International Journal of Academic and Applied Research (IJAAR)
ISSN: 2000-005X
Vol. 2 Issue 10, October – 2018, Pages: 33-39

Optimal Allocation of Wind Turbines in a Radial Distribution Network Using a Two Step method based on Improved Teaching-Learning Algorithm

Mehdi Ershadi Nejad[1], Masume Hedayati[2] and Sarah Khoei[3]

Department of Electrical Engineering, Sabzevar Branch, Islamic Azad University, Sabzevar, Iran

Abstract: *In this paper, a two-stage method for the allocation of wind turbines with respect to their maximum capacity is used using the teaching-learning method (ITLBO). The location and capacity of the maximum permitted wind turbines are designed to reduce the distribution network losses and taking into account the operating constraints. The proposed method has been developed in two stages. In the first stage, the installation site of wind turbines in the network is considered as an optimization variable, and then in the second stage, the amount of network losses from the scenarios generated based on the number and capacity of wind turbines, so that all the constraints of the problem are met, optimally designated. The proposed method has been implemented on the 84 bus Distribution Network. In this study, considering the maximum capacity limit for wind turbines, regardless of the amount of losses, loss percentages, minimum network voltages and the capacity and location of wind turbines has been studied. In addition, the results of the ITLBO method have been compared and analyzed with the results of the problem using the conventional TLBO method.*

Keywords: distribution network, loss reduction, maximum permissible wind turbine capacity, improved teaching-learning algorithm

1. INTRODUCTION

Power generation by wind power plants has advantages such as increasing system reliability, reducing network power losses, improving voltage specifications, improving peak traffic and speeding up transportation on transmission and distribution lines. In contrast, reducing power quality, reducing reliability, voltage and protection problems, there are some disadvantages of integrating wind turbines into a distribution system that may occur if the capacity and position of wind turbines is not appropriate [3-1]. The incorrect selection of the location, number and / or capacity of the wind turbine leads to network problems such as voltage deviation, power losses, and so on. Therefore, determining the optimal amount and position of wind turbines is very important. In order to achieve this goal, we must consider several limitations such as power reduction, loading, voltage characteristics and reliability. To reduce the negative aspects of wind turbines in recent years, many techniques have been used to determine the best place. The two-degree displacement method for placing DG is introduced in reference [4]. In reference [8-5], Desired DGs position in the distribution network. In references [12-9], the desired location and size of DGs are set. The assessment of maximum permissible DGs capacity was carried out using a dual genetic algorithm approach [11]. In this work, several factors such as overall system efficiency, voltage characteristics, system reliability, load change, transmission density, network losses and uncertainty problems of distribution system operating conditions have been investigated.

In this paper, an optimal wind turbine location is proposed using a two-stage method based on the ITLBO algorithm. In the first stage, the control variables are determined and in the second stage, the maximum capacity of the wind turbines is achieved with respect to the reduction of losses and compliance with the constraints. At this stage, the target function is obtained according to the scenarios that are created based on the number and capacity of the turbines.

2. STATEMENT OF THE PROBLEM

2.1 Objective function

In this paper, the objective function of the problem of the location of wind turbines in the network of losses minimization is considered as follows [12].

$$f(x) = \sum_{i=1}^{N_{br}} R_i \times |I_i|^2$$
$$X_i = \left[pWTG_1, pWTG_2, \ldots, pWTG_{N_{WTG}}, pf_1, pf_2, \ldots, pf_{N_{WTG}}\right]_{1\times(N_{WTG}\times 2)} \quad (1)$$

In the above relation, R_i and Ii are respectively the resistance and current of the i-th branch. Here, the vector X has two parts. The first part is P_{WTGi}, which represents the location of the wind turbine unit. The second part is the X vector wind turbine power factor. In this equation, Nbr and the number of N_{WTG} wind turbines show the number of branches and the number of wind turbines, respectively.

2.2 Constraints

The objective function of the problem should be optimized under the following constraints [12]:

- Power Distribution Line Limit

$$\left|P_{ij}^{Line}\right| < P_{ij,\max}^{Line} \quad (2)$$

In the above relation, P_{ij}^{Line} refers to the line power and the $P_{ij,\max}^{Line}$ is thermal limit of the line.

