International Journal of Academic Engineering Research (IJAER)
ISSN: 2000-001X
Vol. 2 Issue 10, October – 2018, Pages: 12-18

Technical and Economic Design of Solar/Wind Hybrid Systems with the Goal of Minimizing the Annual Cost of Energy Using the Improved Teaching-Learning Algorithm

Mehdi Ershadi Nejad[1], Esmail Ghezi[2] and Mohammad Reza Tashakori Sabzevar[3]

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

Abstract: *In this study, the optimization of solar-wind hybrid systems includes solar panels, wind turbines and batteries with the aim of minimizing system costs, including initial investment costs, maintenance and restoration of the balance of production and consumption power. The objective of optimizing the hybrid systems is to determine the capacity or number of solar and wind units together with the number of batteries. The optimization of the system has been made using the ITLBO improved learning-learning algorithm and for solar-only combinations, wind and hybrid. The optimization results showed that the ITLBO method showed better performance in optimizing the system than the usual TLBO algorithms, harmonic search (DHSA), and B & B method. The results also show that the capacity of solar and wind units has an important role in optimizing the capacity of the equipment as well as energy costs.*

Keywords: Hybrid Systems, Technical and Economic Design, Power Balance Constraint, Improved Teaching-Learning Algorithm

1. INTRODUCTION

A program that help in creating more than ITS with relatively easy way and provide the experience of crating ITS without the need of expert programmer to made it.

Today, population growth and the process of industrialization and the increasing demand for energy on the one hand, and the endangerment of fossil fuels, on the other hand, have led to more attention to renewable energy sources such as solar panels. Free energy of these types of resources is one of the reasons for welcoming them. But the lack of uniformity of sunlight and wind speed is one of the problems with using these types of resources. For this reason, energy utilization in hybrid systems used to combine energy sources is used to improve the system's supply of power from a storage system such as batteries. One of the most important issues is the use of hybrid systems to design these types of systems, taking into account economic and technical indicators. The economic indexes of energy system costs and the technical index indicate the supply of goods [4-1]. Therefore, in most studies, the goal is to minimize system costs by achieving optimal load-retention. Using intelligent optimization algorithms in order to achieve the optimum equipment capacity of the system, according to the achieved economic and technical indicators are common. It's also a competition for using algorithms with high computational speed and optimization. So far, several studies have been carried out in the field of optimizing hybrid systems, and some of these studies have been presented [9-1]. In [1], the particle optimization algorithm has been used to minimize the cost of wind, solar, and hydrogen power plants. In [2], the genetic algorithm is used to find the angle of installation of solar panels and to obtain maximum energy from sunlight. In the reference [3], the optimization model has been proposed to determine the optimal size of the solar-wind system with a battery bin. System optimization is based on two reliability and cost indicators. The optimal capacity of the system equipment is presented in this study. In [4], an improved method of determining the optimal capacity of a combined system connected to a solar-wind-battery network is proposed with the aim of minimizing system costs and providing high reliability of the load. In [5], the technical and economical optimization of the solar-wind-diesel-battery system independent of the network is aimed at optimizing the equipment of the system and minimizing the system power shortage and production costs. In [6], a method for determining the size of solar-wind equipment together with battery storage is proposed. Optimization is based on two reliability and cost indicators. In this study, a genetic algorithm is used to solve the optimization problem. The results show that by increasing the reliability of the system, the cost of system energy production increases. In reference [7], the aim is to determine the optimum size of equipment equipment capacity at minimum cost and reliable load reliability. In this study, a new optimization method is proposed to determine the optimal capacity of the equipment. In [8] modeling, simulation, control and energy management, a micro-turbine wind-tidal power generation system is presented with a battery storage using a genetic algorithm. In [9], an optimization of a solar-wind hybrid system is proposed using a discrete optimization method for harmonic search. In this paper, the optimal design of solar-wind-hybrid systems with battery storage using the Improved Learning-Learning Optimization (ITLBO) algorithm [11-11] aims to minimize investment costs and maintenance costs of the system subject to optimization constraints. Provided. The goal of optimization is to determine the optimum number of system equipment including the number of solar panels, wind turbines and

International Journal of Academic Engineering Research (IJAER)
ISSN: 2000-001X
Vol. 2 Issue 10, October – 2018, Pages: 12-18

batteries. Also, the results of the proposed method are compared with the results obtained from the TLBO [12], DHSA [9] and B & B methods [13]. In Section 2, mathematical modeling of the proposed system and its equipment are discussed. Then, in Section 3, the optimization problem is presented along with the objective function and problem constraints. In Section 4, the implementation of the ITLBO algorithm is presented in the problem solving, and in Section 5, the simulation results are presented and in Section 6 a general conclusion is presented.

