Journal of Solar Energy Research (JSER)

Journal homepage: www.jser.ut.ac.ir

Design and optimization of a PV-wind hybrid system with storage system by HOMER software, Case study: Tehran

Katooli[a,*],M.H., Esmaeili Rouzbahani[a],A., Tahani[a],M., Babayan[a], N.

[a] *Faculty of new Sciences and Technologies, University of Tehran, Iran* **E-Mail: , hadi.katoly@ut.ac.ir*

ARTICLE INFO

Received: 11 May 2017
Received in revised form:
1 June 2017
Accepted: 4 June 2017

Keywords:
solar, wind, hybrid,
HOMER ENERGY,
optimization

A B S T R A C T

Due to the growing rate of the cost of energy carriers and the shortage of different kinds of fuels, day by day it becomes more essential to use renewable energies such as wind, solar, hydrogen, geothermal, etc. The application of renewable energies for household use is an ideal solution to reduce enviromental pollution. It is possible to use different kinds of renewable energy systems either single or hybrid. Because of the fact that by using the single method it is not possible to use any kinds of these energies in a continuous way, so it is better to use the hybrid system in order to use these energies in a continuous way. In this paper an ordinary household user in Tehran is studied for the feasibility and financial optimization of the PV-wind renewable hybrid energy system by HOMER[a] ENERGY software. Also, the results are analyzed and compared with some other cities with their own data. The optimization results contain the number of components and primary costs. In this designed system for the specified user, the price of electricity generated per kWh is given by the software and equals to 22.4 cents. The price of electricity per kWh which is generated and sold in Iran almost equals to 10 cents. Due to the advantages of renewable energies for the enviroment, it is cost effective to use PV-wind hybrid energy system. A storage system is also considered to store the excess energy produced by the hybrid system. Also, during a 25-year period, all the costs which are used for this system are returned back.

1. Introduction

Nowadays hybrid systems have become one of the most promising solutions to provide electricity for different areas and to meet theirs needs [1]. According to the discontinuous energy that is produced by renewable energies, practically is proven that a hybrid system of these renewable energies can be a proper solution in order to produce energy in different weather situations. With a proper hybrid system, it is possible to reach to a cost-effective, clean and reliable energy system [2]. Using renewable energy for buildings is an important step toward zero energy consumption and buildings with zero emission [3]. Renewable energy systems can be used as a single stand-alone system or hybrid systems. In fact, by comparing factors of efficiency, cost, and reliability for single and hybrid renewable systems, it is concluded that a renewable energy based hybrid system (REHS) offers a better option than a single source based system [4]. In particular, in urban areas due to the accessibility of the wind and solar energy, it is more common to use Photovoltaic (PV)-wind based systems as off-grid hybrid systems. In addition to that, wind energy and solar energy's availability is contrary during a year. Thus, that's another proof for the PV-wind systems pervasive approach. Several studies approved PV-wind hybrid systems as a promising power generating source [5-8]. In order to obtain the most optimum design of the hybrid system, modeling and estimating the solar insolation has much importance. There are a lot of research and review studies about global solar insolation in the literature. By combining the modeling of the PV/Wind/Battery system with an appropriate optimization algorithm, the operation of the system can be optimized.

Electricity is an important factor for industrialization, urbanization and financial growth of any country [10]. Solar and wind energy systems are the most important sources of energy. The utilization of solar and wind energy systems have become increasingly popular due to modular and environment-friendly nature [11]. The field of solar–the wind has experienced a remarkable growth for past two decades in its widespread use of standalone to utility interactive solar–wind systems [12]. Solar and wind energy system works normally in stand-alone or grid connected mode, but the efficiency of these sources is less due to the stochastic nature of solar and wind resources. The hybrid renewable energy sources with grid integration overcome this drawback of being unpredictable in nature [13].

The main purpose of this study is to reach to a hybrid system consisting of PV-wind and battery bank as a storage part that is cost-effective and is suitable for household use. Target function is the time needed to bring back the money that is invested [14].

2. Materials and Methods

2.1. Hybrid system

A hybrid system basically consists of energy sources that work together in parallel and they are also parallel with a battery storage system [15]. Figure 1 shows a general schematic of a hybrid system. This plan is to reduce the amount of the electricity used in the network.