- Load flow equations

$$P_i = \sum_{i=1}^{N_{bus}} V_i V_j Y_{ij} \cos(\theta_{ij} - \delta_i + \delta_j)$$
$$Q_i = \sum_{i=1}^{N_{bus}} V_i V_j Y_{ij} \sin(\theta_{ij} - \delta_i + \delta_j) \quad (3)$$

In the above relations, Pi and Qi are reactive and active reactive powers, Vi and δi are the amplitude and voltage angle of the i-th bus. Also, Yij and θij are the amplitudes and edges of the edges between the bus i and j.

- Limit Loading Lines

$$\left|L_{f,i}\right| \le L_{f,i}^{\max} \qquad i = 1, 2, \ldots, N_f \quad (4)$$

In the above relation, Nf is the number of feeders, and $L_{f,i}$ and $L_{f,i}^{\max}$ respectively the amplitude and maximum flow of the feeder i.

- Wind turbine wind power limit

$$P_{\min,w,i} \le P_{w,i} \le P_{\max,w,i} \quad (5)$$

In the above relation, $P_{\min,w,i}$ and $P_{\max,w,i}$ are the minimum and maximum authorized power of WTG i.

- Bus voltage limit

$$V_{\min} \le V_i \le V_{\max} \quad (6)$$

Where, $V_{\min}$ and $V_{\max}$ are the minimum and maximum voltages of the bus.

- Capacity of wind turbine power

$$pf_{\min,i} \le pf_i \le pf_{\max,i} \quad (7)$$

In the above relation, pfmin,i, and pfmax,i are the maximum and minimum values of the power factor WTG i.

3. PROBLEM SOLUTION METHOD

3.1 Teaching-learning algorithm based optimization (TLBO)

An optimization algorithm based on learning-learning [13] is an intelligent optimization method that was introduced by Mr. Rao based on the teacher's impact on students to increase the level of science. The basis of this approach is based on the principle that the teacher tries to bring the class closer and that students, in addition to using the teacher's knowledge and in conjunction with classmates, use their knowledge to increase their level of self-esteem. They make. Since the teacher cannot reach the level of each student, he tries to raise the overall level of the class and assess the level of the class based on the exams and grades of students. The mathematical expression of this method is that at first a population of problem variables (students and teachers) is defined randomly. The whole population is compared using the objective function, and the set of variables is considered with the best answer as a teacher. This method is divided into two phases, teacher phase and student phase.

3.1.1 Teacher phase

In this phase, the teacher tries to take the average grade. But since this is very difficult, I try to increase the average of the class from the value of Mi to the M_new. Each set of problem variables is based on the difference between these two values. The difference between these two values can be saved as follows in the Diff_Mean parameter [13].

$$Diff\_Mean_i = r_i (M\_new - T_f M_i) \quad (8)$$

In which T_f is the teacher's parameter, which is chosen as a random number of 1 and 2. ri is also a random number between 0 and 1. Using the following equation, each set of variables appears [13].

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

3.1.2 Student phase

In addition to using the teacher's knowledge, students benefit from the knowledge of each other. The mathematical expression of this phase is such that in each phase and in each repetition, each set of variables (students) is chosen as one of the other students. For example, a student j chooses a j student and this is certainly the opposite of j. If a j student has more knowledge than an i student, then the student will show his / her situation according to the following relationship [13].

$$X_{new,i} = X_{old,i} + r_i (X_i - X_j) \quad (10)$$

Otherwise, the student's status changes as follows [13].

$$X_{new,i} = X_{old,i} + r_i (X_j - X_i) \quad (11)$$

After all students have changed their status, they are evaluated using their target target function. In this situation, the best student will be compared with the teacher of the previous stage, and if he has a better result, he will be replaced with the teacher of previous rehearsal. This trend continues until the conditions of convergence are met.

