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Research paper

Combined Economic and Emission Load Dispatch Problem Solving by ITLBO Algorithm

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Abstract

Recent trends in economic and emission dispatch problem which turn has to promote the rise in the number of power generating stations and their capacity of generation. The Sulphur Dioxide (SO2), Nitrogen Oxides (N2O) and Carbon Dioxide (CO2) are yields the CEED problem and they are created from generation of electricity from fossil fuel. Combined economic and emission load dispatch problem is a procedure to determine the generation of electrical power isdevoted generating units in a power system so that the both total generation costand total emission of the system is minimized, while fulfilling the load demand in directly. Improved teaching learning based optimization algorithm is used to solve combined economic emission load dispatch problem with constraints in generation of power system. This method was verified by thirteen generating bus and use with different load demand and compared with other existing techniques display the advantage of the proposed algorithm. The simulation has been done in MATLAB/Simulink with required formulation and the result is gotten in graph and numerical.

Keywords: *Economic Load Dispatch (ELD); Economic Emission Dispatch (EED); Combined Economic Emission Load Dispatch (CEED); Improved Teaching Learning Based Optimization (ITLBO).*

1. Introduction

Now a day the electrical power market becomes more competitive in the world. In order to live in this atmosphere, we have to locate the optimal power generations which minimize the total cost and reduce emission. The main purpose of the CEED is to minimize the total cost and minimize emission rate of generation as satisfying the operationalconstraints.

Economic load dispatch (ELD) is one of the majorityvery importantharms to be explained for the economic operation of a power system. Economic load dispatch is to describe the production level of every plant so that the cost of fuel is reduced for the arrangedplan of load [1]. The objective of economic load dispatch (ELD) is to assign the generation among the committed units such that the cost of fuel is minimized, while sufficient the equality constrain and inequality constrain [2].The economic load dispatch (ELD) problem seeks the finest generation plandesigned for the generating plants to supply the essential demand plus transmission losses with the minimum production cost [3]. conservatively, the importance on presentation optimization of fossil-fuel power system was on economic operation only, using the ELD approach, as better solution would result in significant economicbenefits [4]. However, due to the urgentmunicipal demand for dirt free air as well as due to the “global warming” concept, new clean air policies and system have been required on the industrial development [5]. Thermal power units are responsible in a main way for creating major atmospheric pollution because of high concentrations of pollutants, such as NO_X, SO_X, and CO_X, contained in their emission. Therefore, power segments have appreciated the position of keeping a cleaner atmosphere [6]. Due to this constraint, generation distribution is not only ruled by manufacture costs, but also by the supremeacceptable emission level. As a outcome, a novelmethod has originate up known as the economic emission dispatch (EED) problem method [7].EED is an optimization problematic that chases the lowest emission level of development of a power scheme [8].

ELD problem is solved to use some conventional methods. Lagrangian multiplier process was introduced to explain the ELD difficult. Economic load dispatch (ELD) problem using standard method like Newton-Raphson method, effective method were presented [9]. In these methods statement is prove that the incremental cost curves of the generators is linear so the practical case of the cost curves units are highly nonlinear [10]. Dynamic programming is used but it created has dimensionality and native optimality problem [11]. The artificial intelligence techniques and particle swarm optimization (PSO), modified PSO (MPSO) areapplied inHierarchical structure method, which is a numerical technique was planned to solve ELD problem with piece-wise quadratic cost function [12].In large scalesystem, the problem is more complex and difficult to find out optimal solutionbecause it is nonlinear function and it contains number of local optimal. Combinedeconomic emission dispatch (CEED) problem is to schedule the committedgenerating unit’s outputs to meet the required load demand at minimum operatingcost with minimum emission simultaneously. There are various techniquesproposed by several researchers to solve CEED problem based on optimizationtechniques. But still some problems such as slower convergence and higher computation a complexity exist in using the optimization techniques such as GA for solvingCEED problem [13].