In order to optimize the hybrid system, modeling every part of the system is necessary in order to have the maximum efficiency. By combining PV, wind, and battery, it is possible to reach to an optimized model [14].

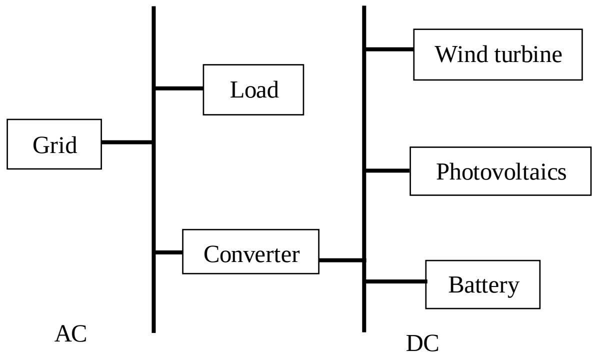

Figure 1. General Schematic of hybrid system

2.2. Describing the system and the area

The specified system in this study is a hybrid off-grid system which consists of wind turbine, solar panels and battery storage system. The overall schematic of this system is shown in figure 2.

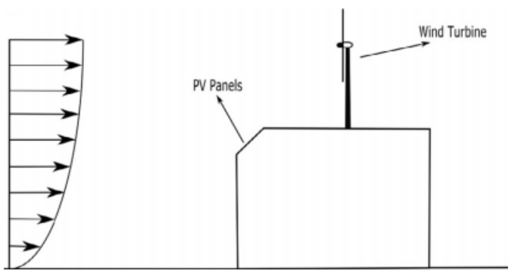

Figure 2. Overall schematic of the system

The amount of the wind that is passed through turbine blades can be controlled by intersecting the edge of the roof.

The case study is a residential house in Tehran city and the goal of this paper is to design a hybrid energy system by means of solar and wind energy regarding its load profile.

2.3. Introduction to HOMER ENERGY software

HOMER ENERGY software is used for simulation, technical and economical evaluation of hybrid systems. This software was created and developed by NREL (national renewable energy laboratory). HOMER gives this ability to users to compare different design alternatives from technical and economical aspects. Also, it provides the ability to apply changes and uncertainties. It can also model performance of a special array of an energy system for each hour of a year by determining different possible ways of providing the required energy and the cost of its life cycle. In optimization process, HOMER studies all the possible arrays of providing power by considering constraints, in order to choose the most economical case regarding the cost of the life cycle.

In order to model a system of photovoltaic cells and a wind turbine, the information of the solar source and wind speed of the area must be given in HOMER. It calculates the amount of energy of renewable energy by one-hour steps. For most of small energy systems, especially those that contain periodical renewable energies, one-hour step seems to be a precise step. This software uses net present value equation for the cost of the life cycle that consists of initial investment costs, replacement cost, repairment, fuel, buying electricity from the grid, selling electricity to the grid and the penalties from air pollution. When calculating the net present value of costs, expenses are considered to be negative and incomes are considered to be positive [16].

Incomes and expenses are evaluated by a constant rate during a year. In this evaluation in order to consider the effect of inflation in calculations, at the end of the analysis process, the system must be again considered by the real interest rate which is originated from inflation rate.

In simulation process, all the possible alternatives are simulated and then the software will arrange them according to the net value of expenses and finally will introduce the best array that has the least net value expenses as the best one.

2.4. Modeling and economical analysis of a hybrid PV/Wind/Battery storage system with HOMER

The purpose of this part is to design a hybrid PV/Wind/Battery storage system for a case study in Tehran. The first and basic step to design an energy system is to study the area and to estimate the monthly wind speed and solar radiation during 24 hours of the day.

Schematic of designed system

The schematic of designed system which is considered in this paper is shown Figure 3.