3.2 Improved teaching-learning algorithm (ITLBO)

In the modified TLBO method, in addition to the two phases of the student and teacher, another phase is added as the modified phase. In this phase, based on the technique of self-adaptive mutation, the students of the wavelet increase their level of knowledge. Given that in TLBO students usually move only in the direction of the teacher, there is a chance that they will fall into the local optimal point and reduce the convergence rate. Accordingly, in the modified phase, each student moves randomly towards the teacher or the worst pupil. First, a parameter called the probability of mutation is attributed to each learner. Then a probability number between 0 and 1 is selected. If this number is less likely to be mutated, the student will perform the mutation and otherwise this will not be done [13].

The mutation is defined as follows [13].

$$X_{new,i} = \begin{cases} X_{old,i} + \omega(T_i - X_{old,i}) & if\ \omega > 0 \\ X_{old,i} + \omega(W_i - X_{old,i}) & if\ \omega \le 0 \end{cases} \tag{12}$$

Where ,Ti is the teacher (best student) and Wi is the worst student. The parameter ω is calculated as follows [13].

$$\omega = \frac{1}{\sqrt{h}} \exp\left[-(\frac{1}{2})(\frac{\varphi}{h})^2 \cos(\omega_c (\frac{\varphi}{h})) \right] \tag{13}$$

Where, cω is the center frequency of the wavelet and its value is considered in this project. The larger the ω is, the more changes and vice versa. If ω is positive, the student moves towards the teacher and if it is negative, he moves to the opposite side. Given that 99% of the total energy of the maternal wavelet function is located between [-2.5.2.5], the parameter φ is chosen as the rhode between [-2.5h, + 2.5h]. The search is initially performed in a large space to indicate the optimal main point range and then the search space is shifted around this point to select the final optimal answer. h is the dilatation factor, which is changed in each repetition as follows [13].

$$h = \exp\left[-\ln(\eta) \times (1 - {}^{k}\!/\!_{k_{\max}})^{\sigma} + \ln(\eta) \right] \tag{14}$$

Where k and kmax, respectively, are the current repetition and total repeats. The upper bound and the h shape are defined by the two parameters η and σ. In this paper, the value of η 2 and the value of σ are obtained from the following equation [13].

$$\sigma = \sigma_{\min} + (\frac{\sigma_{\max} - \sigma_{\min}}{k_{\max}})k \tag{15}$$

Where σ_{min} and σ_{max} are respectively 1 and 3 [13].

3.3 Proposed Method Implementation

In this section, the proposed solution method is explained. In this method, there are two steps in which, during these two stages, the installation location, power factor and maximum WTG capacity are calculated. In the first step, the location of the installation and the power factor of the WTG are determined, and in the second stage, the maximum capacity of the WTG is determined. The various steps of this method are described below.

Step 1-1) Random generation of the initial population (determining the number of students)

Step 2-1) To calculate the maximum capacity of WTGs, scenarios will be created based on the number of WTGs, 2n-1. For example, if 4 WTGs exist, 15 scenarios will be created.

Step 2-2) Consider the steps below to compute the maximum capacity of the WTGs according to the scenarios of the previous stage.

A) Increase the WTG capacity if the deviation from the network voltage criterion is exceeded.

B) Reduce the capacity of the WTG if the deviation from the network voltage criterion is lower than the optimal value and the overloading lines are allowed.

Step 2-3) In the teacher's phase, extract the scenario with the least amount of casualties from different scenarios.

Step 1-2) Organize the population based on the student's phase of the best answer and save the best answer to each set so far and save the best answer.

Step 1-3) Optimize the variables based on the TLBO optimization method

Step 1-4) If convergence conditions are created, the program stops, otherwise go to step 2-2-

4. SIMULATION RESULTS AND DISCUSSION

The network studied is the IEEE 84 bus bus 84 with its single-line diagram shown in Figure 1. The network is divided into 4 districts and 4 wind turbines or WTGs are supposed to be located in 4 districts. In other words, a WTG for each area. The network has an active and reactive load of 28,350 kilowatts and 20,700 kilowatts. The total loss of this network is 531.8 kilowatts, and the lowest voltage of this network occurs at the bus 10, which is 0.9285 [12].