2. HYBRID SYSTEM UNDER STUDY

The hybrid system studied, consisting of solar panels, wind turbines, battery storage and inverter, is shown in Fig. 1 [9].

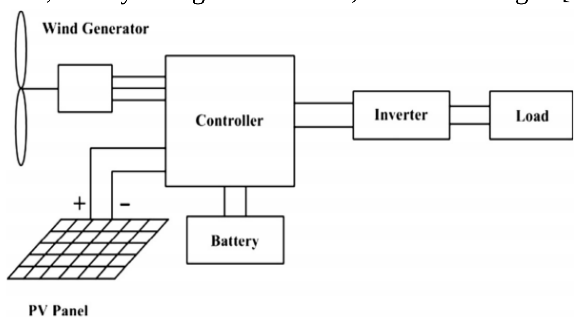

Figure 1. Solar-Wind Turbine System with Battery Storage [9]

In the studied system, solar panels, wind turbines, and battery storage systems are intended to provide the required power in a hybrid system. If the total power of solar panels and wind turbines is more than the power required, additional power is injected into the battery and the battery is charged. When the required power is greater than the total solar panel power and wind turbine power, the battery system is in discharge mode and compensates for the lack of power.

2.1 Solar modeling

If the power of a solar panel is equal, then, considering the number of solar panels, the total power generated is obtained from the following equation [9].

$$P_{PV}^{T}(t) = N_{PV} . P_{PV}(t) \quad (1)$$

2.2 Wind turbine modeling

Given the number of NWG turbines, the power produced by wind turbines is defined as follows.

$$P_{WG}^{T}(t) = N_{WG} . P_{WG}(t) \quad (2)$$

2.3 Power generated by renewable units

The total power produced by solar panels and wind turbines represents the amount of power produced by the renewable units. Generated power is calculated by all the regenerated units injected into the load from the following equation [9].

$$P_{ren}(t) = P_{PV}^{T}(t) + P_{WG}^{T}(t) = N_{PV} . P_{PV}(t) + N_{WG} . P_{WG}(t) \quad (3)$$

2.4 Battery modeling

Due to fluctuations in solar panel power production due to solar fluctuations and wind turbine power fluctuations, due to wind speed fluctuations, a battery storage system should be used to provide continuous supply. Therefore, the battery should manage excess capacity and lack of power with its charge and discharge mode in order to provide continuous supply. Therefore, the number of batteries is formulated as follows [9].

$$N_{Batt} = Roundup\left[\frac{S_{Req}}{\eta \times S_{Batt}}\right] \quad (4)$$

In the above relation rounded rounded amount, SBatt is the nominal capacity of each battery, SReq is the required storage capacity and η percent of the nominal capacity utilization.

The required storage capacity is defined as follows [9].

$$S_{Req} = E_{storage,\max} - E_{storage,\min} \quad (5)$$

$E_{Batt,\min}^{T}$ and $E_{Batt,\max}^{T}$ refer to the minimum and maximum storage capacities are defined as follows:

$$E_{storage} = (P_{PV}(t) + P_{WG}(t)) - P_{L}(t) \quad (6)$$

In the above relation, $P_L(t)$ the load demand is expressed in t hour, which is called the power difference relation.

3. OPTIMAL DESIGN OF THE STUDIED SYSTEM

The purpose of optimal design of the system is to determine the size or capacity of the equipment, including the capacity of producing solar arrays, the number of solar arrays, the capacity of producing wind turbines, the number of wind turbines and the number of batteries. In this study, determining the optimal capacity of the system equipment for supply demand with the aim of minimizing energy costs.

3.1 Objective function of optimization problem

The objective function of the problem of optimization can be considered based on the annual cost index of energy system. In the solution of the problem of determining the size of equipment equipment, cost analysis is one of the most important factors. The annual cost of the system includes investment costs and maintenance costs. In this study, the ultimate goal of the system equipment capacity optimization problem is to minimize the annual cost of the system. The total annual cost is equal to the total annual investment cost and maintenance cost. Therefore, the problem function problem is formulated math based on the following relations [9].

$$MIN\ ACS = C_{Cap} + C_{Main} \quad (7)$$

Where, ACS is annual cost of the system (dollars), C_{cap} is investment cost (dollars) and C_{Main} is maintenance costs (Dollars).

