Comparable investigation on TLBO algorithm for power system optimization

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ABSTRACT. *This paper discusses about ELD Problem is modeled by non-convex functions. These are problem are not solvable using a convex optimization technique. So there is a need for using a heuristic method. Among such methods Teaching and Learning Based Optimization (TLBO) is a newly known algorithm and showed promising results. This paper utilized this algorithm to provide load dispatch solutions. Comparisons of this solution with other standard algorithms like Particle Swarm Optimization (PSO), Differential Evolution (DE) and Harmony Search Algorithm (HSA). This projected algorithm is implemented to resolve the ELD problem for 6 unit and 10 unit test systems along with the other algorithms. This comparison investigation explored various merits of TLBO with respect to PSO, DE, and HSA in the field economic load dispatch.*

RÉSUMÉ. *Cet article traite du problème de répartition de charge économique (ELD, le sigle de « Economic Load Dispatch » en anglais) qui est modélisé par des fonctions non convexes. Ce sont des problèmes qui ne peuvent pas être résolus en utilisant la technique d'optimisation convexe. Il est donc nécessaire d'utiliser une méthode heuristique. Parmi ces méthodes, l'optimisation en fonction de l'enseignement et de l'apprentissage (TLBO, le sigle de « Teaching and Learning Based Optimization » en anglais) est un nouvel algorithme connu qui a donné des résultats prometteurs. Cet article a utilisé cet algorithme pour fournir des solutions de répartition de charge. Les comparaisons de cette solution avec d'autres algorithmes standard tels que l'optimisation par essaims particulaires (OEP), l'évolution différentielle (ED) et l'algorithme recherche harmonie (RH) sont étudiés. Cet algorithme projeté est implémenté afin de résoudre le problème d'ELD pour les systèmes de test à 6 unités et à 10 unités avec les autres algorithmes. Cette enquête de comparaison a exploré divers avantages de TLBO en ce qui concerne OEP, ED et RH dans la répartition de charge économique sur le terrain.*

KEYWORDS: *valve point loading effects, non-convex, T & L based optimization, PSO, DE, HSA, economic dispatch.*

MOTS-CLÉS: *effets de chargement de point de soupape, non convexe, optimisation en fonction de l'enseignement et de l'apprentissage, OEP, ED, RH, répartition économique.*

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1. Introduction

As a Power Engineer scheduling the generators is very big Problem. Since from the past so many techniques are in practice for the economic load dispatch. Economic load dispatch means optimal allocation of loads to the generators so as to maintain power supply must be equal to load demand also to decrease the losses and fuel cost (Wood and Wollenberg, 1996). We are all know that power generation is highly costlier. In countries like India the major power generation is form thermal power plants only where the running cost is very high. The one of the best way to minimize the cost and losses of generating station is to Economic dispatch of loads (Amjady and Nasiri-Rad, 2010; Pothiya *et al.,* 2011; Walters and Sheble, 1993). Researchers developed lot of methods for Economic load dispatch. In this work concentrates on an innovative optimization algorithm that is teaching and learning based optimization.

Electrical power plays vital role for any county development. For achieving proper load demand we should have the optimal power flow generation to reduce the cost of production and this can be achieved by economic load dispatch with proper integration of sources to the load centres. The principal goal of Economic Load Dispatch (ELD) is to build effective power flow path while compromising all constraints. The cost function of every alternator can be characterized with quadratic function and it can solve by minimization methods like Lambda iteration and gradient based methods in convention ELD problem (Mahor et al., 2009; Elaiw and Xia, 2010; Chakrabory *et al.,* 2011).

Anciently we developed many methods to clear up the ELD problem like mathematical programming methods and these are more delicate for start and occasionally converge to local optimum solution or diverge altogether. Linear programming approaches are quick and effective however main bad thing is correlated with the piecewise linear cost. Nonlinear programming approaches have a struggle of convergence and algorithmic trouble. Newton based approaches cannot handle many number of equality constraints (Sharifzadeh and Amijady, 2010; Wang, 2013).

