129.95	130.662	200
TG(MW)	865.79	865.82	865.829	859.56
TL(MW)	15.798	15.826	15.8290	9.56
FC($/h)	8,344.5	8,344.5	8,344.59	8337.6
E(kg/h)	0.0986	0.0986	0.09869	0.0442

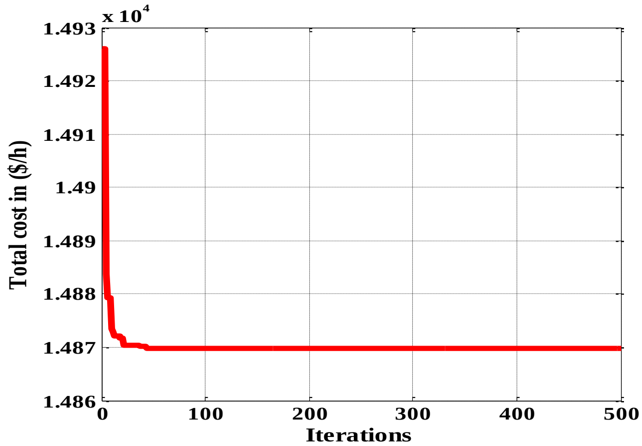

Figure4 Total Cost Variation for 3-Units System

Case-II: In the second case to demonstrate the deliberate algorithmic six power generating units having price and emission in the form of quadratic equation is taken into account. All the information is taken from [17].

Table 4 Generating unit capacity and coefficients for case-II

Unit	P_i^{min}	P_i^{max}	a_i ($)	b_i ($/MW)	c_i ($/MW^2)
1	10	125	756.88	38.53973	0.15247
2	10	150	451.32	46.15916	0.10587
3	35	225	1049.9	40.39655	0.02803
4	35	210	1243.5	38.30553	0.03546
5	130	325	1658.5	36.32782	0.02111
6	125	315	1356.6	38.27041	0.01799

Table5 Emission coefficients for case-II

Units	*f*(lb/h)	e (lb/MW/h)	d(lb/MW^2/h)
1	13.85932	0.32767	0.00419
2	13.85932	0.32767	0.00419
3	40.26690	-0.54551	0.00683
4	40.26690	-0.54551	0.00683
5	42.89553	-0.51116	0.00461
6	42.89553	-0.51116	0.00461

Table6 loss coefficients for case-II

$$B=\begin{bmatrix} 0.002022 & -0.000286 & -0.000534 & -0.000565 & -0.000454 & -0.000103 \\ -0.000286 & 0.003243 & 0.000016 & -0.000307 & -0.000422 & -0.000147 \\ -0.000533 & 0.000016 & 0.002085 & 0.000831 & 0.000023 & -0.000270 \\ -0.000565 & -0.000307 & 0.000831 & 0.001129 & 0.000113 & -0.000295 \\ -0.000454 & -0.000422 & 0.000023 & 0.000113 & 0.000460 & -0.000153 \\ 0.000103 & -0.000147 & -0.000270 & -0.000295 & -0.000153 & 0.000898 \end{bmatrix}$$

Table 7 Best compromise solution for case-II

Load (MW)	***Algorithms***	***P1 (MW)***	***P2 (MW)***	***P3 (MW)***	***P4 (MW)***	***P5 (MW)***	***P6 (MW)***	***TL (MW)***	***FC ($/h)***	***E (kg/h)***
	NR[19]	59.87	39.65	35.000	72.397	185.241	125.000	17.162	28,550.15	312.51
500	*FCGA[20]*	65.23	24.29	40.44	74.22	187.75	125.48	17.41	28,231.06	304.90
	NSGA[17]	54.04	34.25	54.497	80.413	161.874	135.426	20.508	28,291.12	284.36
	BBO[21]	49.89	33.90	62.987	82.881	153.405	139.032	22.107	28,318.51	279.30
	PSO-TLBO	55.792	38.097	65.289	82.1723	147.847	133.383	22.582	28455.102	277.75
	NR[19]	85.92	60.96	53.909	107.124	250.503	176.504	34.927	39,070.74	528.44
	FCGA[20]	80.16	53.71	40.93	116.23	251.20	190.62	32.85	38,408.82	527.46
700	*NSGA[17]*	86.28	60.28	73.064	109.036	223.448	184.111	36.234	38,671.81	484.93
	BBO[21]	84.01	61.92	78.728	110.918	211.985	187.892	39.262	38,828.27	476.40
	PSO-TLBO	93.048	66.727	83.291	110.682	205.984	178.6639	38.399	38998.303	472.70