The teaching learning based optimization(TLBO)algorithm need not require special factors setting for functioningthe algorithm, but there are some shortcomings such as sluggishconvergence speed and lengthy running time [14]-[15].The main purpose of economic load dispatchisthe necessary equality and inequality constraints should also be full filled and also diminish the total production cost of the generating system. This leads to the development of another CEED techniques. This paper is proposed to solving combined economic and emission load dispatch problem using ITLBO algorithm. The system is used todiminish the emission in the environment and reduce the total cost .

2. Problem Statement

a) Economic Dispatch

The economic dispatch problem may be expressed by minimizing the fuel cost of generator units under constraints. The output of generators has to be changed to meet the balance between loads and generation of a power system is deciding the load variation.
The ED problem can be expressed as:

$$\mathrm{Min}, F_1 = \sum_{i=1}^{N} F_i(P_i) \quad (1)$$

$$\sum_{i=1}^{N} P_i - (P_D + P_L) = 0 \quad (2)$$

Where,

$F_i(P_i)$ =Fuel cost function
P_i =generator power of unit
N=number of online units
P_D=system load demand
P_L=transmission loss
The fuel cost function of i^{th}generating unit can be defined by

$$E_i(P_i) = a_i P_i^2 + b_i P_i + c_i \quad \$/hr \quad (3)$$

Where $F_i(P_i)$the total operating fuel cost in $\$/hr$. N is the number of generators including the bus.and$a_i, b_i, c_i$are the cost coefficients of the ith generating unit.
Subjects to the following constraints

$$P_i^{min} \le P_i \le P_i^{max} \quad \text{for } i = 1, \dots, N \quad (4)$$

P_i^{min}, P_i^{max}=minimum and maximum operating limits of generator i

$$\sum_{i=1}^{N} P_i - (P_D + P_L) = 0 \quad (5)$$

P_D= Total demand (MW)
P_L=Transmission losses (MW)
P_i=Real power of output of the i-th generator

Economic dispatch total cost

$$F_T = \sum_{i=1}^{N_G} \{a_i P_i^2 + b_i P_i + c_i + |e_i^* \sin\{f_i^*(P_i^{min} - P_i)\}|\} \quad (6)$$

b) Emission Dispatch

The main objective of the emission dispatch is to maintain the pollution within environment license irrespective of the fuel type. The minimum emission dispatch problem can be formulated as follows:
The objective function can be described as:

$$\mathrm{Min}\, F_2 = \sum_{i=1}^{N} \alpha_i P_i^2 + \beta_i P_i + \gamma_i \quad \$/hr \quad (7)$$

Where $F_i(P_i)$the total operating fuel cost in $\mathrm{ton/hr}$. N is the number of generators including the bus. And $\alpha_i, \beta_i, \gamma_i$are the emission coefficients of the ith generating unit.
Emission dispatch total cost

$$F_T = \sum_{i=1}^{N_G} \{\alpha_i P_i^2 + \beta_i P_i + \gamma_i + \xi_i e^{\tau_i P_i}\} \,\$/hr \quad (8)$$

c)CombinedEconomic and Emission Dispatch

The CEED problem can be expressed in term of combination of two objectives viz. fuel cost and emission by implementing a price penalty and weighting factors. Hence, the bi-objective CEED can be formulated into a single objective form, as follows

$$\mathrm{Min}\, F_{CEED} = F + h * E$$

$$\mathrm{Min}\, F_{CEED} = \sum_{i=1}^{N} \left(\left(a_i P_i^2 + b_i P_i + c_i + \left| e_i^* \sin\{f_i^*(P_i^{min} - P_i)\} \right| \right) + h * \left(h * \left(\alpha_i P_i^2 + \beta_i P_i + \gamma_i + \eta_i \exp(\delta_i P_i) \right) \right) \right) \quad (10)$$