This paper explains TLBO algorithm to resolve ELD problem with valve point loading effect of thermal plants by taking transmission losses in to account. We proposed the effectiveness of T&L based Optimization on 6 unit test system and compared with PSO, DE, HSA. Finally T & L based optimization technique gives the high quality solution.

2. Economic load dispatch formulation

Economic load dispatch means minimizing the fuel cost, balanced Real power, and satisfying real power demand. The ELD problem is shown below (Thanushkodi and Selvakumar, 2007).

$$FC(P_i) = \sum_{i=1}^{N} F_i(P_i) \tag{1}$$

Here, $FC(P_i)$ = overall fuel cost,

N = Total number of thermal generating unit,

P_i= Power generation of i^{th}thermal generating unit

The fuel cost is quadratic function so it is,

$$F_i(P_i) = a_i P_{gi}^2 + b_i P_{gi} + c_i \quad (2)$$

Subjected to $$\sum_{i=1}^{n} P_i = P_D + P_L \quad (3)$$

$$P_{i,\min} \le P_i \le P_{i,\max} \quad (4)$$

Here a_i,b_i, c_i are fuel cost coefficients of the i^{th} thermal generating unit,

P_i = Total true power generation of i^{th} unit

P_D= overall load demand,

P_L= overall transmission line loss,

$P_{i,min}$ = The minimum generation limit of unit i and

$P_{i,max}$ = The maximum generation limits of unit i.

2.1. Economic dispatch problem with valve-point loading effect

Here the combination of quadratic and sinusoidal functions of fuel cost to represent the valve-point loading effects. It follows as (Noman and Iba, 2008; Coelho and Mariani, 2009; Zou et al., 2016; Rao et al., 2011)

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 + \left| e_i * \sin(f_i * (P_i^{\min} - P_i)) \right| \quad (5)$$

Here e_i and f_i are coefficient of the generating units reflecting valve-point loading effects.

The transmission line losses are written as

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} P_i B_{0i} + B_{00} \quad (6)$$

Here B_{ij}, B_{0i} and B_{00} are transmission line loss coefficients.

3. T & L based optimization algorithm

Teaching and Learning (T&L) inspired optimization process proposed by Rao et al. (2011) and Rao and Patel (2013) depends on Teacher and Learner Mechanism. The Teaching and Learning (T&L) based optimization is a meta-heuristic population based search algorithm like HSA, Ant Colony Optimization (ACO), PSO and Artificial Bee Colony (ABC). The Teaching and Learning (T&L) based optimization method is a simple mathematical model to resolve different optimization difficulties.

The projected work concentrates on a new optimization algorithm that is teaching and Learning (T&L) based optimization. Incorporated T&L based optimization algorithm is effective remedy for diminishing the flaws in traditional approach like provincial optimal trapping, inadequate effective to identify adjacent risky points and inefficient appliance to analyzing the constraints. According to our T&L based optimization algorithm a learner can gains knowledge in two ways: (i) by teacher and (ii) interacting with the neighbor learners. In this algorithm beginners are called as population. Design variable are called as subjects of the learners. The top beginner is treated as Teacher.

3.1. Teacher phase

Pupil gains information from the instructor ever and instructor should expand the mean outcome of class by his skills. The best learner is that once knowledge is equal to the teachers knowledge means teacher make to learners to reach his knowledge. But practically is not possible because all learners are not cleverer. This follows as (Kyruakides and Ciornei, 2012)

Let M_i= Mean

T_i= Teacher at any iteration i.