Maintenance costs are considered in the life of the project, provided that the investment cost is considered at the start of the project. In order to convert the initial investment cost to the annual cost of investment, the return on capital ratio (CRF) is defined as follows [9].

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (8)$$

In the above relation i is the interest rate and n is the useful life of the system.

The investment cost of the system includes the cost of investing solar arrays, wind turbines and battery banks in relation to the cost of purchasing solar, wind and storage units as follows: [9].

$$C_{cap} = CRF.\left[N_{PV}.C_{PV} + N_{WG}.C_{WG} + \left(\frac{n}{LS_{Batt}}\right).N_{Batt}.C_{Batt}\right] \quad (9)$$

Where $C_{PV} = P_P + P_{if}$ and $C_{WG} = T_P + T_{if}$. N_{PV} number of solar panels, N_{WG} number of wind turbines, P_P cost of per panel, C_{WG} investment cost of per turbine, P_{if} cost of solar installation, T_P and T_{if} is turbine cost and its installation cost, C_{Batt} cost of per battery and LS_{Batt} is battery life time.

The annual maintenance cost is also defined as follows [9].

$$C_{main} = \left(C_{main}^{PV}.\sum_{t=1}^{T} E_{PV}^{T}(t) + C_{main}^{WG}.\sum_{t=1}^{T} E_{WG}^{T}(t)\right).365 \quad (10)$$

Where C_{main}^{PV} is maintenance cost of solar panel for each *kWh*, C_{main}^{WG} is maintenance cost of wind turbine for each *kWh*, $E_{PV}^{T}(t)$ and $E_{WG}^{T}(t)$ is generated energy by solar panels and wind turbines respectively.

3.2 Optimization constraints

The constraints considered for optimization are considered as follows [9].

$$0 \le N_{pv} \le N_{pv,\max} \quad (10)$$

$$0 \le N_{WG} \le N_{WG,\max}$$

$$0 \le N_{Batt} \le N_{Batt,\max}$$

$$\sum P_{PV}^{T}(t) + \sum P_{WG}^{T}(t) = \sum P_L(t)$$

In the above relations, $N_{PV,\max}$ the maximum number of solar panels, $N_{WG,\max}$ the maximum number of wind turbines and $N_{Batt,\max}$ the maximum number of batteries.

4. PROPOSED ALGORITHM

4.1 Teaching-learning algorithm based optimization (TLBO)

An optimization algorithm based on learning-learning [11-10] 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 can not 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.

4.1.1 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 [11-10].

$$Diff\_Mean_i = r_i(M\_new - T_f M_i) \quad (15)$$

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 [11-10].

$$X_{new,i} = X_{old,i} + Diff\_Mean_i \quad (16)$$

4.1.2 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 [11-10].

$$X_{new,i} = X_{old,i} + r_i (X_i - X_j) \qquad (17)$$

Otherwise, the student's status changes as follows [11-10].

$$X_{new,i} = X_{old,i} + r_i (X_j - X_i) \qquad (18)$$

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.

4.2 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 [23-22].

The mutation is defined as follows [23-22].

$$X_{new,i} = \begin{cases} X_{old,i} + \omega(T_i - X_{old,i}) & if\ \omega > 0 \\ X_{old,i} + \omega(W_i - X_{old,i}) & if\ \omega \le 0 \end{cases} \qquad (19)$$

Where ,Ti is the teacher (best student) and Wi is the worst student. The parameter ω is calculated as follows [23-22].

$$\omega = \frac{1}{\sqrt{h}} \exp\left[-(\frac{1}{2})(\frac{\varphi}{h})^2 \cos(\omega_c (\frac{\varphi}{h})) \right] \qquad (20)$$

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 [23-22].

$$h = \exp\left[-\ln(\eta) \times (1 - {k}/{k_{\max}})^{\sigma} + \ln(\eta) \right] \qquad (21)$$

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 [23-22.[

$$\sigma = \sigma_{\min} + (\frac{\sigma_{\max} - \sigma_{\min}}{k_{\max}})k \qquad (22)$$

Where σ_{min} and σ_{max} are respectively 1 and 3 [23-22]

4.3 General implementation of the optimization method in problem solving

In this study, the problem variables are the number of solar panels, wind turbines, and ultimately the optimal number of battery optimization problems. The procedure for implementing the ITLBO approach to solving the optimization problem is as follows.