The price penalty factor hi is the ratio between the maximum fuel costand maximum emission of corresponding generator

$$h = \frac{F(P_{i,max})}{E(P_{i,max})} \,\$/ton \quad (11)$$

3. Improved Teaching Learning Based Optimization

In the basic TLBO algorithm, the result of the learners is improved either by a single teacher (through classroom teaching) or by interrelating with other learners. However, in the traditional teaching-learning environment, the students also learn during lecture hours by discussing with their member classmates or even by discussion with the teacher himself/herself. Moreover, sometime students are self-motivated and attempt to learn by themselves. Furthermore, the teaching factor in the basic TLBO algorithm is either 2 or 1, which reproduces two riskyconditions where a learner learns either all or nobody from the teacher.
In this system, a teacher has to apply more effort to improve the results of learners. During the course of optimization, this condition results in a slower convergence rate of the optimization problem. In view of this fact, to improve the exploration and exploitation capacities, some improvements have been introduced to the basic TLBO algorithm. Another author made some modifications to the basic TLBO algorithm and applied the same to the optimization of a two stage thermoelectric cooler and heat exchangers.
In the fundamental TLBO algorithm, the results of the students are improved either by learning from the teacher or by interacting with the other students. However, it is also probable that students are self motivated and improve their knowledge by self-learning. Thus, the self-learning aspect to make do the knowledge is considered in the I-TLBO algorithm.
Step 1; Define the optimization problem as Minimize or Maximize f (X), where f (X) is the objective function value and X is a vector for design variables or number of subjects.
Step 2; Initialize the population matrix (i.e. learners, k = 1, 2 . . . n) and design variables of the optimization problem (i.e., number of subjects offered to the learners, j = 1, 2, . . . ,m), and determine the objective function(i.e cost function of economic load dispatch)
Step 3; Select the best solution who acts as chief teacher for that iteration. Assign him/her to first rank.
Step 4;

$$(X_{Teacher})_1 = f(X)_1 = f(X)_{best} \quad (18)$$

Step 5; Choose the other teachers (T) based on the head teacher and rank them,
Step 6;

$$f(X)_s = f(X)_1 - rand^* f(X)_1 \quad s{=}2, 3, \dots T \quad (19)$$

Step 7; Consign the learners to the teachers according to their Fitness value.
Step 8; Keep the best solutions of every group.
Step 9; Calculate the mean result of each group of learners in each subject $(M_J)_S$

Step 10; For each group, estimate the dissimilarity between the current mean and the equivalent result of the teacher of that group for each subject by utilizing the adaptive teaching factor [which is evaluated using (20) & (21) as (22).

$$(T_F)_i=\left(\frac{X_{total\_k}}{X_{total\_kbest}}\right)_i$$

$$k=1,2,..,n \quad \text{if } X_{total\_kbest,i} \neq 0 \tag{20}$$

$$(T_F)_I = 1, \quad if X_{total\_kbest,i} = 0 \tag{21}$$

$$\left(Difference_{mean_j}\right)_s = rand^*\left(X_{J,Teacher} - T_F M_j\right)_s \tag{22}$$

$$s = 1,2,\dots,T, \quad j = 1,2,\dots,m$$

Step 11; For each group, update the learners' knowledge with the help of the teacher's knowledge, along with the knowledge of learners using (23)& (24)

$$\left(X^*_{j,k}\right)_s = \left(X_{j,k} + Difference_{mean\,j}\right)_s + rand^*(X_{hh} - X_k)_s iff(X_{hh}) < f(X_k) \tag{23}$$

$$\left(X^*_{j,k}\right)_s = \left(X_{j,k} + Difference_{mean\,j}\right)_s + rand^*(X_k - X_{hh})_s \quad iff(X_k) < f(X_{hh}) \tag{24}$$

Step 12; For each group, update the learners' knowledge by Interaction with other learners, as well as by self learning using (25) & (26)

$$\left(X^*_{j,k}\right)_s = X_{j,k,i} + rand\left(X'_{j,k} - X'_{j,p}\right)_s + rand\left(X_{teacher} - E_F X'_{j,k}\right)_s \quad iff(X'_k) < f\left(X'_p\right) \tag{25}$$

$$\left(X^*_{j,k}\right)_s = X_{j,k,i} + rand\left(X'_{j,p} - X'_{j,k}\right)_s + rand\left(X_{teacher} - E_F X'_{j,k}\right)_s \quad iff\left(X'_p\right) < f(X'_k) \tag{26}$$

where E_F= exploration factor = round(1 + rand).