T_i Makes the mean M_i to move towards its own knowledge level, therefore T_i chosen as M_{new}. Hence the best learner is treated as teacher. The variance of the current mean result of every subject and the matching result of the teacher for every subject is given by,

$$Difference = r*(M_{new} - T_F M_i) \quad (7)$$

Where T_F= Teaching factor. It is given as follows:

$$T_F = round[1 + rand*(0,1)*(2-1)] \quad (8)$$

This difference modifies the existing solution according to the following expression

$$X_{new,i} = X_{old,i} + difference \quad (9)$$

3.2. Learner phase

The input for the beginner phase is the teacher in beginner phase learner gains knowledge learner gains knowledge by two ways: one is gaining knowledge form teacher and other is by sharing knowledge between learners interaction.

The learner phase is shows as follows. Randomly select two learners and where i≠j

$$X_{new,i} = X_{old,i} + r*(X_i - X_j) \text{ if } f(X_i) < f(X_j)$$

$$X_{new,i} = X_{old,i} + r*(X_j - X_i) \text{ if } f(X_i) > f(X_j) \quad (10)$$

4. Comparison of T&L based optimization algorithm with other algorithms

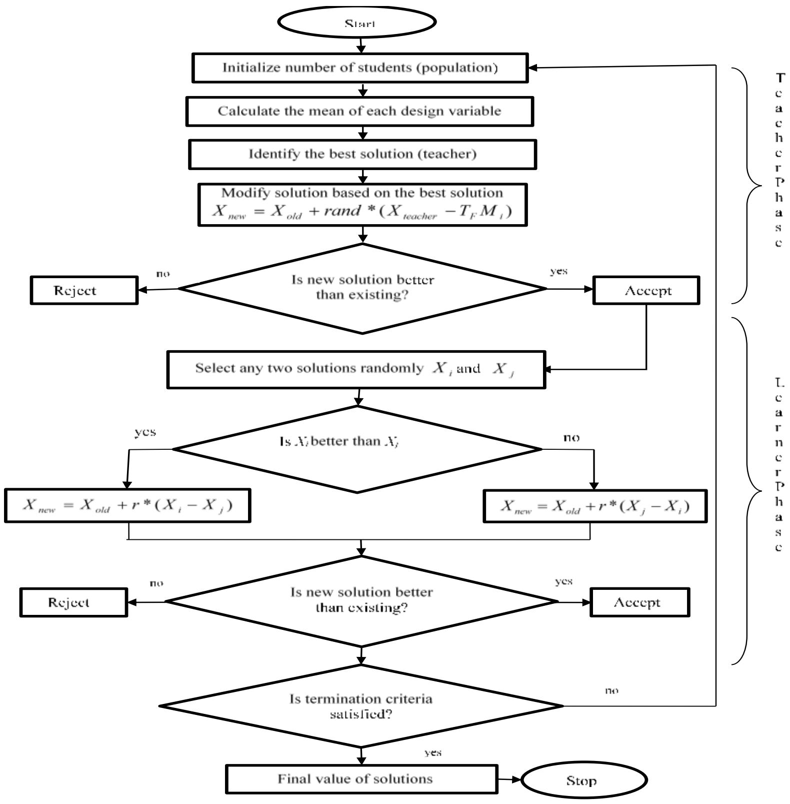

Figure 1. Flow Chart of T & L based optimization algorithm

There are several algorithms like PSO, HSA, ABC, GA. The proposed the effectiveness of T&L based Optimization on 6 unit test system and compared with PSO, DE, HSA. Finally, T & L based optimization technique gives the high quality solution.

5. Simulation results & discussion

The Proposed T & L based Optimization algorithm was implemented for two cases case: 1 consisting 6-Baseload generation units preferring loading valve point loading effect and losses. The T & L based optimization algorithm was written using MATLAB 8.5 (R2018b) running on i5 processor, 2.56GHz, 8GB RAM, PC.

A. Case 1

This case contains 6-base load generation units considering loading valve point loading effect and losses. Generating units have to attain the load demand of 1263MW. To calculate the efficiency of the T & L based optimization method, 25 individual trails can made at 60-population with 200 iterations.

