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Teacher Learning based Optimization Algorithm for Optimal Sizing of Hybrid Wind and Solar Renewable Energy System

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Abstract: ***In this paper the Teacher Learning process Based Optimization (TLBO) algorithm was employed in order to optimize wind and solar hybrid energy. Minimizing total annual cost, by determining appropriate numbers components to satisfy the desired load based on the given constraints is the main concern of this research. The algorithm was recently innovated random search meta heuristic algorithm. When it was signed the actual of process learning in a class was imitated. The result has shown that TLBO could be applied to optimize hybrid system. It was concluded that, the algorithm converges to optimal solution with relatively good convergence rate. It has shown that, TLBO has some advantage over other algorithms by comparing the result with some results in literature.***

Keywords: ***Hybrid Renewable Energy, Optimization, Nature Inspired Algorithm, Teaching Learning Based Optimization Algorithm***

I. INTRODUCTION

Importance of energy is not questionable nowadays. It was the vital element for human life which manly obtained from traditional sources. But these sources are growing down to the contrary of energy demand direction. A number of short comings like, the issue of environmental concern was also associated to the source. Additionally, traditional energy sources are not endless and not balanced with energy demand. This force the world in to the era of renewable energy [1] .

Additionally, lack of electricity access in many remote areas and growth of urban industrialization all over the world can be the course for searching less impact, naturallyendless sources called renewable energy [2], [3].

Using renewable energy was promising choice to increase power access except fluctuation of its power output. Renewable sources are weather dependant. To avoid this employing hybrid source may reduce the difficulty. As a result, researchers wish to optimize total annual cost of the hybrid system in this paper. For this, teachers learning based (TLBO) algorithm, which takes its inspiration from the teaching learning process what teacher do to maximize the output of the learners.

Organization of the rest section is as follows: Section 2 Describes some basic literature review.

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Under Section 3 basic reviews of the model was stated. Section 4 optimization problem. Section 5 reviews teaching learning optimization algorithm. Section 6 presents numerical data. Section 7 optimal results and its discussions. Lastly, the conclusions and future directions in Section 8.

II. LITERATURE REVIEW

Different scholars have done their work on hybrids of renewable energy system by applying their own different algorithms. Some of them were reviewed next. The Iteration method by [4]employed in our previous work was focus to find the minimal total annual cost of the hybrid renewable system which can balance the load through a set of constraints.From the result it was shown as iteration method can solve the system.

The ABC algorithm employed by [5]to optimize the hybrid system by taking its total annual cost (the economic aspect) in to consideration. Their result sows such algorithms are superior over conventional. [6]have used cuckoo search optimization algorithm to minimize the costs of the vendor robust mixed-integer linear programming model for liquefied natural gas sales planning.

[7] have designed hybrids of renewable energy system for the development of highly reliable, cost effective and continuously supply of energy for the rural area. [8]have for Optimized the size of hybrid wind/ solar renewable energy system by using artificial bee colony algorithm.

His aim was to minimize the involved components of the system.

Their result show that, the employed methodology was promising and has got superior over the rest algorithms in the literature used to compare with it [9].

GWO was employed by [10]to optimize economic value of the system which can balance the desired load.

From the results one can see that, the utilized algorithm was solved the problem with encouraging result.

III. MODELLING THE HYBRID SYSTEM

Modelling in this paper refers to showing the physical representation of the system. All the components were shown in one figure in order to design the problem utilized to solve the system.

All the involved components we have considered in this paper to optimize the system was given in figure 1 [11].

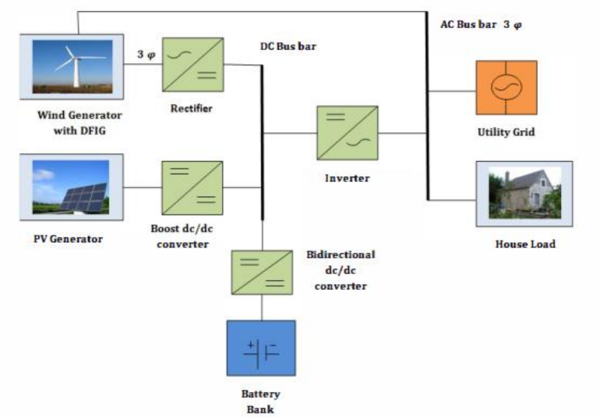

Fig.1 System component to be optimized [12]

All the mathematical modelling of different components mentioned in diagram were discussed in in our previous works [1], [5].