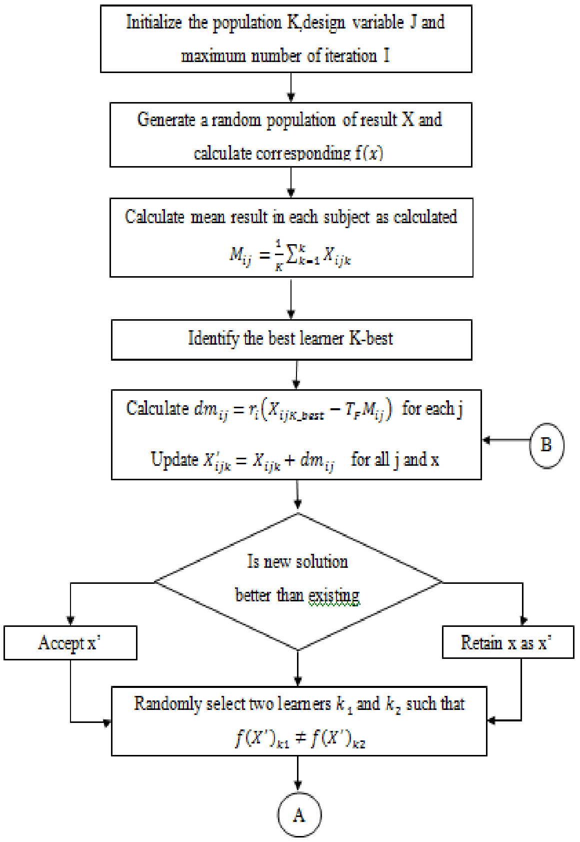
(The above equations are for a minimization problem, the reverse is true for a maximization problem.)

Step 13; Replace the worst solution of each group with best solution.

Step 14; Eliminate the duplicate solutions randomly.

Step 15; Combine all the groups.

Step 16; Repeat the procedure from step 3 to 13 until the Stopping criteria is met.



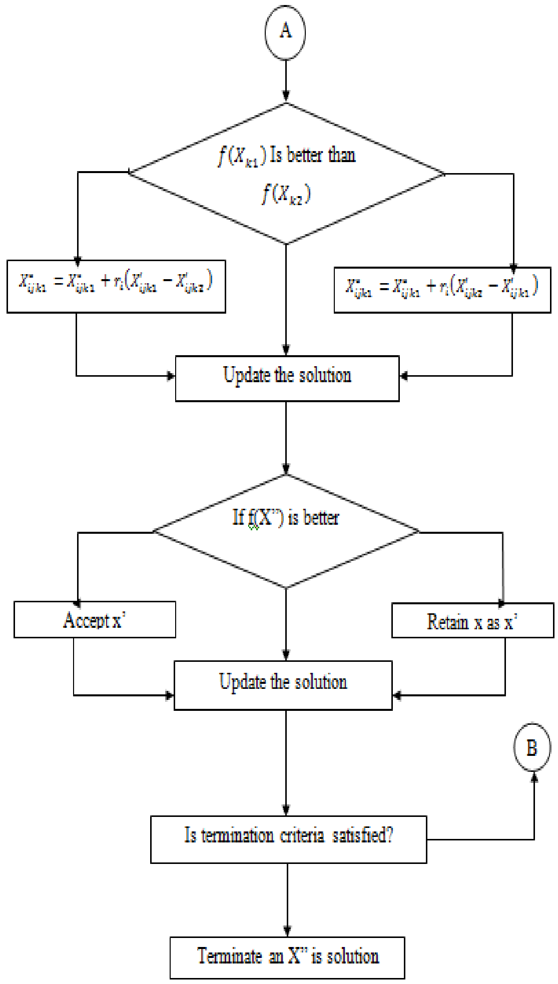


Fig. 1: Flow chart of ITLBO

4. Result and Discussions

The applicability of the ITLBO algorithm for practical use has been tested in thirteen unit bus generating system and using various demands. The programs are industrial using MATLAB.

