International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

December 2017	Issue 33	Volume 9	Number 4	Pages 16-20

APPLICATION OF AN OFF-GRID PV SYSTEM TO MEET THE ELECTRICAL ENERGY OF A HOUSE

H. Uzmus N. Genc I. H. Dilber

Electrical and Electronics Engineering Department, Van Yuzuncu Yil University, Van, Turkey
hasanuzmus@yyu.edu.tr, nacigenc@yyu.edu.tr, ibrahimdilber@yyu.edu.tr

Abstract- In this study, an off-grid photovoltaic (PV) system has been established to produce electrical energy. This off-grid PV system has 2.25 KWp power which was designed to produce electrical energy required for a residential building located at Van Yuzuncu Yil University in Van, Turkey. The electrical energy that produced by PV panels is stored in gel batteries by means of charging regulator that controlled by maximum power point tracking (MPPT) controller. This stored dc electrical energy is converted desired AC value by DC/AC inverter. In this way, the average electrical energy of a house where a family live was obtained without polluting the environment and consuming limited energy sources. The system became a model for people who want to provide their own electrical energy from solar energy in Eastern Anatolia.

Keywords: Solar Energy, PV System, Off-Grid.

I. INTRODUCTION

In the recent times, the need for electricity is increasing in days due to the rapid growth of industry and population [1], at the same time the price of electricity is constantly increased. To satisfy the energy demands and reduce the electricity price renewable energy resources are used, and it is a suitable way to reduce environmental pollution, the using of fossil for energy and cost of transports [2], so the use of renewable energy resource to produce the electricity has increased very quickly. The renewable energy resources are eco-friendly, not very expensive and can deliver the electricity to remote areas where have not an electric grid system.

The generation of electric energy from solar energy via photovoltaic (PV) panel is widespread because it is easy and simple for implementations, clean, free, maintenance, used for both connected to grid (on-grid) and not connected to grid (off-grid) systems [3]. The PV panels have a little efficiency and they have a one-step conversion process that, convert the solar energy to electrical energy [4]. There are two types of PV systems: tracking PV system and stationary PV system. The tracking PV system follows the solar radiation and the stationary PV system doesn't follow solar radiation.

Turkey is advantageous in terms of solar energy potential compared to many other countries due to its geographical location shown in Figure 1. The average annual total sunshine duration of Turkey is 2640 hours (total 7.2 hours/day) and average total radiation intensity is 1311 kWh/m^2-year (total daily 3.6 kWh/m^2) [5].

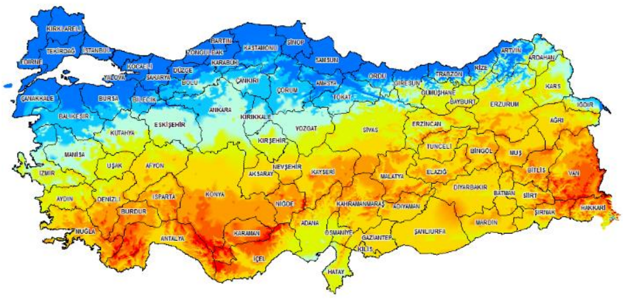


Figure 1. Solar energy potential of Turkey [6]

Eastern Anatolia Region is one of the two richest regions in terms of solar energy potential in Turkey. In terms of direct radiation, Van, located on latitude 38.566 and longitude 43.282, is one of Turkey's largest solar energy usage potentials due to its potential for land availability and solar energy, with Turkey having the highest solar energy input. The average daily global radiation and annual total global radiation value of Van is 4.48 kWh/m^2-day, 1635.81 kWh/m^2-year (4.48×365), respectively [5]. The total solar radiation for Van is given in Figure 2.

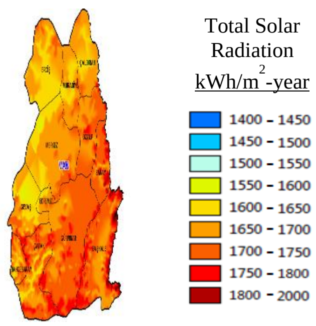


Figure 2. Total solar radiation for Van [6]

In this study, a stationary off-grid PV system was installed at 2.25 kWp power (with 9 solar panels at 250 Wp power) to produce electrical energy for residential building. The produced electrical energy is regulated thanks to charge regulator that controlled by maximum power point tracking (MPPT) controller to store in gel batteries as DC electrical energy. The DC electrical energy that stored in battery is converted AC value for being used for a house by means of DC/AC inverter. In inverters, maximum power point tracking, current control and voltage boosting are all done in one single step. MPPT is always used in both off-grid and on-grid systems. The MPPT, an electronic control system, ensures maximum power from the radiation falling on the PV panel [7].