Table 1. Global generations for 6unit system per trail

Number of units	Global generations in MW			
	PSO	HSA	DE	TLBO
1	400.6115	399.4068	500	500
2	199.5996	200	149.9957	151.4009
3	232.1225	232.0630	230.3581	300
4	124.7998	125.2627	125.8899	87.7215
5	199.5996	200	149.9629	149.4573
6	120	120	120	88.4572
Min.cost ($/h)	15616.7991	15624.4473	15615.6937	15611.6988
Power loss (MW)	13.7331	13.5483	13.2068	14.0371

The comparisons of cost and global are tabulated in Table 1 and Table 2. The global generations and the independent trails convergence characteristics are also plotted which are shown in fig. 2 and 3 respectively.

Table 1 clearly shows that for PSO the minimum cost attained was 15616.7991$/h, for HSA the minimum cost attained was 15624.4473$/h, for DE the minimum cost attained was 15615.6937$/h, and for TLBO the minimum cost attained was 15611.6988. Hence the above results shows that, the minimum cost is attained for

TLBO as compared with the other algorithms. The power loss attained for TLBO was 14.0371MW.

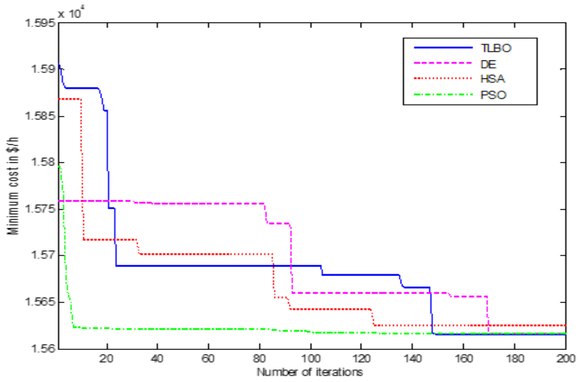

Figure 2. Convergence characteristics of 6 unit system

Table 2. Minimum cost obtained for 25 runs

Number of runs	Minimum cost in $/h			
	PSO	HSA	DE	TLBO
1	15616.8546	15688.4303	15635.2652	15681.9111
2	15616.8756	15677.7093	15660.2286	15611.6988
3	15758.1765	15750.0689	15646.7544	15680.6254
4	15782.4748	15647.0857	15645.1185	15621.5284
5	15616.8511	15657.9900	15631.8830	15624.2276
6	15625.1855	15726.5923	15615.6937	15621.4526
7	15738.7735	15739.6564	15632.6176	15659.3512
8	15743.2094	15647.9531	15636.6707	15650.3453
9	15626.6348	15655.4437	15626.5942	15650.3141
10	15665.8478	15688.3176	15673.4684	15621.5109
11	15627.0714	15703.6266	15641.7270	15622.5178
12	15616.7991	15759.3145	15665.2332	15621.6119
13	15691.2273	15624.4473	15652.6820	15622.4532
14	15626.6205	15656.2226	15665.7099	15622.1312
15	15616.9367	15695.9180	15679.2265	15621.6684
16	15623.5040	15715.6528	15638.6161	15621.6008
17	15625.1855	15740.7103	15648.2682	15621.5467

18	15626.5741	15688.7322	15670.0528	15621.3824
19	15626.7418	15750.1998	15629.4167	15620.9401
20	15626.7085	15769.2848	15643.9360	15621.6385
21	15618.0267	15725.9458	15626.4920	15622.2550
22	15647.0017	15834.2254	15639.1709	15622.9964
23	15619.6076	15751.9471	15635.1169	15621.7541
24	15623.5005	15744.5482	15633.0052	15622.5070
25	15624.3020	15694.8515	15637.5919	15621.6983
Min. cost ($/h)	15616.7991	15624.4473	15615.6937	15611.6988
Max. cost ($/h)	15782.4748	15834.2254	15679.2265	15681.9111
Avg. cost ($/h)	15649.2276	15709.3950	15644.4216	15630.0667