The thirteen unit generating unit measured are having different feature. Their individuality are given by the following the table. Table 1 is represents the cost coefficient and emission coefficient value in the thirteen unit bus system

Table 1: Charecteristics of 13 Unit Bus System

S.No	P_D=200MW		P_D=600MW		P_D=900MW		P_D=1800MW	
	Iteration	Fuel cost 10^3 ($/hr)	Iteration	Fuel cost 10^3 ($/hr)	Iteration	Fuel cost 10^3 ($/hr)	Iteration	Fuel cost 10^3 ($/hr)
1	0	1.4	0	1.620	0	1.52	0	1.934
2	20	0.76	20	1.595	20	1.49	20	1.920
3	40	0.76	40	1.590	40	1.43	40	1.915
4	60	0.76	60	1.585	60	1.40	60	1.913
5	80	0.76	80	1.580	80	1.38	80	1.912
6	100	0.76	100	1.575	100	1.37	100	1.911
7	120	0.76	120	1.570	120	1.37	120	1.90
8	140	0.76	140	1.567	140	1.36	140	1.908
9	160	0.76	160	1.564	160	1.35	160	1.907
10	180	0.76	180	1.560	180	1.345	180	1.905
11	200	0.76	200	1.555	200	1.34	200	1.902

Table 2: Output for 13 Unit Bus System in Variuos Demand(200mw,600mw,900mw,1800mw)

Generating Unit (MW)	P_D=200MW			P_D=600MW			P_D=900MW			P_D=1800MW		
	Economic Fuel Cost ($/hr)	Emission cost ($/hr)	CEED ($/hr)	Economic Fuel Cost ($/hr)	Emission cost ($/hr)	CEED ($/hr)	Economic Fuel Cost($/hr)	Emission cost ($/hr)	CEED ($/hr)	Economic Fuel Cost ($/hr)	Emission cost($/hr)	CEED ($/hr)
P_1(MW)	0	0.06	0	727	780.42	1346.34	2675	2873.03	3897.56	1616	1735.97	3231.99
P_2(MW)	0	0.05	0	451	378.48	1340.23	602	505.69	1086.98	1466	1231.12	2931.99
P_3(MW)	0	0.03	0	720	604.21	1145.24	605	508.00	986.28	1474	1237.70	2947.99
P_4(MW)	464	510.05	927.99	464	510.02	927.99	824	905.44	927.99	1236	1357.69	2472.00
P_5(MW)	464	510.04	928.00	682	748.82	928.00	605	663.91	928.00	1237	1357.92	2474.00
P_6(MW)	464	510.06	927.99	537	589.83	927.99	464	510.03	927.99	1078	1183.33	2155.99
P_7(MW)	464	510.02	928.00	464	510.02	928.00	850	933.54	928.00	850	933.79	1699.99
P_8(MW)	464	510.06	928.00	1235	1356.42	928.00	464	510.00	928.00	1236	1357.79	2471.99
P_9(MW)	464	510.03	928.00	464	510.06	928.00	507	557.21	876.94	882	968.73	1764.00
P_{10}(MW)	344	208.01	928.00	344	208.06	928.00	344	208.00	826.63	658	398.08	1317.30
P_{11}(MW)	344	208.02	687.99	662	400.44	687.99	344	208.05	753..45	987	596.94	1973.99
P_{12}(MW)	473	302.52	688.00	777	496.74	688.00	473	302.52	688.03	958	612.59	1915.99
P_{13}(MW)	473	302.53	946.01	780	498.99	946.02	785	501.95	946.01	795	508.22	1590.62
Total Generation Cost($/hr)	**4421**	**4081.51**	**8842.00**	**8308**	**7592.54**	**16615.98**	**9544**	**9187.41**	**19087.97**	**14474**	**13479.92**	**28947.93**

The solution for CEED problem of thirteen unit bus Considered here is given below. The demand takenhere is 200MW,600MW,900MW,1800MW.

Table 2 is represents the output for thirteen unit bus system in 200MW,600MW,900MW,1800MWdemand. Table 3 is represents the output for thirteen unit bus system in total generation cost and demand.