II. PV SYSTEM

Along with the increase in the use of renewable energy sources, the use of these resources by connecting to the electricity grid used has become a priority issue. Taking into consideration the developing technology and existing applications, in the coming years, houses/institutions will come to the position of producers by producing and using their own electricity from solar energy and returning excess energy to the grid. The solar electricity production systems that convert solar energy to electric energy by PV system are the main technique that, use the renewable energy resource. There are two different PV systems that can be set up to meet energy demands according to connection of grid.

A. On-Grid PV System

The difference between on-grid and off-grid system is systems is that the battery group does not exist. The excess energy generated by the panels is not stored. It is given to the grid. When enough electric energy is not produced by the on-grid PV system, the electric energy is taken from the grid. The general structure of an on-grid system is given in Figure 3 [8].

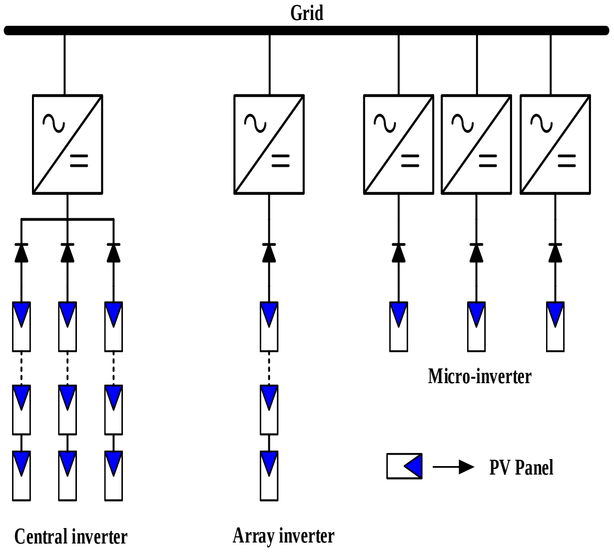


Figure 3. On-grid PV system

On-grid PV systems, which have an important place in the PV system types, are becoming increasingly popular. The inverters used in such systems are divided into a central, array and micro-inverter. Micro-inverters are divided into two main groups, one-stage and two-stage, according to power processing stages [9]. The fact that a micro-inverter has easy installation in a plug and plays manner, independent MPPT, no DC cable etc. Despite its advantages, it has a low usage area due to its high cost, low efficiency and low life [10]. For this reason, central and array inverters are often preferred for on-grid PV applications. Array inverters can be used to generate energy with higher efficiency and lower cost than central inverters [11].

B. Off-Grid PV System

Off-grid PV systems are often used to meet the energy needs of systems such as telecommunications and traffic signs and houses remote from residential areas where access to the grid is difficult [8]. Thus, the need for installation of off-grid PV systems with small and medium power ratings is inevitable. The general structure of an off-grid system is given in Figure 4.

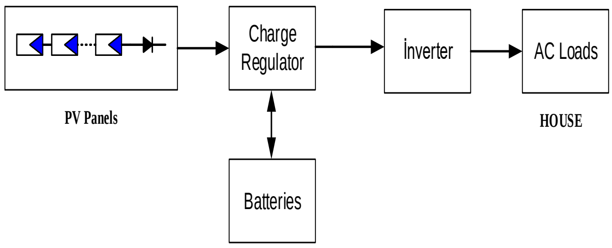


Figure 4. Off-grid PV system

III. DESIGN OF THE OFF-GRİD PV SYSTEM

The whole electrical energy that generated by PV system could not be transferred to the load. The energy loss occurs depending on the efficiency of the devices that used in the system. Therefore, the generated power must be produced considering this energy loss. The materials that required for establishing the off-grid PV system are given in Table 1.