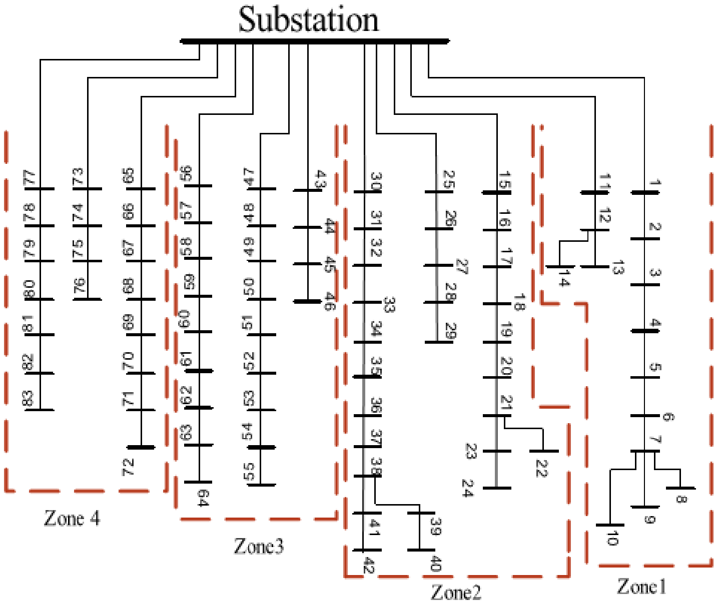

Figure 1. 84 bus distribution network

4.1 Simulation results without constraints

In this section, constraints are not considered in solving the WTG location problem with the goal of reducing casualties. In other words, the capacity of all wind turbines is fixed at a capacity of 5 megawatts. The convergence curve of the ITLBO method in Fig. 2 is presented for the number of 1 to 4 turbines aligned in the network according to the results of Table 1. The results show that with increasing number of turbines, the amount of losses is reduced further. The presence of only 1 turbine has led to a 19.5% decrease in casualties. The increase in the number of turbines reduced to 2 and 3 times, respectively, by 30.74 and 40.55%, and the use of 4 turbines reduced the total network losses by 35.47%, which means that the amount of network losses is half the base state It has been.

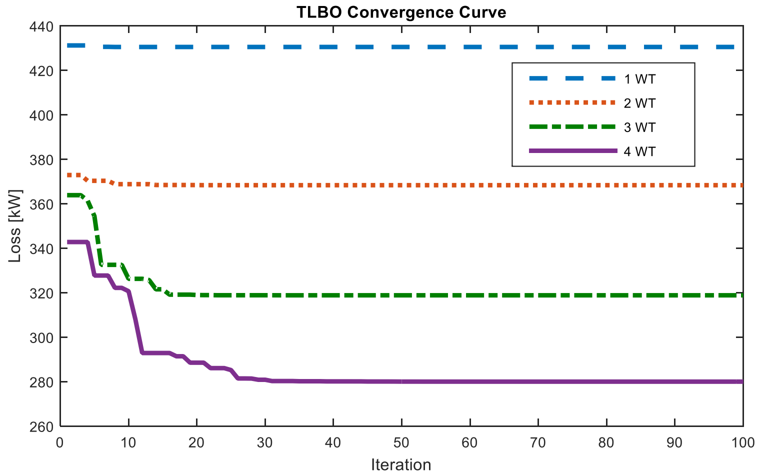

Figure 2. The convergence curve of the ITLBO method in the position of wind turbines, regardless of constraints

Table 1. Results from the optimal location of WTGs regardless of constraint

Loss reduction perentage	Loss value	Optimal power factor	Optimal size	Optimal location	number of wind turbine
--	531.8	--	--	--	0
19.05	430.45	0.9066	5	6	1
30.74	368.30	0.9066 و 0.8900	5, 5	6 , 37	2
40.05	318.78	0.9065 ،0.8685 و 0.8899	5, 5, 5	6 , 15 , 17	3
47.35	279.96	0.9065 ،0.9 ،0.8685 , 0.89	5, 5, 5, 5	6 , 15 , 20 , 40	4

The network voltage profile in the position of wind turbines, regardless of constraints, is presented in Fig. 3. It is observed that with the use of wind turbines, the network voltage profile has improved compared to the previous state of use.

