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Teaching and Learning Based algorithm in optimal power system planning problem

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ABSTRACT

The placement and sizing of distributed generation (DG) is becoming need of the power system because of numerous increases in requirement of power. The DGs are preferred because of its natural of producing power at distribution side which reduces the cost of transmission. So as the DG placement becomes more important the cost analysis is needed. The planning of optimal power system is discussed here and a problem is formulated for the optimal planning and the solution is achieved by teaching and learning based optimization algorithms and the performance is analyzed using MATLAB software and the test system considered here is Indian 28-bus distribution system.

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I. INTRODUCTION

The paratha kayal in 2014 has presented the expansion planning of power system using renewable resources by placing it in the distribution system. The multi-objective problem is formed for the optimal placement. DG placement is planed in 2011 by raj kumar using multi-objective. It is done by using impact indices [1,2]. The multi-objective is used in economic dispatch problem in [5]. Kayal in 2013 has implemented the solar and wind DG placement using the static mathematical model to improve the voltage stability and reduce the power loss [6]. In these problem solutions the evolutionary algorithms play important roles in it. But all these works are dealing with the real power injection or penetration [8].

This paper is presented with the multi-objective problem solutions using the teaching-learning based algorithm (TLBO), to increase the benefit to cost ratio and satisfying the security constraints of the distributed system. This algorithm is compared with the cuckoo search algorithm (CSA) and particle swarm optimization (PSO) in [10].

The cost minimization problem solved by parthakayal [1] is modified by adding the reactive power consideration and the solution is compared with the CSA and PSO presented in [10].

This article is organized as the section II tells about the problem formulation. Section III talks about the implementation of TLBO, CSA[10] and PSO[10]. Section IV showcases the results obtained and final section is conclusion and references.

Problem formulation

The problem is formulated to minimize the total cost. In the total cost there are three parts. First one is investment cost (IC), operation and maintenance cost (OMC) of DG. In this interest rate and inflation rate are also considered. Second one is benefits of cost due to the placement of DG. Third one involves the first and second that is the benefit to cost ratio (BCR). This has to be maximum so that the benefits are more, while maintaining the voltage stability factor (VSF) and network security index within limit. So, the formulation is as follows [10],

(i) Total cost of renewable DGs due to installation, operation and maintenance,

$$Cost_{DG\,ren} = \sum_{i=1}^{N}\sum_{j\in type} IC_{ij} * n_i * l_i + \left(\sum_{i=1}^{N}\sum_{j\in type} OMC_{ij} * P_{DG\,ren\,ij} * n_i * l_i\right) * CPV$$
(1)

Where

IC_{ij} – Inverstment cost type-j renewable DGat bus-i
OMC_{ij} – Operation and maintenance cost of type-j renewable DGat bus-i
n_i – number of DG unit connected at bus 'i'
l_i – location variable at bus-i (0 or 1)
$P_{DG\,ren\,ij}$ – Power generated by type-j DG at bus 'i'
N – number of buses in the network
CPV – cumulative present value

$$CPV = \frac{(1-PV^{N_y})}{(1-PV)} \quad (2)$$

Here,
Present value of cost

$$PV = \frac{1+\frac{IF}{100}}{1+\frac{IR}{100}} \quad (3)$$

Where,

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Present value of cost

$$PV = \frac{1+\frac{IF}{100}}{1+\frac{IR}{100}} \quad (3)$$

Where,

IF – Inflation rate
IR – interest rate
N_y – Number of year in planning horizon

(i) Total benefit that can be achieved from operation of distribution network with renewable DGs is given by,

$$Benefit_{DG\,ren} = \left(\left(\sum_{i=1}^{N}\sum_{j\in type}(P_{DG\,ren\,ij} + Q_{DG\,ren\,ij}) * n_i * l_i\right) + \Delta Ploss_{DG\,ren}\right) * C_{kr} * 8760 * CPV$$

(4)

$\Delta Ploss_{DG\,ren}$ – Power loss due to allocation of renewable DGs
C_{kr} – Cost of electricity

Benefit to cost ratio

$$BCR_{DG\,ren} = \frac{Benefit_{DG\,ren}}{Cost_{DG\,ren}} \quad (5)$$

(i) Voltage stability factor

Due to the placement of DGs in power system changes the voltage profile so there is a need for improving the voltage profile, the below equation shows the VSF for any bus i+1in the distribution network,

$$VSF_{i+1} = (2V_{i+1} - V_i) \quad (6)$$

Here,

V_i – voltage magnitude at bus i
V_{i+1} – voltage magnitude at bus i+1

VSF for the entire network is given by

$$VSF = \frac{\sum_{i=1}^{N-1} VSF_{i+1}}{(N-1)} \quad (7)$$

(ii) Network security index

Security of the network also should be considered on placement of DG

$$LL_i = \frac{L_{MVA\,,i}}{L_{MVA\ max\,,i}} \quad (8)$$

Network security index can be formulated as below

$$NSI = \frac{\sum_{i=1}^{N-1} LL_i}{(N-1)} \quad (9)$$

Low value is better.