IV.OPTIMIZATION FORMULATION

As mentioned in [1]the optimization problem is given by:

$$\min f_{TAC} = C_{ICC} + C_{mnt} \quad (1)$$

In order to compare maintenance cost $C_{mnt}$and initial cost C_{ICC}, the balancing factor (BF) given in [13, 5].

$$BF = \frac{i\,(i+1)^t}{(i+1)^t - 1} \quad (2)$$

Where, i the interest rate and t denote the life span of the system.

Now the C_{ICC} of the system was given by:

$$C_{ICC} = BF\left[N_{pv}C_{pv} + N_{WT}C_{WT} + \left(\frac{n}{LS_{Batt}}\right)N_{Batt}C_{Batt} + C_{Backup}\right] (3)$$

The batteries N_{Batt} which is based up on power generating components are determined by the following function:

$$N_{Batt}(N_{pv}, N_{WT}) = f\left(\frac{S_{Req}}{\eta S_{Batt}}\right) \quad (4)$$

Where, f is integral output function; S_{Req} is the needed storage capacity; η is usage % controller of battery's life time; and S_{Batt} is belongs the rate of battery.

As in [1] total maintenance cost of the hybrid system was given by following equation.

$$C_{Maint} = \left(C_{PV,Maint} \times \sum_{t=1}^{24} P_{PV}^{t}\,\Delta t + C_{WT,Maint} \times \sum_{t=1}^{24} P_{WT}^{t}\,\Delta t\right) \times 365 (5)$$

I. Constraints

The main constraints in this problem were given below.

A. Decision Variables constraints

$$N_{PV} \in \mathbb{Z}, N_{PV} \geq 0 \text{ and} N_{PV} \leq N_{PV,max}$$

$$N_{WT} \in \mathbb{Z}, N_{WT} \geq 0 \text{ and} N_{WT} \leq N_{WT,max} (6)$$

B. Power Generated Constraint

$$P_{Total}^{k}(t) = N_{PV}P_{PV}^{k}(t) + N_{WG}P_{WG}^{k}(t)$$

$$1 \leq k \leq 365, 1 \leq t \leq 24 \ (7)$$

C. Power Balance Constraint

$$P_{total} = P_{demand} + P_{Loss} + P_{stored}$$

$$P_{Total\ demand} \leq P_{Total\ supply} \ (8)$$

V. TEACHERLEARNING BASED OPTIMIZATION ALGORITHMS

The newly proposed metaheuristic algorithm called TLBO is introduced by Rao et al. in 2011 [2]. It has got its inspiration from the process teachers made in the class to increase learners' output. The two basic components of this algorithm are from teachers view and learners view.

Teacher phase and learner phase are two basic models of learning for this algorithm. A lot of optimization problems have been solved by this algorithm and increasing its popularity from time to time [3]. Population of the algorithm of TLBO was represented by a group of learners and courses given to the students. The design variables of this optimization problem were represented by the populations in the algorithms.

A. Teacher Phase

Teacher has great role to maximize the average result of the learners. Difference Of the averages in between the result scored by each subject and result from the father of knowledge (teacher) for each subject is given by:

$$Mean\_Differ_{j,k,i} = t_i * \left(T_{j,kbest,i} - X_F M_{j,i}\right) (8)$$

Where, $T_{j,kbest,i}$ is the maximum result of the student in subject j. $X_F$is the value given for teaching that control the value of average to be changed, and t_i is the arbitrary number in the interval [0, 1]. The expression $X_F$taken the value 1 or 2.

The value of $X_F$is may be decided randomly with equal probability as,

$$X_F = round[1 + rand(0,1)\{2 - 1\}] \quad (9)$$

The expression $X_F$is not considered as parameter of the TLBO algorithm.

Based on the $Mean\_Differ_{j,k,i}$, the involved solution is iterated in the teacher view and calculated by the following expression.

$$M'_{j,k,i} = M_{j,k,i} + Mean\_Differ_{j,k,i} \quad (10)$$

Where $M'_{j,k,i}$ is the updated value of $M_{j,k,i}$. $M'_{j,k,i}$is accepted if it gives better function value. The students (learners) phase is followed by most knowledgeable teacher phase.