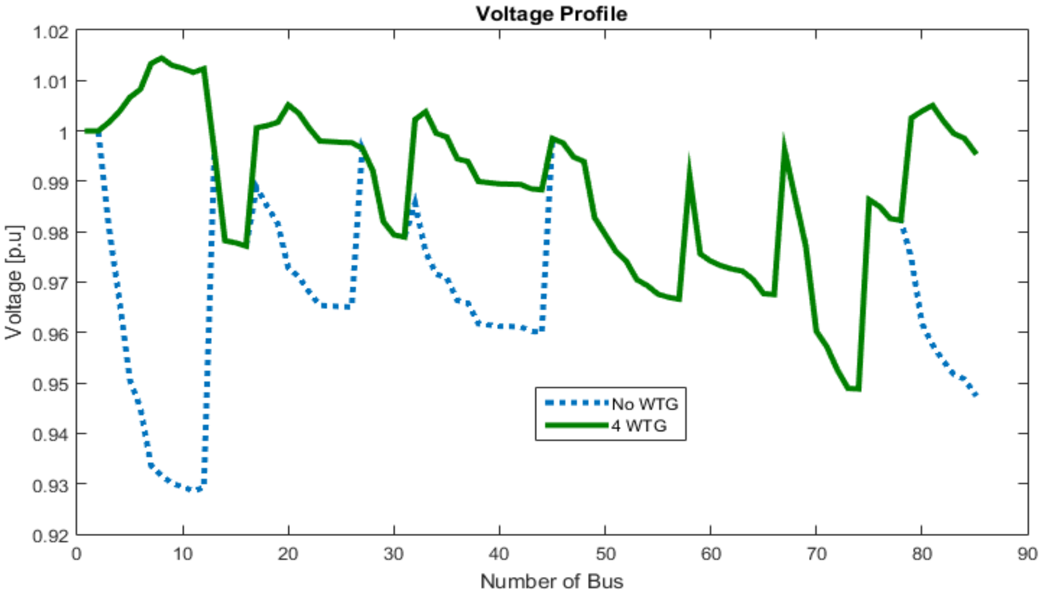

Fig. 3. Network voltage profile in the position of wind turbines, regardless of constraints

4.2 Simulation results with constraints

In this section, the right location for the installation of 4 wind turbines has been set up with the aim of reducing losses and observing the constraints. As shown in Figure 1, the network is divided into 4 regions. Given the presence of 4 turbines, 15 scenarios will be created, which will be classified in 4 different modes.

Mode 1) The capacity of the wind turbine 3 is kept at its maximum value, and the capacity of one of the wind turbines is changed in such a way that the constraints are observed. This mode will include 4 scenarios.

Mode 2) In this case, the capacity of the 2 wind turbines is kept at a maximum value and 2 other wind turbines will be variable. This mode will include 6 scenarios.

Mode 3) In this case, the capacity of the wind turbine is constant and the capacity of the other three wind turbines will be variable. This mode will also include 4 scenarios.

Mode 4) In this case, the capacity of all wind turbines will be variable. This state is just one scenario.

The convergence curve of the ITLBO method in this section is presented for the number of turbines in Fig. 3. As can be seen, the losses are lower in the use of four turbines. The results of this optimization with consideration of the constraints are given in Table 2. As can be seen from the results of the table, the variable considering all wind turbines leads to a greater reduction in losses. The network voltage profile before and after the installation of wind turbines is shown in Figure 5. It is clear that the presence of wind turbines has greatly improved the network voltage profile.