So,

the objective function is represented as

$$\text{minimize } f(P_{DG\ ren\ ij}, n_i, l_i) = -BCR - VSF + NSI$$
(10)

II. TEACHING AND LEARNING BASED ALGORITHM

This algorithm is made of the teacher-learning ability of the teacher and student in a classroom. The TLBO algorithm is divided into two parts.

Teacher phase
Learner phase

The population (control variable/the parameters need to be identified) X is Randomly initialized. The search space is of N × D. The N is the number of learners and D is the course offered. This is the problem dimension. The iteration count (IT_{max}) is the total number iteration carried out and this is the stopping criteria. The initial random population is formed using below equation,

$$X_{i,j}^{l} = X_j^{min} + rand \times (X_j^{max} - X_j^{min}) \quad (11)$$

Where,

rand – uniformly distributed random number betwee 0 to 1
i – population count
i = 1,2..N
j – control variable
j – 1,2,..D
X_j^{max} – maximum limit of control variable
X_i^{max} – minimum limit of control variable

Teacher phase

The mean value of the X vector is the mean vector $M^{IT_{max}}$.

Here,

$$M^{IT_{max}} = [mean\,(X_{i,1...j})] \quad (12)$$

This can be represented as

$$M^{IT_{max}} = [m_1^{IT}, m_2^{IT} \dots, m_D^{IT}] \quad (13)$$

The best vector which produces the minimum objective function is taken as X_{teach}^{IT} for each iteration. The algorithm shifts the mean value towards the teacher. Below equation does the job of it.

$$X_{new}^{IT} = X_i^{IT} + rand \times \left(X_{teach}^{IT} - T_f M^{IT_{max}}\right) \quad (14)$$

Here,

T_f – teacher factor it can be between(1 to 2)

$$T_f = round(1 + rand) \quad (15)$$

here, round is the round of function.

If X_{new}^{IT} *is superior* then this is considered in X_{ij}

Learner Phase

Each learner interacts with randomly other learners and hence it is known as knowledge sharing. The below equation denotes the same,

$$X_{new}^{IT_{max}} = \begin{cases} X_i^{IT} + rand \times \left(X_i^{IT} - X_j^{IT}\right) & \text{if } \left(X_i^{IT} < X_j^{IT}\right) \\ X_i^{IT} + rand \times \left(X_j^{IT} - X_i^{IT}\right) & \text{otherwise} \end{cases} \quad (16)$$

here, $X_r^{IT_{max}}$ is the randomly selected control variable algorithm goes again to teacher phase and continues till the end of iteration.

III. RESULTS AND ANALYSIS

The results are taken for the Indian 28 distributed system taken from [2] and listed in appendix. The minimization of objective function is implemented with the TLBO algorithm by following the above procedure.

Here the number of DG installed in each bus (N) is considered as 6. The duration for the planning horizon (N_{yr}) is taken for 10 years. The types are taken as solar wind and biomass. The type '1' is solar, type '2' is wind and type '3' is biomass.