The problem-solving process based on the ITLBO method is as follows:

Step 1. Generate Primary Population

Step 2. The value of the objective function is calculated for each set of variables and the best set is selected in terms of the value of the objective function (Eq (7)) as the teacher of the whole population.

Step 3. Each set of variables is updated according to the Eqs. (15) and (16) in the student phase, and if the new variables have better results, they will be replaced with the previous set.

Step 4. Each of the variables is updated by (17) and (18) and replaced by the set if they have better results.

Step 5. Each set of variables is updated in the improved phase of the mutation in (19) and replaces the set if it has better results.

International Journal of Academic Engineering Research (IJAER)
ISSN: 2000-001X
Vol. 2 Issue 10, October – 2018, Pages: 12-18

Step 6. If the condition of convergence is not met, we go to step 2.

5. SIMULATION

5.1 Simulation data

The system data, including the power produced by each solar panel and each wind turbine, and the power required by the load during the same day, are shown in Figures 2 to 4, respectively. The design parameters used for the solar-wind system are presented in Table 1.

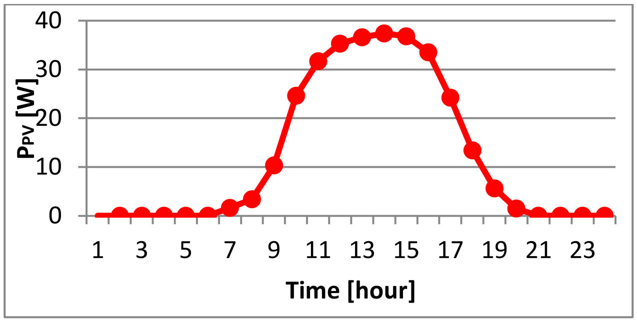

Figure 2: Generation of solar panels over 24 hours [9]

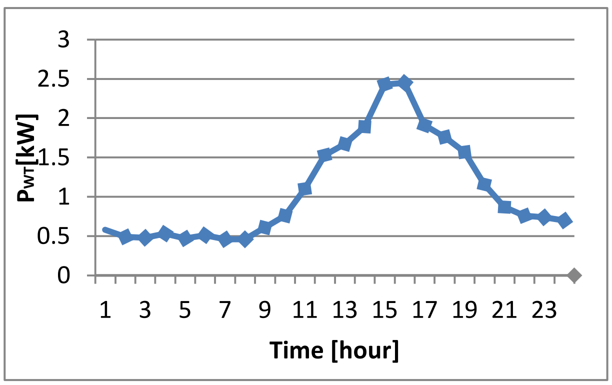

Figure 3: Generation of wind turbine over 24 hours [9]

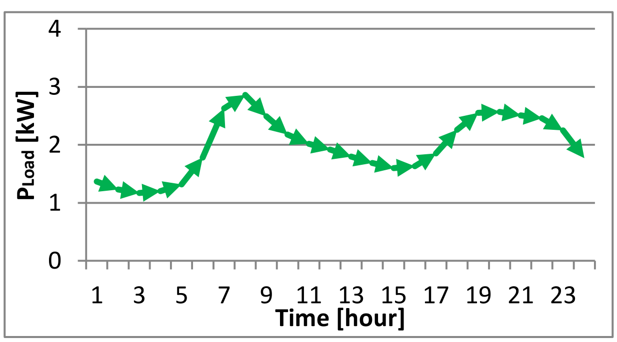

Figure 4: Load demand over 24 hours [9]

Table 1. Solar-Wind System Design Parameters [9[

Parameter	Value
i	0.06
n	20 years
T_P	20,000 $/turbine
T_{if}	0.25* T_p
P_P	350 $/panel
P_{if}	0.5* P_p
C_{Batt}	170 $
C_{Backup}	2000 $
η	0.8
S_{Batt}	2.1 kW h
Δt	1 h
C_{main}^{PV}	0.005 $/kW h
C_{main}^{WG}	0.02 $/kW h

5.2 Simulation results

In this section, the results are related to the number of optimal solar panels, wind turbines and batteries to minimize system costs using the ITLBO algorithm. The results of the proposed method have been compared and compared with the results of TLBO, DHSA and B & B methods. The parameters of the ITLBO algorithm are presented in Tables 2. The convergence curve of the ITLBO algorithm is shown in Figure 5, as shown in Fig.