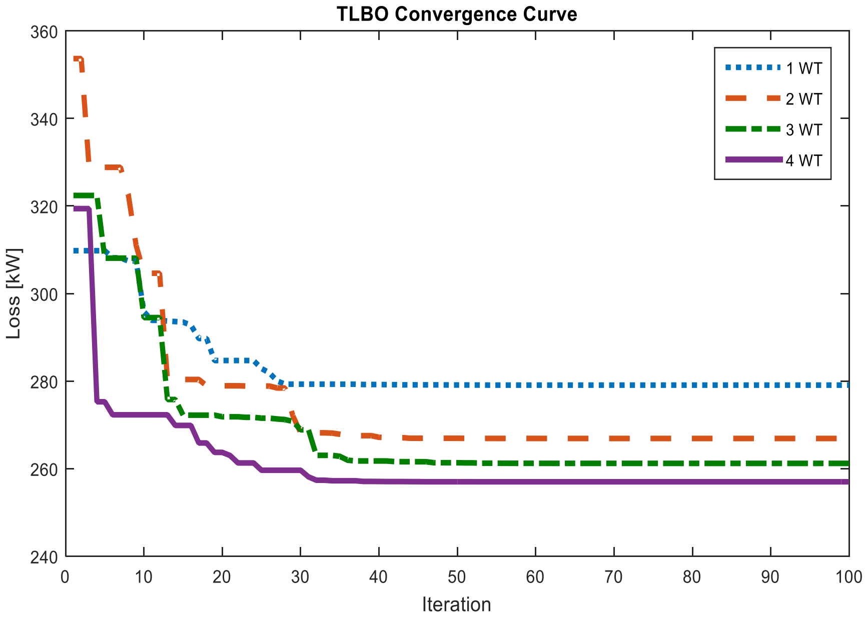

Figure 4. The convergence curve of the ITLBO method in the position of wind turbines with regard to the constraints

Table 2. The results of this optimization with consideration of the constraints

Loss reduction perentage	Loss value	Optimal power factor	Optimal size	Optimal location	number of wind turbine
--	531.8	--	--	--	0
47.52	279.07	0.8756 ،0.8684 ، 0.9389 و 0.8899	5 , 5 , 5 , 4.13	8 , 33 , 53 , 81	1
49.81	266.89	0.8756 ،0.8685 ، 0.9166 و 0.89	5 , 4.13 , 5 , 4.13	8 , 33 , 53 , 81	2
50.88	261.19	0.8755 ،0.8685 ، 0.9168 و 0.8518	4.13 , 4.13 , 5 , 4.13	8 , 33 , 53 , 81	3
51.67	256.99	0.8755 ،0.85 ،0.9167 و0.8517	4.13 , 4.13 , 4.13 , 4.13	8 , 33 , 53 , 81	4

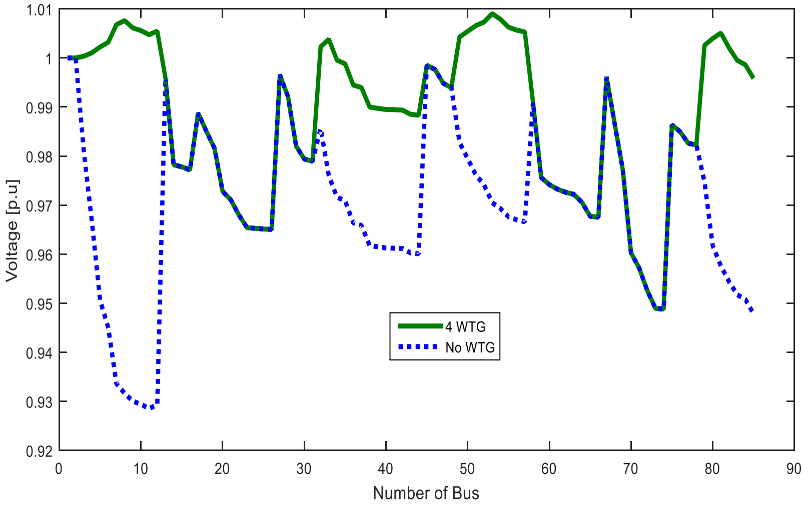

Figure 5. Network Voltage Profile in the Position of Wind Turbines, Considering Constraints

4.3 Compare results with and without constraints

In this section, the comparison of the results of using four wind turbines without and with respect to constraints is presented in Table 3. According to the table, with the variable considering the capacity of the turbines, the amount of network losses is reduced further. In other words, considering the constraints, the percentage reduction in losses is 51.67%, and regardless of the constraints, it is 35.47%.