Table 1. The system materials

Materials	
1	PV panel
2	Gel battery
3	DC/AC inverter
4	Charge regulator
5	Connecting cable
	Mounting hardware

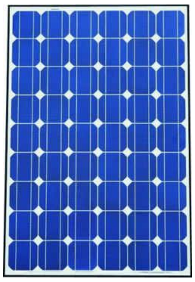
The PV panel can use solar radiation with only 18% efficiency. It converts the radiation that the PV panel can use, to electric energy with 85% efficiency and the efficiency of PV panel is calculated as given in Equation (1) (Table 2).

The efficiency of battery and inverter is 90% and 95%, respectively. The total efficiency (TE) of PV system can be calculated as given in Equation (2).

$$\text{The efficiency of PV} = 0.85 \times 0.18\ (15.3\%) \quad (1)$$

$$TE = 0.153 \times 0.9 * 0.96 = 0.1321 (13.21\%) \quad (2)$$

Table 2. PV panel parameters

	P_{max} (W)	250
	η (%)	15.3
	V_{mpp} (V)	29.8
	I_{mpp} (A)	8.39
	V_{oc} (V)	37.6
	I_{sc} (A)	8.92
	Dimensions	1650 mm / 990 mm / 40 mm
	Weight	18.5 kg

The required power that must be produced in order to provide the necessary power for the house (*HP*) is calculated in Equation (3).

$$HP = RP \times (0.1321)$$
$$RP = 17032 \text{ Wh} \quad (3)$$

The number of panels is determined by the required power (*RP*) to be produced, the duration of sunshine for Van (*T*) and the power of the panel to be used (*PP*) (Equation (3));

$$Panel = \frac{RP}{PP \times T}$$
$$Panel = \frac{17032(\text{Wh})}{250(\text{W}) \times 8.41(\text{h})} = 8.1 \quad (4)$$

In this case, as given in Equation (3) eight panels (per panel power is 250 W) are required. However, when considering the decrease in the efficiency of the PV panels over time, 8 panels are not enough for installing the system, so 9 panels that calculated by adding more 10% to Equation (4), are used.

The capacities of the batteries were calculated to meet the needs of the house when electric power was not generated from the PV panels. At the same time, the discharge factor (depth of discharge) is also taken into account. The inverter must withstand the maximum power load can be pulled.

Nine PV panels were used to produce require electric energy for a residential building located at Van Yuzuncu Yil University in Van, Turkey. The produced DC electric energy was stored in gel batter group that consists of four serial gel batteries, by means of charge regulator which controlled by MPPT controller. DC electric energy stored in the gel batteries is transmitted to the DC/AC inverter to supply the required AC electric energy for house. The AC electric energy is transferred to the house electric panel by making connections. Once these connections are made, the energy that the house needs are independently supplied from the grid. The configuration of the system is given Figure 5.

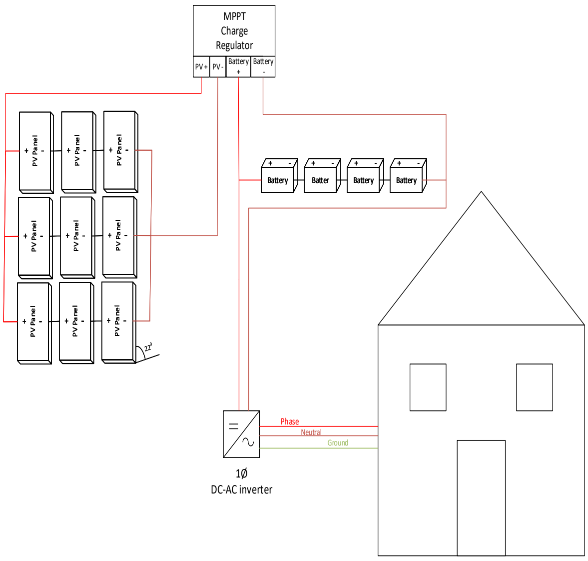


Figure 5. The configuration of the system

IV. RESULTS

Firstly, as shown in Figure 6, PV Panels are arrayed on the house roof to minimize the negative effects of shadowing.

Figure 6. The array of PV panels

Figure 7. (a) Charge regulator, (b) Inverter, (c) Batteries

The DC nonlinear electric energy that taken from PV panels is converted DC linear electric energy by means of DC-DC buck converter that controlled by MPPT controller. At the same time The DC-DC buck converter adjusts the DC linear electric energy for charging the batteries. This process is done in charging regulator (Figure 7a).

