Comparisional Investigation of Load Dispatch Solutions with TLBO

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ABSTRACT

This paper discusses economic load dispatch Problem is modeled with non-convex functions. These are problem are not solvable using a convex optimization techniques. So there is a need for using a heuristic method. Among such methods Teaching and Learning Based Optimization (TLBO) is a recently 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 proposed algorithm is applied to solve the load dispatch problem for 6 unit and 10 unit test systems along with the other algorithms. This comparisional investigation explored various merits of TLBO with respect to PSO, DE, and HAS in the field economic load dispatch.

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 [1]. 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 reduce the cost and losses of power plants is to Economic dispatch of loads [2]-[4]. Researchers developed lot of methods for Economic load dispatch. In this work concentrates on a new 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 centers. The main motto of Economic Load Dispatch (ELD) is to build effective power flow path while compromising all constraints. The cost function of each alternator can be represented with quadratic function and it can solve by several optimization techniques such as Lambda iteration and gradient based methods in convention ELD problem [5]-[6].

Anciently we developed many methods to clear up the ELD problem like mathematical programming methods and these are more delicate to stating points and periodically converge to local
optimum solution or diverge altogether. Linear programming approaches are quick and effective but the main bad thing is correlated with the piecewise linear cost. Nonlinear programming approaches have a problem of convergence and algorithmic complexity. Newton based approaches cannot handle many number of equality constraints [7]-[9].

This paper explains TLBO algorithm to solve ELD problem with valve point loading effect of thermal plants by considering transmission losses. 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 Problem formulation for Economic load dispatch is shown below [10]-[12].

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

Where, \(FC(P_i)\) = Total 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 given as

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i$$ \hspace{1cm} (2)

Subjected to

$$\sum_{i=1}^{n} P_i = P_D + P_L$$ \hspace{1cm} (3)

$$P_{i,\min} \leq P_i \leq P_{i,\max}$$ \hspace{1cm} (4)

Where \(a_i, b_i, c_i\) are fuel cost coefficients of the \(i^{th}\) thermal generating unit,
\(P_i\) = The real power of generating unit i,
\(P_D\) = Total load demand,
\(P_L\) = Total transmission line loss,
\(P_{i,\min}\) = The minimum generation limit of unit i and
\(P_{i,\max}\) = The maximum generation limit of unit i.

2.1. Economic Dispatch Problem with Valve-Point Loading Effect

Sinusoidal functions are added with the quadratic function of fuel cost to represent the valve-point loading effects. It follows as [13]-[15].

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i P_i^2 + e_i \cdot \sin(f_i \cdot (P_{i,\min} - P_i))$$ \hspace{1cm} (5)

Where \(e_i\) and \(f_i\) are coefficient of the generating units reflecting valve-point loading effects. The transmission line losses are written as

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

Where \(B_{ij}, B_{0i}\) 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, Savsani and Patel [16]-[18]. 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 solve different optimization problems.

In this 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 nearby extreme points and inefficient mechanism to analysing the constraints. According to our T&L based optimization algorithm a learner can gains knowledge in two ways: (i) by teacher (called teacher phase) and (ii) interacting with the neighbour learners (called learner phase). In this algorithm learners are called as population. Design variable are called as subjects of the learners. The best learner is treated as teacher.

3.1. Teacher phase

Pupil gains knowledge from the instructor ever and instructor should improve the mean result 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 [19]

Let

\[ M_i = \text{Mean} \]

\[ T_i = \text{Teacher at any iteration i}. \]

\[ T_i \text{Makes the mean } M_i \text{ to move towards its own knowledge level, therefore } T_i \text{ chosen as } M_{\text{new}}. \]

Hence the best learner is treated as teacher. The difference of the current mean result of every subject and the corresponding result of the teacher for every subject is given by,

\[ \text{Difference} = r^*(M_{\text{new}} - T_f M_i) \]

(7)

Where \( T_f = \text{Teaching factor. It is given as follows:} \)

\[ T_f = \text{round}[1 + \text{rand} * (0.1) * (2 - 1)] \]

(8)

This difference modifies the existing solution according to the following expression

\[ X_{\text{new},i} = X_{\text{old},i} + \text{difference} \]

(9)

Where \( X_{\text{new},i} \) is the updated value of \( X_{\text{old},i} \). Accept \( X_{\text{new},i} \)