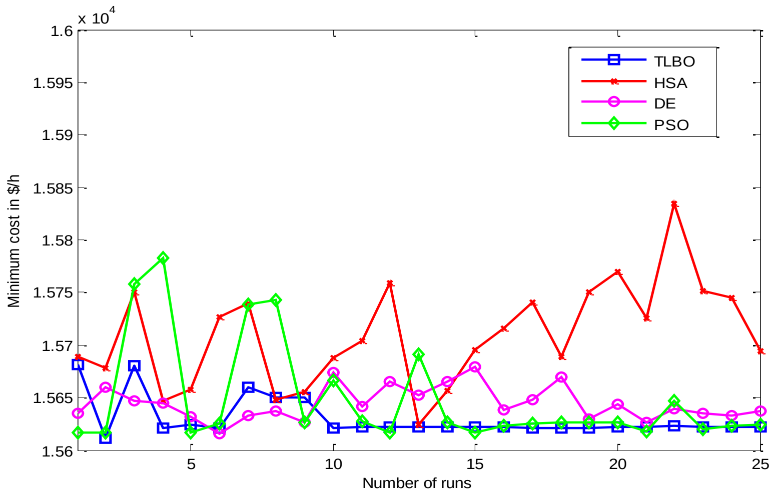

Figure 3. Comparison characteristics of minimum cost Obtainedfor 25 runs

This case consists of ten thermal generation units considering loading valve point loading effect and losses. Generating units have to attain the load demand of 2000 MW. To calculate the efficiency of the T & L based optimization method, 25 individual trails can ready at 100-population with 200 iterations per trail.

The comparisons of cost and global are tabulated in Table 3 and Table 4. The global generations and the independent trails convergence characteristics are also plotted which are shown in fig 4 and 5 respectively.

B. Case 2

Table 3. Global generations for 10unit system

Number of units	***Global generation in MW***			
	PSO	HSA	DE	TLBO
1	55	50.8495	55	55
2	80	75.8420	78.7733	80
3	107.3388	115.8420	99.3983	106.9392
4	100.3117	94.02348	107.1068	100.5765
5	81.4700	109.7019	89.0972	81.5012
6	82.9208	95.2030	81.4078	83.0217
7	300	295.8420	296.1400	300
8	340	335.8420	340	340
9	470	465.8420	470	470
10	470	446.8475	470	470
Min.cost ($/h)	111497.6596	111907.4666	111537.6219	111497.6301
Power loss (MW)	87.0414	85.8360	86.9237	87.0387

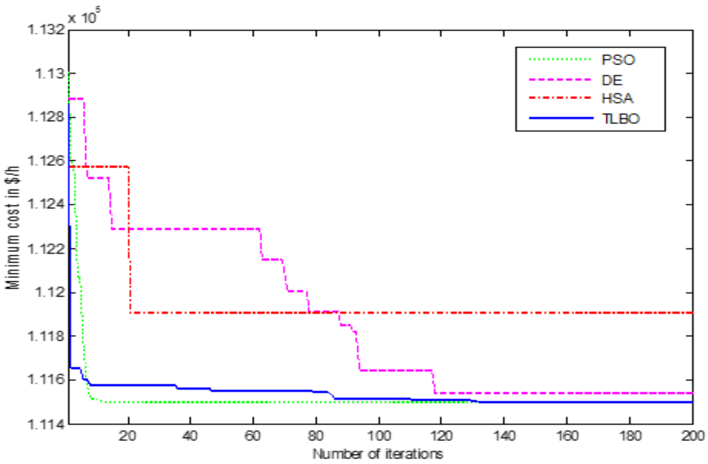

Figure 4. Convergence characteristics of 10-unit system

Table 3 shows that for PSO the minimum cost attained was 111497.6596$/h, for HSA the minimum cost attained was 111907.4666$/h, for DE the minimum cost attained was 111537.6219$/h, and for TLBO the minimum cost attained was

111497.630. Hence the above results shows that, the minimum cost is attained for TLBO as compared with the other algorithms. The power loss attained for TLBO was 87.0387MW.