Table 2: Parameters of the TLBO algorithm

Parameter	Value
Population	20
Max. Iteration	30

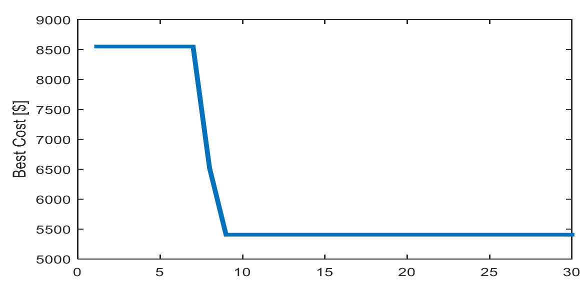

Figure 5. The convergence curve of the ITLBO algorithm in terms of its repetition

According to Fig. 5, in the ITLBO method, the value of the objective function in terms of the cost of generating the system's power is fixed from a repetition of 8 to a value of $

International Journal of Academic Engineering Research (IJAER)
ISSN: 2000-001X
Vol. 2 Issue 10, October – 2018, Pages: 12-18

2.5404. The results of basic state optimization are also presented in Table 3. By observing the results of the proposed method, it is clear that the program provides wind-only mode as the optimum system for cost minimization. According to the results obtained for the system load, 2 turbines, 9 batteries and a cost of 5404 dollars are required. The results show that in both the proposed method and the TLBO, DHSA and B & B methods, optimum mode is the least costly combination of the system, the wind-battery mode, and the number of solar panels equal to zero. Because the cost of a turbine unit is less than that for power generation for a given power output relative to solar panels, the ITLBO algorithm tries to use wind turbines to provide load. Therefore, the optimization method selects a wind-only system to supply the load. According to Table 3, the results of the proposed optimization method are better than the DHSA method.

Table 3: Optimization of wind-battery system

	N_{PV}	N_{WG}	N_{Batt}	ACS ($)
ITLBO	0	2	9	5404
TLBO	0	2	10	5652.15
DHSA [21]	0	2	11	5652.66
B&B [28]	0	2	10	5652.3

After determining the optimal mode by the program, according to TLBO, DHSA and B & B methods, the capacity of the system equipment included the number of solar panels, batteries, as well as the system cost per zero and one wind turbine. According to table 4, in optimizing the solar-battery system, the results show that the proposed method has a lower cost than other methods. Also, according to the results of optimization of the solar-wind-battery or hybrid system presented in Table 5, proposed methods and methods, the number of solar panels has been determined by 72, and the proposed method has chosen 10 batteries with the TLBO method. Is. In this case, the proposed method is less costly than other methods.

Table 4: Solar System Optimization Results

	N_{PV}	N_{WG}	N_{Batt}	ACS ($)
ITLBO	159	0	16	8549
TLBO	160	0	17	8843.28
DHSA [21]	160	0	17	8844
B&B [28]	160	0	17	8843.463

Table 5: Results of optimization of solar-wind-battery hybrid systems

	N_{PV}	N_{WG}	N_{Batt}	AC ($)
ITLBO	72	1	10	6518
TLBO	72	1	10	6528
DHSA [21]	72	1	11	6692
B&B [28]	72	1	11	6692

Considering the optimization of different system combinations, it can be concluded that wind turbines, in addition to producing more energy than solar panels, have lower initial investment costs compared to the same number of solar panels for producing similar energy. On the other hand, the proposed method, in optimizing different systems of the system than other proposed methods, has shown the desirability of minimizing system costs, which indicates the high efficiency of the proposed method in solving the optimization problem. The power difference in Fig. 6 is obtained in different scenarios, namely wind mode, solar only, and solar-wind, which should be overcharged in batteries and discharged from batteries. In Figure 6, in the case of wind turbines only (2 turbines and 9 batteries), power shortages are less than just solar and combined. Also, the power surplus has a smaller amount. Therefore, it can be concluded that a smaller number of batteries are needed for charging and discharging energy. On the contrary, it is seen that the power shortage and excess power in the solar only mode are more than wind and hybrid conditions. Therefore, in this case, more batteries are needed. According to the results, it can be seen that the number of batteries in the wind mode is equal to 9, only solar is equal to 16, and the combination is equal to 10, which confirms the logic of Figure 6. On the other hand, the wind mode is chosen as optimal mode with the lowest cost.