Table 3: Output For Total Cost Vs Demand 13 Unit Bus

S.no	Demand (MW)	Total Economic Fuel Cost($/hr)	Total Emission cost($/hr)	Total CEED cost($/hr)
1	200	4421	4081.52	8842.00
2	600	8308	7592.54	16615.98
3	900	9544	9187.41	19087.97
4	1800	14474	13479.93	28947.93

Table 4: Output For Iteration Vs Fuel Cost 13 Unit Bus System (Demand=200mw,600mw,900mw,1800mw)

Gen No	**Fuel Cost Coefficients**					**Emission Coefficients**					**Generation Limits**	
	a_i (\$)	**b_i (\$/MW)**	**c_i (\$/MW^2)**	**Di**	**Ei**	**Ai**	**Bi**	**γi**	**Ξi**	**Δi**	**P_{min} (MW)**	**P_{max} (MW)**
1	0.00028	8.10	550	300	0.035	0.0632	-2.434	40	0.855	0.0087	0	680
2	0.00056	8.10	309	200	0.042	0.03480	-3.630	50	0.623	0.0068	0	360
3	0.00056	8.10	307	150	0.042	0.03480	-3.630	50	0.623	0.0068	0	360
4	0.00324	7.74	240	150	0.063	0.04376	-5.271	40	0.312	0.0085	60	180
5	0.00324	7.74	240	150	0.063	0.04376	-5.271	40	0.312	0.0085	60	180
6	0.00324	7.74	240	150	0.063	0.04376	-5.271	40	0.312	0.0085	60	180
7	0.00324	7.74	240	150	0.063	0.04376	-5.271	40	0.312	0.0085	60	180
8	0.00324	7.74	240	150	0.063	0.04376	-5.271	40	0.312	0.0085	60	180
9	0.00324	7.74	240	150	0.063	0.04376	-5.271	40	0.312	0.0085	60	180
10	0.00284	8.60	126	100	0.084	0.05710	-4.852	100	0.424	0.0052	40	120
11	0.00284	8.60	126	100	0.084	0.05710	-4.852	100	0.424	0.0052	40	120
12	0.00284	8.60	126	100	0.084	0.05710	-4.343	100	1.130	0.0055	55	120
13	0.00284	8.60	126	100	0.084	0.05710	-4.343	100	1.130	0.0055	55	120