The batteries (Figure 7c) that can be implemented as a generator are used as a linear DC source for DC/AC inverter. The AC electric energy demand for house is supplied by means of DC/AC inverter (Figure 7b). This project is done for house that is not far away from the grid. The proposed off-grid system is used when the house can't take AC electric energy from grid or when it wants to use free energy. The grid and proposed off-grid system should not be used together. So there is a switch between the grid and proposed off-grid system.

The proposed off-grid system started generating power from sunrise to sunset. The radiation level of the sun is changing as given in Figure 8 and Figure 9.

These figures are taken from proposed off-grid PV system by means of monitoring program. The daily, monthly and yearly efficiency of proposed off-grid PV system can be seen by an online computer that has monitoring program.

The system produced maximum power at noon, because the radiation is maximum at noon. The shadow and clouds have negative effects on the system. The negative effects of clouds can be seen by comparing Figures 8 and 9.

The graph in Figure 8 shows the generation of electrical energy by installed proposed off-grid PV system during a sunny day in Van on August 18, 2016.

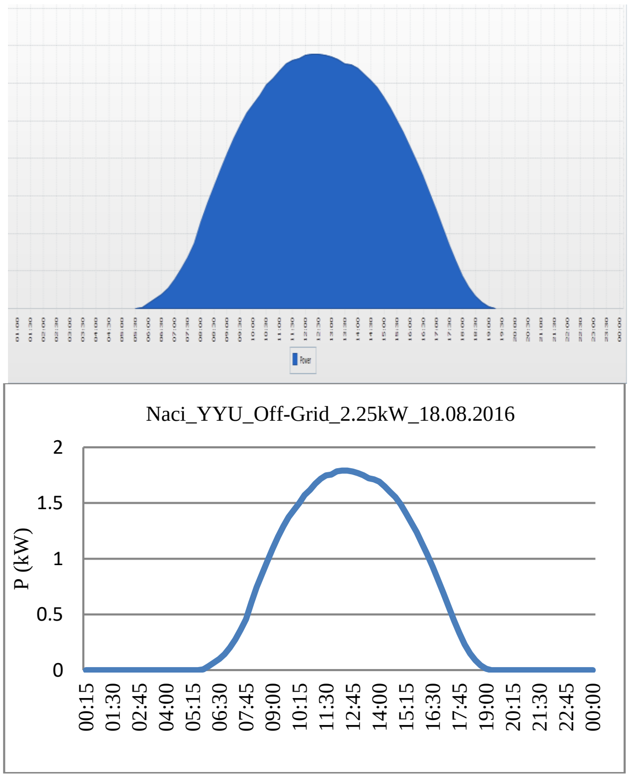


Figure 8. The generation of electrical energy during a sunny day

The graph in Figure 9 shows the generation of electrical energy by installed proposed PV system during a cloudy day in Van on August 19, 2016.

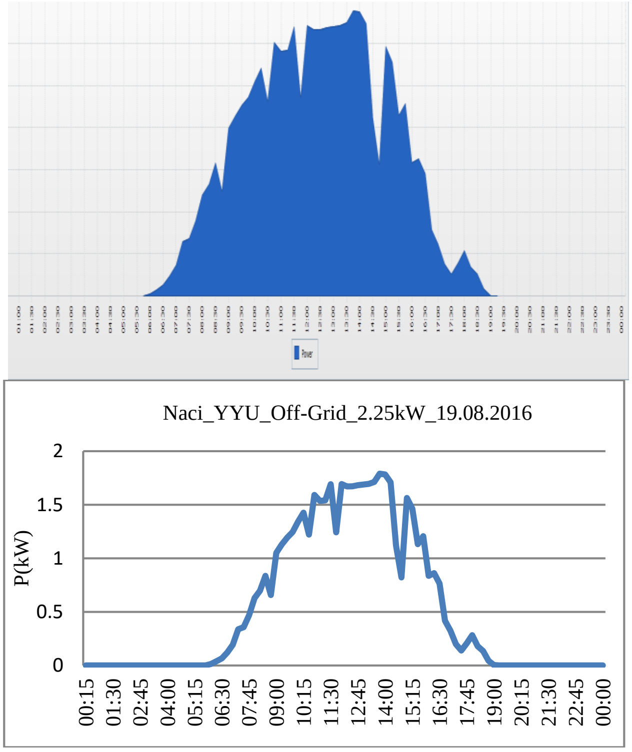


Figure 9. The generation of electrical energy during a cloudy day

V. CONCLUSIONS

This study shows that;

1) The electrical energy required for a house that is in remote area away from the grid can be achieved by an off-grid PV system.