Case-III In this case, six generating units with ramp rate limit and prohibited zones constraints of all units are considered to check the adequacy of the PSO-TLBO algorithm for combined economic emission dispatch. The data are used from [21] for cost coefficients, active power limits, ramp rate limits, and prohibited zones. Table 8, 9 provides information of cost and emission coefficients. Table 10 provides the prohibited zones and ramp rate limit and table 11 provides loss coefficients.

Table 8 Generating Unit Capacity And Coefficients For Case-III

Unit	P_i^{min}	P_i^{max}	a_i ($)	b_i ($/MW)	c_i ($/MW^2)
1	100	500	240	7.0	0.0070
2	50	200	200	10.0	0.0095
3	80	300	220	8.5	0.0090
4	50	150	200	11.0	0.0090
5	50	200	220	10.5	0.0080
6	50	120	190	12.0	0.0075

Table 9 Emission Coefficients For Case-III

Units	*f* (lb/h)	e (lb/MW/h)	d (lb/MW^2/h)
1	13.85932	0.32767	0.00419
2	13.85932	0.32767	0.00419
3	40.26690	-0.54551	0.00683
4	40.26690	-0.54551	0.00683
5	42.89553	-0.51116	0.00461
6	42.89553	-0.51116	0.00461

Table10 Prohibited zones and ramp rate limits for case-III

Unit	Prohibited zones MW)	P_i^0	UPR_i	DPR_i
1	[210 240][350 380]	440	80	120
2	[90 110][140 160]	170	50	90
3	[150 170][210 240]	200	65	100
4	[80 90][110 120]	150	50	90
5	[90 110][140 150]	190	50	90
6	[75 85][100 105]	110	50	90

Table11 loss coefficients for case-III

$$B=\begin{bmatrix} 0.002022 & -0.000286 & -0.000534 & -0.000565 & -0.000454 & -0.000103 \\ -0.000286 & 0.003243 & 0.000016 & -0.000307 & -0.000422 & -0.000147 \\ -0.000533 & 0.000016 & 0.002085 & 0.000831 & 0.000023 & -0.000270 \\ -0.000565 & -0.000307 & 0.000831 & 0.001129 & 0.000113 & -0.000295 \\ -0.000454 & -0.000422 & 0.000023 & 0.000113 & 0.000460 & -0.000153 \\ 0.000103 & -0.000147 & -0.000270 & -0.000295 & -0.000153 & 0.000898 \end{bmatrix}$$

$$B_0 = 1.0e^{-0.3*}[-0.3908 \quad -01297 \quad 0.7047 \quad 0.0591 \quad 0.2161 \quad -0.6635]$$

$$B_{\infty} = 0.056$$

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Table12 Simulation Result of 6-Grnerator System With Different Algorithms For Case -III

Units	Algorithms							
	DEMAND (1000 MW)				DEMAND (1200 MW)			
	GA	PSO	BBO[21]	**PSO-TLBO**	GA	PSO	BBO[21]	**PSO-TLBO**
P1(MW)	320.0	320.00	320.00	320.1186	329.1083	329.6465	349.216	330.4007
P2(MW)	140.00	164.61	160.00	162.6623	198.0966	198.1324	200.000	197.3993
P3(MW)	142.14	138.10	137.77	137.3499	243.8283	240.0493	211.779	240.0173
P4(MW)	90.000	77.37	80.000	79.55501	121.3974	124.792	131.000	120.3688
P5(MW)	197.50	189.98	191.82	185.4665	199.8071	199.5031	200.000	199.6839
P6(MW)	119.99	119.50	120.00	119.9956	119.4460	119.9729	120.000	119.9663
TG(MW)	1,009.6	1,009.58	1,009.6	1005.1479	1,212.172	1,212.116	1,211.99	1207.8365
TL(MW)	9.6489	9.5813	9.6084	5.0663	12.1823	12.116	11.9964	7.7992
PF	6.1152	6.1152	6.1152	6.1152	12.8718	12.8718	12.8718	12.8718
TC($/h)	22,130.8	22,130	22,108.3	21963.0756	50,728.5	50,650.0	50,330.7	50226.3975
FC($/h)	12,199.8	12,205.6	12,206.2	12145.9905	14,725.9	14,725.4	14,715.4	14667.4159
E(lb/h)	1,623.98	1,622.85	1,619.27	1605.3598	2,797.0	2,790.95	2,766.9	2762.5557