Table 4. Minimum cost values for 25 runs

Number of runs	Minimum cost in $/h			
	PSO	HSA	DE	TLBO
1	111641.4441	111959.2697	111569.1983	111500.9854
2	111525.8322	112694.2246	111673.5325	111505.7236
3	111497.6763	111947.6861	111695.2852	111497.6765
4	111521.5108	112047.7053	111567.3306	111521.7364
5	111525.8275	112302.8949	111742.5223	111525.7565
6	111525.6877	112206.2944	111743.0718	111521.5768
7	111525.7571	112052.4801	111670.3818	111502.6754
8	111525.7976	112071.9085	111705.6591	111505.8768
9	111525.8834	111947.8623	111751.1809	111497.6301
10	111497.7631	111987.3196	111648.195	111497.6764
11	111497.6695	111919.8793	111645.2498	111497.6765
12	111497.7148	112337.6419	111601.2568	111497.6987
13	111497.6784	112250.1165	111689.5033	111497.6877
14	111525.7557	112185.1190	111663.6215	111500.6301
15	111497.8285	112235.6711	111679.4047	111504.6375
16	111497.7403	112094.2826	111654.574	111525.6384
17	111525.6996	112026.1773	111629.5029	111518.6311
18	111525.7043	112125.7557	111537.6219	111499.6343
19	111525.5897	112010.5037	111706.3123	111497.6301
20	111525.8344	112131.3220	111714.4087	111497.6301
21	111525.7345	112421.2877	111551.2658	111497.6301
22	111525.7724	112461.9869	111675.4585	111499.6383
23	111497.6596	112385.1277	111707.5187	111499.6376
24	111525.71	112111.6850	111608.6125	111497.6301
25	111497.7123	111907.4666	111652.1783	111497.6301
Min cost($/h)	111497.6596	111907.4666	111537.6219	111497.6301
Max. cost($/h)	111641.4441	112694.2246	111751.1809	111525.7565
Avg.cost($/h)	111520.1193	112152.8667	111659.3138	111504.2789

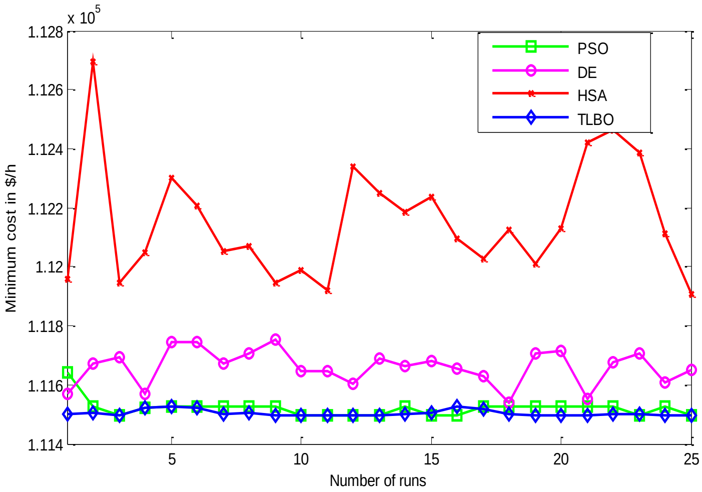

Figure 5. Comparison features of minimum cost obtained for 25 runs

5. Conclusion

Hence form the above results we can conclude that Incorporated T & L based optimization algorithm is Effective remedy for diminishing the flaws in traditional approach like provincial optimal trapping, inadequate effective to identify adjacent extreme points and inefficient mechanism to analyzing the constraints. The proposed T&L based optimization on 6 unit test system, 10 unit test system compared with PSO, DE, HSA. Finally TL based optimization technique gives the Effective high quality solution for Economic load dispatch problem.

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