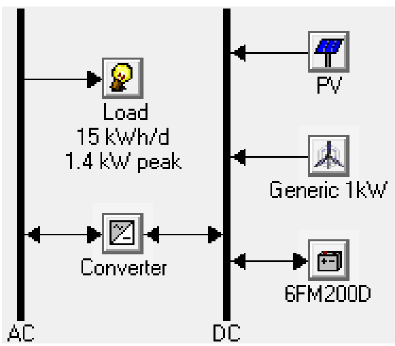

Figure 3. Hybrid system designed in HOMER

Load profile during day and night
Average load profile during day and night is shown in figure 4. Changes in electricity usage are considered to be 10 %.

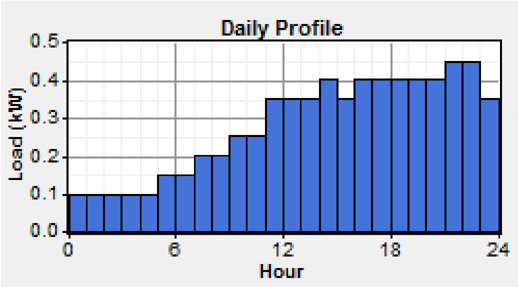

Figure 4. load profile during 24 hour

Intensity and solar radiation in the area

It is necessary to consider the intensity of solar radiation in the area, so solar radiation profile during 22 years for Tehran with the latitude of 35.6892° N and longitude of 51.3890° E and with a tilt angle of 49.7° is shown in figure 5.

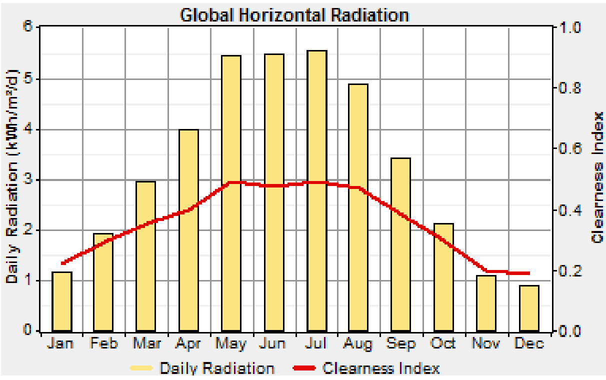

Figure 5. profile of solar radiation in different months ($kWh/m^2/day$)

Wind energy

Another feature that should be considered is average wind speed during different seasons. According to the geographical coordinates of Tehran that were mentioned earlier, wind speed during 10 years in 10 meters is shown in figure 6.

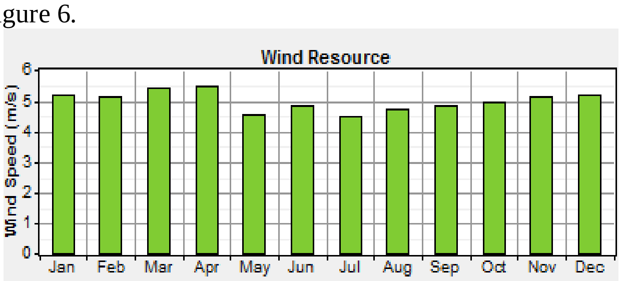

Figure 6. wind speed profile during different months in the area (m/s)

3. Results and Discussions

Wind turbine
The turbine used in this design is 1 kW wind turbine and the cost of each unit, replacement, and O&M costs are 550, 550 and 50 $. (Figure 7, 8)