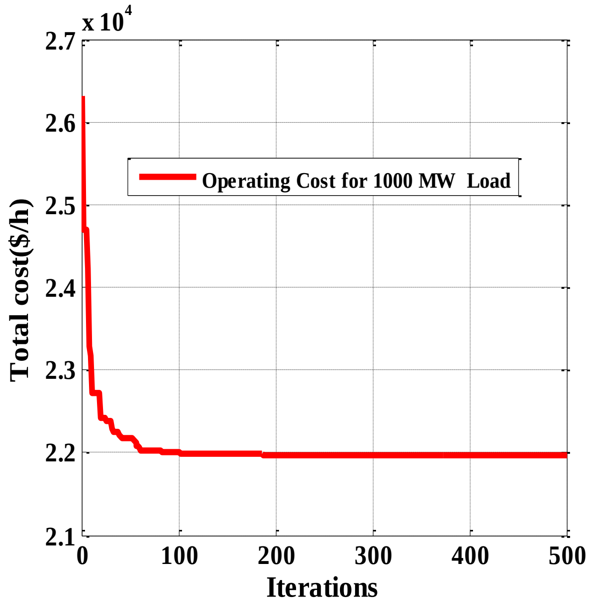

Figure5 Total Cost for 1000 MW load case-III

Case-IV: In this case, six generation units with ramp-rate limit and prohibited zones constraints of all units are considered to check the adequacy of the PSO- TLBO algorithm for combined economic emission dispatch with additionally constraint environmental cost constraints. The all data is same as the case –III additionally data required for the for the case-iv that is coefficient of health and environmental damage C_{HE}

That depend on the power generated by thermal power plants here C_{HE} is assumed as 100 $/MWh. It is observed that major part of the optimized cost corresponding to each level of power demand is the cost paid for health and environmental damage that damage caused because of emission from the thermal units. So it needs to pay this part by thermal power plant to compensate the health and environmental damage because of emission. Case-iv is considered for three loads that's are 1000 MW, 1200 MW and 1500 MW. Here TEC represents the total environment cost in $/h.

Table13 Best Compromise Solution For Case-IV

Unit	PSO-TLBO		
	1000(MW)	1200(MW)	1500(MW)
P1(MW)	320.0071	344.4352	394.2155
P2(MW)	161.9398	200	200
P3(MW)	130.0942	209.9895	244.8919
P4(MW)	79.70434	133.1488	150
P5(MW)	193.7819	200	200
P6(MW)	119.9045	120	120
TG(MW)	1005.4319	1207.5735	1309.1074
TL(MW)	5.3104	7.5718	9.1074
PF	53.5198	110.3852	110.3852
TC($/h)	198446.97	437312.52	537253.19
FC($/h)	12169.261	14665.460	15939.178
E(lb/h)	1601.9218	2734.8754	3536.7364
TEC($/h)	100543.19	120757.34	130910.73

VIII. CONCLUSION

The paper provides Hybrid optimization based on the particles of swarm and teaching learning to solve the four-case problem of the combined economic emission of load dispatch. In the first case, PSTLBO offers the best fuel price among all its algorithms, and also finds that its best emission alternatives are similar to those found in Tabu search and NSGA. In all three cases of load demand, a system of 6 Generators, not including prohibited zones and raffle-ramp limitations (second example) shows similar fuel costs with a range of algorithms and significantly improves emissions level with PSTLBO. Non-linear property such as ramp rate limits and forbidden zones are provided for the practical operation of thermal generators and it is noted that the proposed algorithm has a better performance than other best-known methods such as the GA and PSO.

In the recent CEED problem, PSTLBO shows a smaller full (goal) importance relative to PSO and GA in the third case. Given all these results, the proposed algorithm is ultimately perfect for near-ground optimization in terms of combined economic and emission dispatch issues with different loads, restrictions and costing functions.

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