B. Students Phase

A student randomly interacts with other students for advancing their own knowledge. This interaction may be formal or informal communication out of the class room. Either formally or informally students communicate with each other to advance their knowledge. For this phase, two learners L and M are selected such that, $T'_{total,L,i} \neq T'_{total,M,i}$ i.e. their practised knowledge is not uniform. Then, TLBO compares the values of students' knowledge by the following equations.

$$P''_{i,P,j} = P'_{i,L,j} + r_i\left(P'_{i,L,j} - P'_{i,M,j}\right)$$

$$if\ P'_{i,L,j} < P'_{i,M,j} P''_{i,L,j} = P'_{i,L,j} + r_i\left(P'_{i,M,j} - P'_{i,L,j}\right)$$

$$if\ P'_{i,M,j} < P'_{i,L,j} \quad (11)$$

Where, $P''_{i,L,j}$ is the iterated value which has taken only if it is improved than the result obtained before. The result becomes an input for the next iteration. Based on this, the optimal result was obtained from the better result of all iterations which satisfy all the designed constraints.

II. NUMERICAL DATA SETS

All the data ordinally taken from [14] and updated by [1] used fo this algorithm was given as follows.

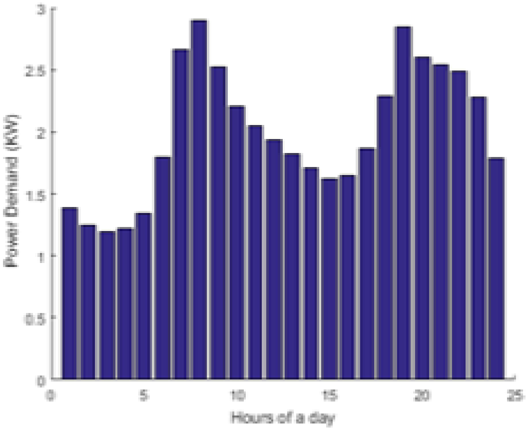

Fig. 2 Daily average power demand

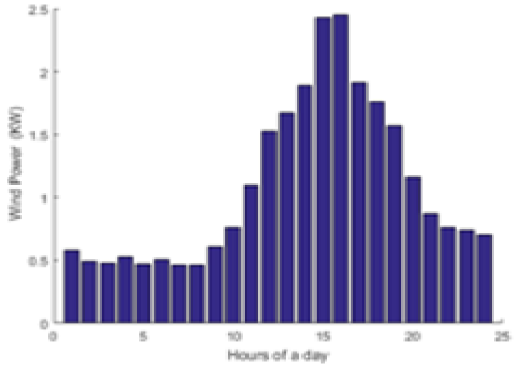

Fig. 3 Daily average power demand

Table 2. Improved Design Variables

Items	Cost/values
Annual interest	6%
Duration of the project	20 years
Panel unit cost	$350/panel
Unit panel construction fee	50% of the price
Turbine unit price	$20000/Turbine
Unit turbine construction fee	25% of the price
Unit price of each battery	$170
Unit price of generator	$2000
Employment % of battery	80%
Batteries duration capacity	2.1Kwh
Batteries life span	4 years
Considered unit time	1hr
Cost needed to maintenance PV	0.5cents/Kwh
Cost needed to maintenance WT	2cents/Kwh