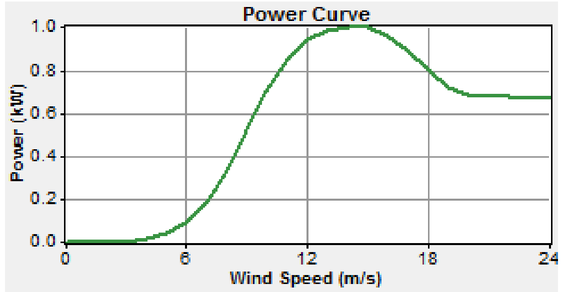

Figure 7. power curve for Generic 1 kW wind turbine

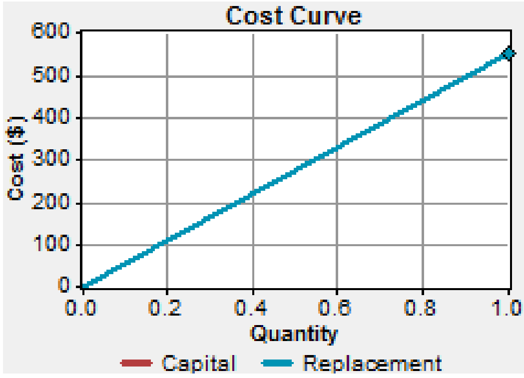

Figure 8. expenses curve for 1 kW wind turbine

Solar panels

The costs of installing solar panels are different from 6-10 $ per watt [17, 18]. In this study, the cost of installation and replacement per 1 kW system equals to 35 and 35 $ and maintenance cost is considered to be 5 $. The life span of these panels is usually between 20 to 25 years (Figure 9).

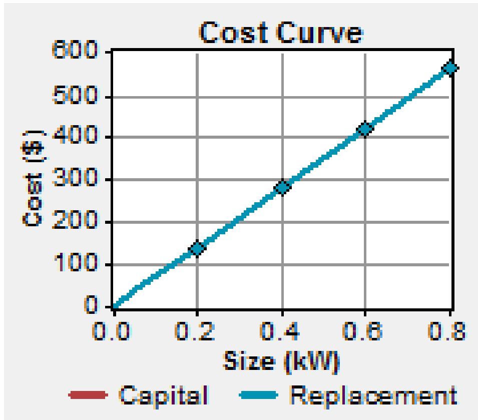

Figure 9. cost curve of solar panels

Battery bank

Since that wind and solar energy are uncontrollable sources, it is necessary to use battery banks in addition to wind turbine and solar panels to store energy. Initial cost and replacement cost of each battery are 180, 180 $. (Figure 10).

Converter

In order to have a connection between AC usage and DC generation, it is needed to have an electronic converter. For a 1 kW system, installation and replacement cost are 300, 300 $, respectively.

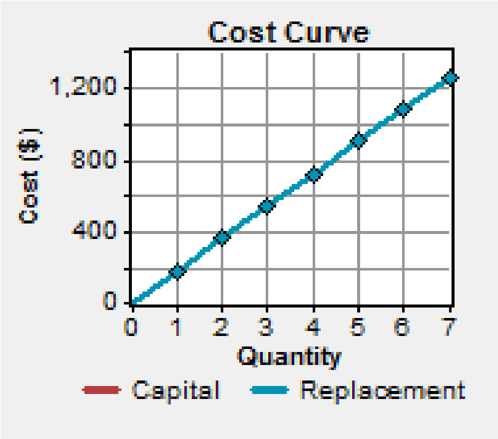

Figure 10. cost curve of battery

Optimization

HOMER ENERGY software considers an optimized array for the hybrid system, after studying different possible cases. Different studied results are shown in table 1.

Table 1. Different studied results studied in HOMER

PV (kW)	G1	6FM200D	Conv. (kW)	Initial Capital
0.2	1	1	0.5	$ 1,020
0.2	1	1	1.0	$ 1,170
0.2	1	2	0.5	$ 1,200
0.4	1	1	0.5	$ 1,160
0.2	1	1	1.5	$ 1,320
0.2	1	2	1.0	$ 1,350
0.4	1	1	1.0	$ 1,310
0.2	1	1	1.8	$ 1,410
0.2	1	3	0.5	$ 1,380
0.4	1	2	0.5	$ 1,340
0.6	1	1	0.5	$ 1,300
0.2	1	2	1.5	$ 1,500

Hybrid analysis during a year

After analyzing the hybrid system in HOMER, finally, the system consists of 1 wind turbine, 1 photovoltaic cells, and 1 battery. The share of each source to generate electricity is shown in Table 2.

Table 2. share of each source to generate electricity

Energy source	kWh/yr	Percent
PV array	190	21
Wind turbine	703	79
Total	892	100

4. Conclusion

The main purpose of a hybrid system is to on one hand provide electricity for a house in different weather situations and on the other hand to reduce construction and operation cost of the system. Due to low costs of electricity in Iran compared to the average cost in the world, it's not much cost-effective to invest in renewable energy in order to supply electricity for a house, although it has many benefits on the environment. But due to the proper geographical location which is being studied for the renewable energy system, it is expected to supply energy with a proper cost with the help of the government that also leads to saving the environment.