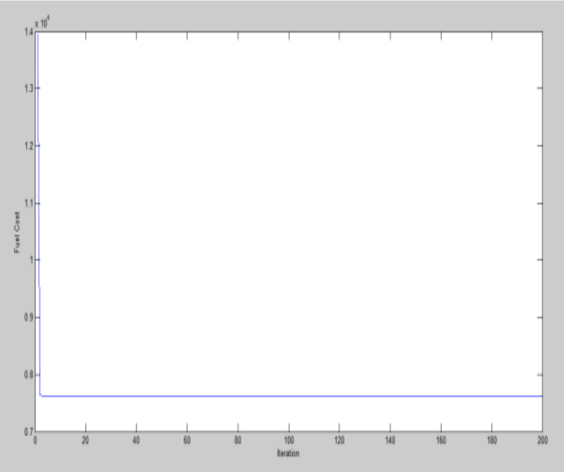


Fig. 2: Convergence Characteristics Of 13-Unit System for 1800MW

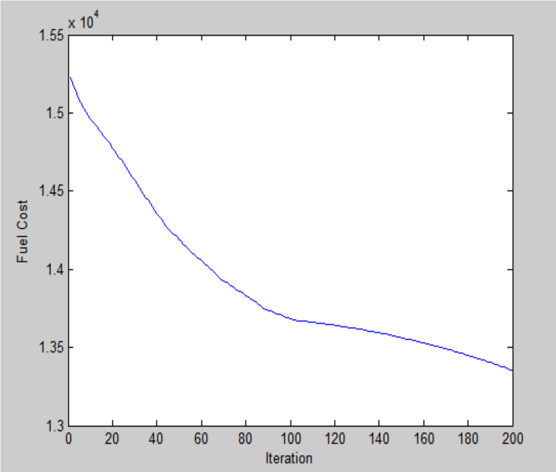


Fig. 4: Convergence Characteristics Of 13-Unit System for 1800MW

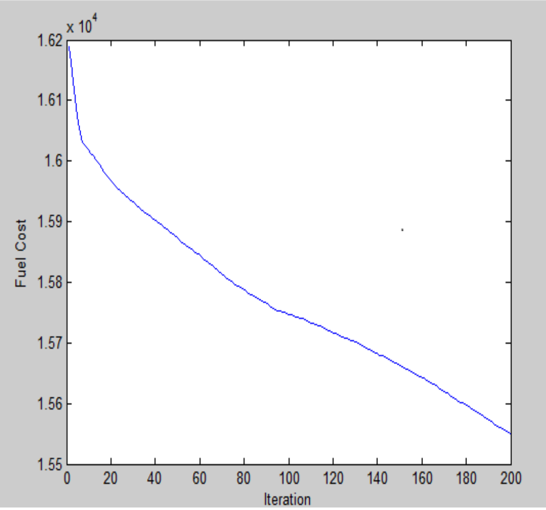


Fig. 3: Convergence Characteristics Of 13-Unit System for 1800MW

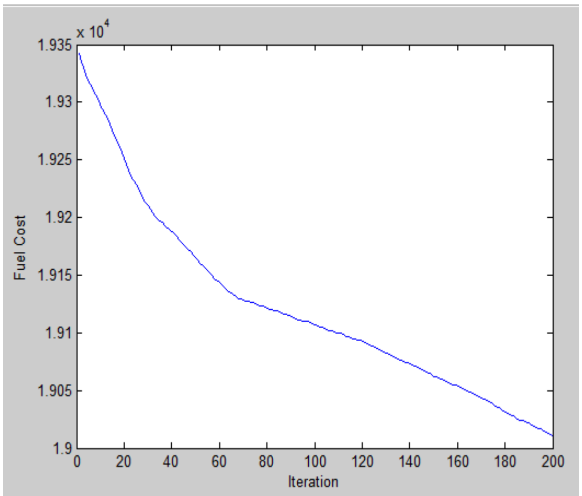


Fig. 5: Convergence Characteristics Of 13-Unit System for 1800MW

Table 5: Comparision Between Output For SA and ITLBO Technique

GENERATING UNIT (MW)	SA			ITLBO		
	Economic Fuel Cost($/hr)	**Emission cost($/hr)**	**CEED($/hr)**	**Economic Fuel Cost($/hr)**	**Emission cost($/hr)**	**CEED($/hr)**
P_1(MW)	668.40	1865.27	2880.67	1616	1735.97	3231.99
P_2(MW)	359.11	1845.36	2765.87	1466	1231.12	2931.99
P_3(MW)	358.20	1813.11	2678.67	1474	1237.70	2947.99
P_4(MW)	104.28	1745.26	2676.98	1236	1357.69	2472.00
P_5(MW)	60.36	1712.12	2657.98	1237	1357.92	2474.00
P_6(MW)	110.64	1699.12	2635.87	1078	1183.33	2155.99
P_7(MW)	162.12	1543.54	2611.76	850	933.79	1699.99
P_8(MW)	163.03	1444.87	2598.65	1236	1357.79	2471.99
P_9(MW)	161.52	1365.98	2566.76	882	968.73	1764.00
P_{10}(MW)	117.09	1347.08	2455.67	658	398.08	1317.30
P_{11}(MW)	75.00	985.87	2367.34	987	596.94	1973.99
P_{12}(MW)	60.00	700.25	2243.65	958	612.59	1915.99
P_{13}(MW)	119..58	625.98	810.37	795	508.22	1590.62
Total Generation Cost($/hr)	**24970.91**	**15679.27**	**39543.97**	**14474**	**13479.92**	**28947.93**

5.Conclusion

In this paper, ITLBO have been successfully executed in CEED problem. For different load demand the proposed method effectively and efficiently applied. The comparison of the existing methods and proposed method reported in literature. Here, ITLBO is capable to find the solution for attaining the global optimum solution. So it can be decided that ITLBO method is a hopeful method for solving CEEDproblem in power system operation.

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