Table 3. Comparison of results with and without consideration of constraints for 4 turbines

Loss reduction perentage	Loss value	Optimal power factor	Optimal size	Optimal location	mode
47.35	279.96	, 0.8685 ،0.9 ،0.9065 0.89	5, 5, 5, 5	6 , 15 , 20 , 40	Without constraints
51.67	256.99	0.9167 ،0.85 ،0.8755 0.8517 و	4.13 , 4.13 , 4.13 , 4.13	8 , 33 , 53 , 81	With constraints

4.4 ITLBO Method Verification

To illustrate the advantage of the proposed ITLBO method, the results of this method are compared with the results of the TLBO method in Table 4. Results show better results than the proposed method in terms of the amount of losses to achieve the best solution.

Table 4. Comparison of results of ITLBO method and TLBO method in different modes

ITLBO	TLBO	Mode
Loss	Loss	
279.07	287.04	1
266.89	274.17	2
261.19	272.3	3
256.99	262.1	4

5. CONCLUSION

In this paper, a two-stage method was proposed for the proper allocation of wind turbines in the distribution network considering the maximum capacity of wind turbines. In the two-step method, firstly, the control variables were determined. Then, for optimization variables, the maximum capacity of the turbines was based on the reduction of losses. In this study, learning-learning method was used to solve the optimization problem. The proposed method was implemented on a 84-busi IEEE test network. The simulation results indicated that changing the capacity of variable wind turbines leads to a further reduction of network losses. Also, the results of the proposed method were compared with the results of the conventional learning-learning method. The performance of the proposed method was confirmed by the conventional learning-learning method. The results also showed that the use of wind turbines improves the network voltage profile.

REFERENCES

[1] R.A. Walling, et al., Summary of Distributed Resources Impact on Power De livery Systems, Power Deliv. IEEE Trans. 23 (2008) 1636e1644.

[2] M. Wolter, L. Hofmann, General estimation of the impact of additional DG sources on distribution grids, in: Power and Energy Society General Meeting, 2011 IEEE, 2011, pp. 1e5.

[3] Y. Firouz, et al., Numerical comparison of the effects of different types of distributed generation units on overcurrent protection systems in MV distri bution grids, Renew. Energy 69 (2014) 271e283.

[4] N.S. Rau, W. Yih-Heui, Optimum location of resources in distributed planning, Power Syst. IEEE Trans. 9 (1994) 2014e2020.

[5] N. Kumar, et al., Optimal DG placement for congestion mitigation andsocial welfare maximization, in: North American Power Symposium (NAPS), 2011, 2011, pp. 1e5.

[6] D. Zhu, et al., Impact of DG placement on reliability and efficiency with time varying loads, Power Syst. IEEE Trans. 21 (2006) 419e427.

[7] W. Caisheng, M.H. Nehrir, Analytical approaches for optimal placement of distributed generation sources in power systems, Power Syst. IEEE Trans. 19 (2004) 2068e2076.

[8] A. Barin, et al., Methodology for placement of Dispersed Generation Systems by analyzing its Impacts in Distribution Networks, Lat. Am. Trans. IEEE Rev. IEEE Am. Lat. 10 (2012) 1544e1549.

[9] M. Gandomkar, et al., A combination of genetic algorithm and simulated annealing for optimal DG allocation in distribution networks, in: Electrical and Computer Engineering, 2005. Canadian Conference on, 2005, pp. 645e648.

[10] D. Singh, K.S. Verma, Multiobjective Optimization for DG Panning With Load Models, Power Syst. IEEE Trans. 24 (2009) 427e436.

[11] Y. Nien-Che, C. Tsai-Hsiang, Dual Genetic Algorithm-Based Approach to Fast Screening Process for Distributed-Generation Interconnections, Power Deliv. IEEE Trans. 26 (2011) 850e858.

[12] Safaei, A., Vahidi, B., Askarian-Abyaneh, H., Azad-Farsani, E., & Ahadi, S. M. (2016). A two step optimization algorithm for wind turbine generator placement considering maximum allowable capacity. Renewable Energy, 92, 75-82.

[13] Rao, R. V., Savsani, V. J., & Vakharia, D. P. (2011). Teaching–learning-based optimization: a novel method for constrained mechanical design optimization problems. Computer-Aided Design, 43(3), 303-315.