Comparing the results between Tehran and Kerman cities with the assumption of same load profile in these cities, the results show that cost of hybrid generated power in Kerman and Tehran is 0.224 $/kWh and 0.247 $/kWh, respectively. The reason for the difference in costs is that these cities have different solar radiation and wind speeds. Final price of electrical power in Kerman is lower, regarding its geographical location.

References

[1] Francois Giraund, and Zyiad M.Salameh, "Steady state performance of a grid-connected rooftop hybrid wind, photovoltaic power system with battery storage", IEEE transactions on energy conversion, vol. 16, NO. 1, (2010)

[2] Lingfeng Wang and Chanan Singh, "PSO Based Multi-Criteria Optimum Design of A Grid- Connected Hybrid Power System With Multiple Renewable Sources of Energy", Proceedings of the 2007 IEEE Swarm Intelligence Symposium (SIS 2007).

[3] Saman, W.Y., 2013. Towards zero energy homes down under. Renewable energy, 49, pp.211-215.

[4] Sinha, S. and Chandel, S.S., 2015. Review of recent trends in optimization techniques for solar photovoltaic–wind based hybrid energy systems.Renewable and Sustainable Energy Reviews, 50, pp.755-769.

[5] Bhave, A.G., 1999. Hybrid solar–wind domestic power generating system—a case study. Renewable energy, 17(3), pp.355-358.

[6] Bakos, G.C. and Tsagas, N.F., 2003. Technoeconomic assessment of a hybrid solar/wind installation for electrical energy saving. Energy and Buildings, 35(2), pp.139-145.

[7] Sateikis, I., Lynikiene, S. and Kavolelis, B., 2006. Analysis of feasibility on heating single family houses in rural areas by using sun and wind energy.Energy and Buildings, 38(6), pp.695-700.

[8] Li, Q.Y., Chen, Q. and Zhang, X., 2013.Performance analysis of a rooftop wind solar hybrid heat pump system for buildings. Energy and Buildings, 65, pp.75-83.

[9] Masterthesis, Esmaili R, A., 2015. "Analysis and economic design of a hybrid system energy for a residential area", MS thesis, Iran University of science and Technology, October.

[10] Khare, V., Nema, S. and Baredar, P., 2013. Status of solar wind renewable energy in India. Renewable and Sustainable Energy Reviews, 27, pp.1-10.

[11] Elhadidy, M.A. and Shaahid, S.M., 2000. Parametric study of hybrid (wind+ solar+ diesel) power generating systems. Renewable Energy, 21(2), pp.129-139.
[12] Nema, S., Nema, R.K. and Agnihotri, G., 2010. MATLAB/Simulink based study of photovoltaic cells/modules/array and their experimental verification.International journal of Energy and Environment, 1(3), pp.487-500.
[13] Katooli, J., Ameri, M. and Katooli, M.H., 2015, June. The Application of a Microgrid Considering Wind Generation. In ASME 2015 9th International Conference on Energy Sustainability collocated with the ASME 2015 Power Conference, the ASME 2015 13th International Conference on Fuel Cell Science, Engineering and Technology, and the ASME 2015 Nuclear Forum (pp.V002T13A010-V002T13A010). American Society of Mechanical Engineers.
[14] Borowy, B.S. and Salameh, Z.M., 1996. Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system.IEEE transactions on energy conversion, 11(2), pp.367-375.
[15] Bekele, G. and Tadesse, G., 2012. Feasibility study of small Hydro/PV/Wind hybrid system for off-grid rural electrification in Ethiopia. Applied Energy, 97, pp.5-15.
[16] Khare, V., Nema, S. and Baredar, P., 2016. Solar–wind hybrid renewable energy system: A review. Renewable and Sustainable Energy Reviews, 58, pp.23-33.
[17] Catalog review, 2016, Jiangsu NaiEr Wind Power Technology Development Co Ltd, http://www.wxnaier.com/s9.htm, June.
[18] Siemens Solar Panels, BULLNET, UnitD, Henfield Business Park, Henfield, Sussex, BN5 9SL.URL:http://www.siemenssolar.co.uk/index.htm