2) The free electrical energy can be produced for a house that is near the grid by using an off-grid PV system.

3) The solar energy which has lower yield than other renewable energy sources is very attractive because it is unlimited, environmentally friendly, easily available and has suitable devices and control methods.

It is seen that the solar energy is very suitable for producing electrical energy by PV system and the required electrical energy can be obtained from solar energy via PV system. The system became a model for people who want to provide their own electrical energy from solar energy in Eastern Anatolia. The PV systems can be used as a generator by means of batteries.

ACKNOWLEDGMENT

The authors would like to acknowledge Scientific Research Fund of Van Yuzuncu Yil University (YYU-BAP) for the financial support of this research with project number of 2015-MIM-B038.

REFERENCES

[1] H. Uzmus, N. Genc, "PEM Fuel Cell Based Cascade Boost Converter", 4th European Conference on Renewable Energy Systems (ECRES 2016), pp. 418-423, 28-31 August 2016.

[2] H.A. Shayanfar, G. Derakhshan, A. Ameli, "Optimal Operation of Microgrids Using Renewable Energy Resources", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 10, Vol. 4, No. 1, pp. 97-102, March 2012.
[3] D. Pop, R. Tirnovan, L. Neamt, D. Sabou, "Study of a Photovoltaic System with MPPT Using Matlab", Carpathian Journal of Electrical Engineering, Vol. 4, No. 1, pp. 25-33, 2012.
[4] N. Genc, S.J.M. Shareef, "Design Dual Axis Sun Power Tracking System Using Arduino", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 29, Vol. 8, No. 4, pp. 34-38, December 2016.
[5] S.B. Bedeloglu (Celik), A. Demir, Y. Bozkurt, "Photovoltaic Technology: Situation in Turkey and in the World, General Application Areas and Photovoltaic Textiles", Textile Technology Electronic Journal, Vol. 4, No. 2, 2010.
[6] www.eie.gov.tr/MyCalculator/Default.aspx.
[7] www.blueskyenergyinc.com.
[8] S. Alkan, A. Ozturk, S. Zavrak, S. Tosun, E. Avci, "Establishment of Photovoltaic System to Meet the Need of a Home Electricity", Symposium on Electrical-Electronic-Computer and Biomedical Engineering (ELECO 2014), Bursa, Turkey, 27-29 November 2014.
[9] Y. Xue, L. Chang, S.B. Kjaer, J. Bordonau, T. Shimizu, "Topologies of Single-Phase Inverters for Small Distributed Power Generators: An Overview", IEEE Trans. on Power Electronics, Vol. 19, No. 5, pp. 1305-1314, September 2004.
[10] S.B. Kjaer, J.K. Pedersen, F. Blaabjerg, "A Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules", IEEE Trans. on Industry Applications, Vol. 41, No. 5, pp. 1292-1306, September 2005.
[11] C. Meza, D. Biel, J. Martinez, F. Guinjoan, "Boost-Buck Inverter Variable Structure Control for Grid-Connected Photovoltaic Systems", Symposium IEEE ISCAS 2005, Vol. 2, pp. 657-662, June 2005.

BIOGRAPHIES

Hasan Uzmus received his B.Sc., and M.Sc. from Karaelmas University (Zonguldak, Turkey) and Yuzuncu Yil University (Van, Turkey) in 2011 and 2016, respectively. He is a Research Assistance in Electrical and Electronics Engineering Department of Van Yuzuncu Yil University. His interests include renewable energy, power electronics and electrical machines.

Naci Genc received the B.Sc., M.Sc., and Ph.D. degrees from Gazi University (Ankara, Turkey), Van Yuzuncu Yil University (Van, Turkey) and Gazi University in 1999, 2002, and 2010, respectively. He is an Associate Professor in the Electrical and Electronics Engineering Department, Van Yuzuncu Yil University. His interests include energy conversion systems, power electronics and electrical machines.

Ibrahim Halil Dilber is a researcher at Electrical and Electronics Engineering Department, Van Yuzuncu Yil University, Van, Turkey. His research interests include renewable energy, power electronics and electrical machines