3.2. Learner phase

The input for the learner phase is the teacher in learner 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 \( i \neq j \)

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

\[ X_{\text{new},j} = X_{\text{old},j} + r^*(X_j - X_i) \quad \text{if } f(X_i) > f(X_j) \]

(10)

Admit if it gives better function value

4. COMPARISON OF T&L BASED OPTIMIZATION ALGORITHM WITH OTHER ALGORITHMS

There are several algorithms like GA, PSO, ABC, HSA, etc. 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. The flow chart for the proposed TLBO algorithm is shown in Figure 1.
5. SIMULATION RESULTS & DISCUSSION

The Proposed T & L based Optimization algorithm was implemented for two cases: 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 (R2016b) running on i5 processor, 2.56GHz, 8GB RAM, PC.

Case 1

This case contains 6-base load generation units considering loading valve point loading effect and losses. The generating units have to meet 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 per trail.

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 Figure 2 and 3 respectively.
Table 1. Global generations for 6 unit system

| 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

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   | 15621.5264   |
| 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

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
Case 2

This case consists of ten thermal generation units considering loading valve point loading effect and losses. The generating units have to meet the load demand of 2000 MW. To calculate the efficiency of the T & L based optimization method, 25 individual trails can made 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 trials convergence characteristics are also plotted which are shown in Figure 4 and 5 respectively.

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**Figure 3.** Comparison characteristics of minimum cost Obtained for 25 run

**Figure 4.** Convergence characteristics of 10-unit system

**Figure 5.** Comparison characteristics of minimum cost obtained for 25 runs
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 $/h. Hence the above results show that, the minimum cost is attained for TLBO as compared with the other algorithms. The power loss attained for TLBO was 87.0387MW.

| 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 |

Table 4. Minimum cost obtained for 25 runs

| Table 4. Minimum cost obtained for 25 runs |
|-------------------------------------------|
| Number of runs | Minimum cost in $/h |
|                | PSO | HSA | DE | TLBO |
| 1              | 111641.4441 | 111959.2697 | 111569.1983 | 111500.9854 |
| 2              | 111525.8322 | 112694.2246 | 111673.5325 | 111505.7236 |
| 3              | 111497.6763 | 111947.6861 | 111695.2852 | 111497.6765 |
| 4              | 111521.5108 | 112047.7053 | 111567.3306 | 111521.7364 |
| 5              | 111528.8275 | 112302.8949 | 111742.5223 | 111525.7565 |
| 6              | 111528.6877 | 112206.2944 | 111743.0718 | 111525.7568 |
| 7              | 111525.7571 | 112052.4801 | 111705.6591 | 111505.8768 |
| 8              | 111525.7976 | 112071.9085 | 111751.1809 | 111497.6301 |
| 9              | 111525.8834 | 111947.8623 | 111751.1809 | 111497.6301 |
| 10             | 111497.7631 | 111987.3196 | 111648.195  | 111497.6764 |
| 11             | 111497.6695 | 111919.8793 | 111645.2498 | 111497.6765 |
| 12             | 111497.7148 | 112337.6419 | 111601.2568 | 111497.6987 |
| 13             | 111497.6784 | 112250.1165 | 111689.5033 | 111497.6877 |
| 14             | 111525.7557 | 112185.190  | 111663.6215 | 111500.6301 |
| 15             | 111497.8285 | 112255.6711 | 111679.4047 | 111504.6375 |
| 16             | 111497.7403 | 112094.2826 | 111654.574  | 111525.6384 |
| 17             | 111525.6996 | 112026.1773 | 111629.5029 | 111518.6311 |
| 18             | 111525.7043 | 112125.7557 | 111537.6219 | 111499.6343 |
| 19             | 111525.5897 | 112010.5037 | 111706.3123 | 111497.6301 |
| 20             | 111525.8344 | 112131.3220 | 111714.4087 | 111497.6301 |
| 21             | 111525.7345 | 112421.8777 | 111551.2658 | 111497.6301 |
| 22             | 111525.7724 | 112461.9869 | 111675.4585 | 111499.6383 |
| 23             | 111497.6596 | 112385.1277 | 111707.5187 | 111497.6576 |
| 24             | 111525.71  | 112111.6850 | 111608.6125 | 111497.6301 |
| 25             | 111497.7123 | 111907.4666 | 111652.1783 | 111497.6301 |
| Min. cost($/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 |

6. 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 nearby 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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