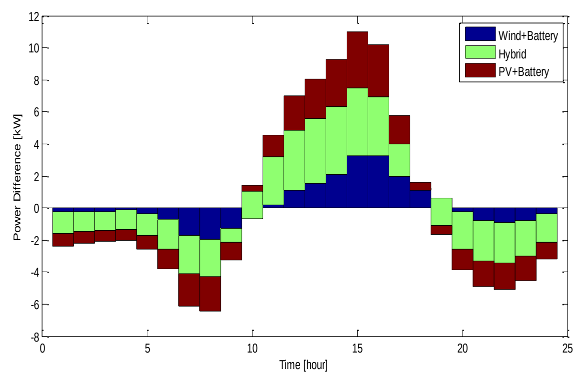

Figure 6. Production and consumption power difference curve

The effect of capacity of wind and solar units on optimization has been investigated. In other words, the capacity of wind and solar units has been increased and reduced by 30%. The results on the hybrid system are presented in Table 6. The results of Table 6 show that by increasing the production capacity of renewable units, the number of solar panels decreased, the number of batteries increased roughly, and the system costs decreased.

Table 6: Effects of the Effects of Solar and Wind Capacity

	N_{PV}	N_{WT}	N_{Batt}	ACS (\$)
$0.7\times(P_{WT}\ \& P_{PV})$	98	1	8	7427
N_{WG}	72	1	11	6518
$1.3\times(P_{WT}\ \& P_{PV})$	45	1	13	5331

6. CONCLUSION

In this study, an optimization of a solar-wind-powered hybrid system with battery storage was presented separately from the network using the ITLBO algorithm to provide load demand. Considering the optimization of different system combinations, it can be concluded that wind turbines, in addition to producing more energy than solar panels, have lower initial investment costs compared to the same number of solar panels for producing similar energy. Also, the results showed that the ITLBO optimization method had better results than other methods in the optimal design of the system at a lower cost. Also, the proposed method and other method, have chosen the wind composition of the system as an optimal combination. In addition, the results show that the cost of the system is reduced by increasing the production capacity of renewable units.

REFERENCE

[1] Kaviani, A. K., Riahy, G. H., & Kouhsari, S. M. (2009). Optimal design of a reliable hydrogen-based stand-alone wind/PV generating system, considering component outages. Renewable Energy, 34(11), 2380-2390.

[2] Koutroulis, E., & Kolokotsa, D. (2010). Design optimization of desalination systems power-supplied by PV and W/G energy sources. Desalination, 258(1), 171-181.

[3] Hongxing Yang, Lin Lu, Wei Zhou, "A novel optimization sizing model for hybrid solar-wind power generation system", Solar Energy, 81 (2007) 76–84.

[4] Xu, L., Ruan, X., Mao, C., Zhang, B., & Luo, Y. (2013). An improved optimal sizing method for wind-solar-battery hybrid power system. Sustainable Energy, IEEE Transactions on, 4(3), 774-785.

[5] Abdelhamid Kaabeche, Rachid Ibtiouen," Techno-economic optimization of hybrid photovoltaic/wind/diesel/battery generation in a stand-alone power system", Solar Energy 103 (2014) 171–182.

[6] Hongxing Yang, Wei Zhou, Lin Lu, Zhaohong Fang," Optimal sizing method for stand-alone hybrid solar–wind system with LPSP technology by using genetic algorithm", Solar Energy, 82 (2008) 354–367.

[7] Fatih O. Hocaoğlu, Ömer N. Gerek, Mehmet Kurban, "A novel hybrid (wind–photovoltaic) system sizing procedure", Solar Energy, 83 (2009) 2019–2028.

[8] S.M. Mousavi G, "An autonomous hybrid energy system of wind/tidal/microturbine/battery storage", International Journal of Electrical Power & Energy Systems 43 (2012) 1144–1154.

[9] Alireza Askarzadeh," Developing a discrete harmony search algorithm for size optimization of wind–photovoltaic hybrid energy system", Solar Energy 98 (2013) 190–195.

[10] R.V. Rao, V.J. Savsani, , D.P. Vakharia, "Teaching–learning-based optimiza- tion: an optimization method for continuous non-linear large scale problem", Inf. Sci. 183, 1–15, 2012.

[11] R.V. Rao, V. Patel, "An elitist teaching–learning-based optimization algorithm for solving complex constrained optimization problems" Int. J. Ind. Eng.Comput., 3, 2012.

[12] Eberhart, R. C., & Shi, Y. (2001). Particle swarm optimization: developments, applications and resources. In evolutionary computation, 2001. Proceedings of the 2001 Congress on (Vol. 1, pp. 81-86). IEEE.

[13] Geem, Z. W. (2012). Size optimization for a hybrid photovoltaic–wind energy system. International Journal of Electrical Power & Energy Systems, 42(1), 448-451.