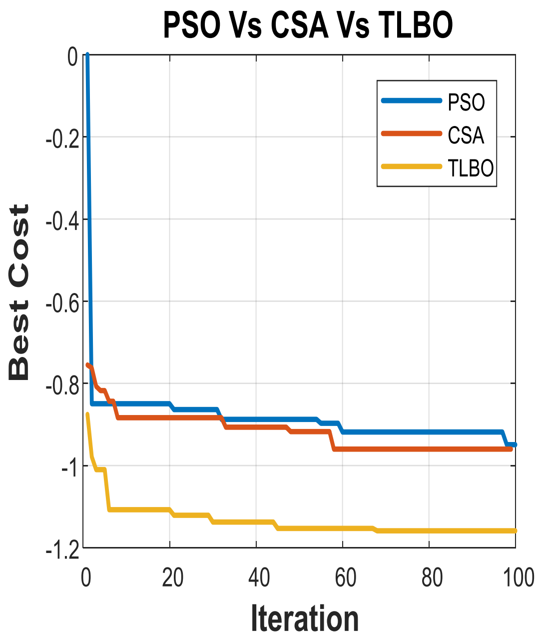

Fig. 1 the fitness function curve for PSO, CSA & TLBO

The Fig. 1 shows the fitness function curve for PSO, CSA & TLBO it can be seen that the TLBO performs better compared to PSO and CSA. Fig.2 shows the Voltage Vs Bus numbers it can be seen that TLBO performances better in voltage stability. The Table-I shows the best results of bus numbers, count of DGs and type of DGs for PSO, CSA and TLBO. Table-II shows the results of best size of DG for PSO, CSA and TLBO. The Table-III shows the results of final total cost in Rs. For PSO, CSA and TLBO algorithms.

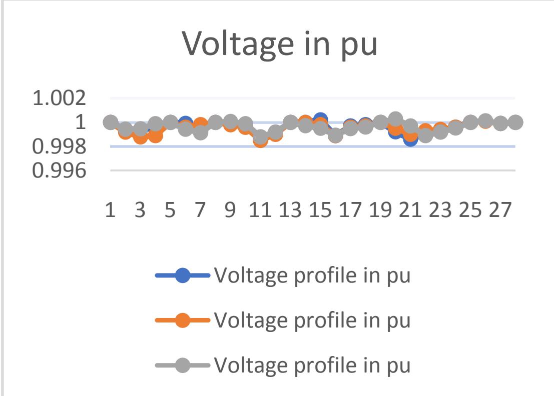

Fig.2 Voltage Vs Bus numbers

Table-I-Results of bus numbers, count of DGs and type of DGs for various algorithms

Bus			nos.			type		
PSO	CSA	TLBO	PSO	CSA	TLBO	PSO	CSA	TLBO
26	14	28	6	5	4	3	3	3
3	20	26	4	3	6	2	2	3
9	19	20	3	4	4	3	3	3
15	26	20	5	6	6	3	3	3
24	13	25	3	5	6	2	3	3
25	7	9	4	6	4	3	2	3

Table-II-Results of size of DG for various algorithms

	PSO		CSA		TLBO	
	Size (MW)	Size (MVar)	Size (MW)	Size (MVar)	Size (MW)	Size (MVar)
DG 1	1.2	0.6	1	0.5	0.8	0.4
DG 2	0.5	0.2	0.375	0.2	1.2	0.6
DG 3	0.6	0.3	0.8	0.4	0.8	0.4
DG 4	1	0.5	1.2	0.6	1.2	0.6
DG 5	0.375	0.2	1	0.5	1.2	0.6
DG 6	0.8	0.4	0.75	0.4	0.8	0.4
Total	4.475	2.2	5.125	2.5	6	2.9

Table-III-Results of Total cost in Rs. for various algorithms

DG nos.	TC Rs/yr		
	PSO	CSA	TLBO
1	910809.8904	632506.868	404804.3957
2	184164.9378	103592.777	883137.3173
3	227702.4726	404804.396	404804.3957
4	632506.8684	910809.89	910809.8904
5	103592.7775	632506.868	910809.8904
6	404804.3957	414371.11	404804.3957
total cost in Rs	2463581.342	3098591.91	3919170.285

Table-IV-Results of Comparison for various algorithms

	loss in MW	BCR	VSF	NSI	Final Obj	Time in sec
PSO	0.075	0.1206	0.9996	0.2056	-0.9145	174.8
CSA	0.0552	0.114	0.9996	0.1711	-0.9424	721.6
TLBO	0.0531	0.1166	0.9996	0.0722	-1.044	123.8

And Table-IV shows the results of comparison real power loss, BCR, VSF and NSI values. It shows that BCR and VSF is nearly same in all the algorithms. The real power loss is lesser in TLBO compared to other two. NSI reaches very less value as it needed to be in TLBO. And the final objective is better in TLBO and the run time of the algorithm is very less compared to other two algorithms.

IV. CONCLUSION

The optimal distributed generation planning using renewable energy resources are done for solar, wind and biomass using the new multi-objective problem formulation and solution using the TLBO algorithm. The comparison is done with the PSO and CSA. The performance of TLBO algorithm is satisfactory compared to PSO and CSA in all the perspectives. And the convergence is more accurate as it can be seen in the figures and tables.

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