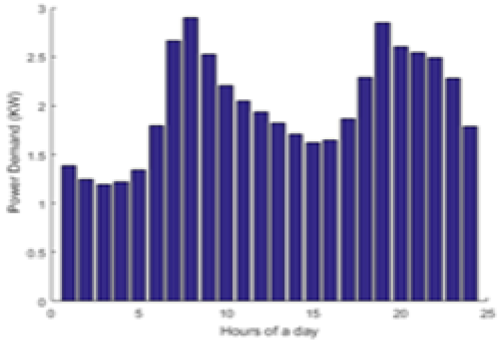

Fig. 4 Daily average wind profile

Table 3. Improved daily power demandand power difference of the system

Time(t)	P_Dema (KW)	P_WT (KW)	P_PV (W)	ΔP(KW)
1	1.39	0.58	0	-0.81
2	1.25	0.49	0	-0.76
3	1.19	0.48	0	-0.71
4	1.22	0.53	0	-0.69
5	1.34	0.47	0	-0.87
6	1.8	0.51	0	-1.29
7	2.66	0.46	1.6	-2.198
8	2.9	0.46	3.4	-2.437
9	2.52	0.61	10.3	-1.899
10	2.21	0.76	24.6	-1.425
11	2.05	1.1	31.7	-0.918
12	1.94	1.53	35.3	-0.375
13	1.82	1.67	36.6	-0.113
14	1.71	1.89	37.4	0.217
15	1.62	2.43	36.8	0.847
16	1.65	2.45	33.5	0.833
17	1.87	1.91	24.2	0.064
18	2.29	1.76	13.4	-0.517
19	2.58	1.57	5.6	-1.004
20	2.6	1.16	1.5	-1.438
21	2.54	0.87	0	-1.67
22	2.49	0.76	0	-1.73
23	2.28	0.74	0	-1.54
24	1.79	0.7	0	-1.09
Total	47.72	25.89		-21.534

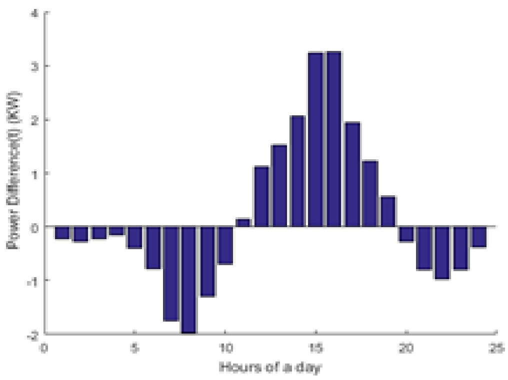

Fig. 5 Daily average power difference

VI.RESULTS AND DISCUSSION

For this research, Teacher Learning Based Optimization (TLBO) algorithm was employed to solve the stated problem. The obtained results have been organized in Tables 3-5 below. As seen from the tables, the results obtained by TLBO were compared with PSO and of iteration method in [4]. Here we consider PSO for justification of the obtained result of TLBO algorithm.

Table 3 Optimal value when wind only generate power.

Method	N_{PV} needed	N_{WT} needed	N_{Batt} needed	LPSP	Total annual Cost ($)
TLBO	0	2	9	0	4871.3
PSO	0	2	9	0	5572.04
Iteration [1]	0	2	9		5753.09

Table 4 Optimal value when solar only generate power.

Method	N_{PV} needed	N_{WT} needed	N_{Batt} needed	LPSP	Total annual Cost ($)
TLBO	161	0	16	0	6395.8
PSO	161	0	16	0	8936.64
Iteration [1]	162	0	17	0	9242.79

Table 5 Optimal value when hybrid of wind-solar generate power.

Method	N_{PV} needed	N_{WT} needed	N_{Batt} needed	LPSP	Total annual Cost ($)
TLBO	74	1	11	0	5209.8
PSO	74	1	11	0	6827.91
Iteration [1]	73	1	12	0	7085.97

The optimal solution of TBLO algorithm was $4871.3. It was better value when compared to PSO and iteration method. From Table 4 the algorithm selects the optimal value $ 6395.8 as in comparative with PSO $ 8936.64 and optimal of iteration method $9242.79. The Optimization results given in Table 5 for hybrids system with battery is $ 5209.8 was promising value from PSO and iteration algorithm also. As shown in Fig. 6, the algorithm converges to its optimal with relatively good convergence rate.

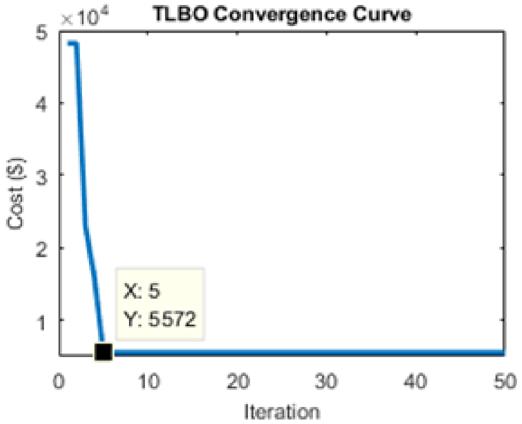

Fig. 6 TLBO convergence curve

VII. CONCLUSION

This paper presents TLBO algorithm to solve the problem of renewable energy with daily average demand of about 47.72 KW power generating under set of constraints. The Obtained result by TLBO was promising when compared with other algorithms. The convergence rate shown on Figure 6 was also good result. Hopefully, the way of organizing this paper would be applicable, important and become a good benchmark for us and other researchers.

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