Analyses of Solar Energy Power Generation Depending on Meteorological Conditions for Istanbul

ŞAFAK SAĞLAM
Technical Education Faculty, Department of Electrical Education
Marmara University
Göztepe Kampüsü, Kadıköy 34722 İstanbul
TURKEY
ssaglam@marmara.edu.tr

Abstract: - In this study, permanent resistive load directly fed from photovoltaic panel which produce DC electrical energy. Experiments were done during 20 month period from 2008 to 2010. Permanent resistive load currents and voltages measured with power analyzer continuously 24 hours a day. At the same time meteorological parameters like outdoor temperature, air pressure, humidity, wind speed and solar radiation etc. measured and recorded with digital weather station. These measurement results compared with the graphics at the same time bases. Photovoltaic panel output power calculated with current and voltage measurements. A mathematical equation found with curve fitting method from power graphics to examine dependencies for meteorological parameters. Thus correlation between photovoltaic performance and meteorological conditions is examined for Istanbul-Goztepe.

Key-Words: - Meteorological Conditions, Photovoltaic System, D.C. Loads, Energy Consumption, Curve fitting.

1 Introduction

The photovoltaic (PV) effect is the electrical potential developed between two dissimilar materials when their common junction is illuminated with radiation of photons. The PV cell, thus, converts lights directly into electricity. A French physicist, Becquerel, discovered the PV effect in 1839. It was limited to the laboratory until 1954, when Bell Laboratories produced the first silicon cell. It soon found application in U.S. space programs for its high power-generating capacity per unit weight. Since then, it has been extensively used to convert sunlight into electricity for earth-orbiting satellites. Having matured in space applications PV technology is now spreading into terrestrial applications ranging from powering remote sites to feeding utility grids around the world [1].

The main applications of photovoltaic (PV) systems are in either stand-alone (water pumping, domestic a street lighting, electric vehicles, military and space applications) or grid connected configurations (hybrid systems, power plants).

PV generation systems have two major problems: the conversion efficiency of electric power generation is very low (9-17%) especially under low irradiation conditions, and the amount of electric power generated by solar array changes continuously with weather conditions [2].

The PV systems are, by nature, non-linear power sources that need accurate estimation of the maximum power generation and following the efficient operation among various distributed power sources. For the operation planning of power systems including PV systems, the accurate prediction of the maximum power from the PV systems is inevitable. The maximum power generation depends on the environmental factors, mainly the irradiation and the cell temperature. The measurement of the temperature is easy compared with that of the cell temperature.

In addition, the wind velocity is also easy to get. Therefore, the environmental factors such as the irradiation, the temperature, and the wind velocity are utilized for the prediction of the maximum power in the studies [3].

Efficiency is an important matter in the photovoltaic (PV) conversion of solar energy because the sun is a source of power whose density is not very low, so it gives some expectations on the feasibility of its generalized cost-effective use in electric power production. However, this density is not so high as to render this task easy. After a quarter of a century of attempting it, cost still does not allow a generalized use of this conversion technology.

Efficiency forecasts have been carried out from the very beginning of PV conversion to guide the research activity. In solar cells the efficiency is strongly related to the generation of electron–hole pairs caused by the light, and their recombination before being delivered to the external circuit at a certain voltage. This recombination is due to a large variety of mechanisms and cannot be easily linked to the material used to make the cell [4].

1.1 Characteristic and Efficiency of PV Cell

The instantaneous electric energy generated by a PV cell depends on several cell parameters and on variable environment conditions such as insulation and temperature. Its electric behavior may be simply modeled by a nonlinear current source connected in series with the intrinsic cell series resistance (R_s). In this model the current source can be represented by the following implicit expression.

$$i_{pv} = I_{ph} - I_{rs}(e^{q(v_{pv}+i_{pv}R_s)/AKT} - 1) \qquad (1)$$

where I_{ph} is the generated current under a given insolation, I_{rs} is the cell reverse saturation current, i_{pv} and v_{pv} are, respectively the output current and voltage of the solar cell, q is the charge of an electron, K is Boltzmann's constant and T is the cell temperature. The factor A considers the cell deviation from ideal p-n junction characteristics, varying between 1 and 5. Besides, the reverse saturation current (I_{rs}) and the photocurrent (I_{ph}) depend on insolation and temperature according to the following expressions:

$$I_{rs} = I_{or}\left(\frac{T}{T_r}\right)^3 e^{qE_{go}(1/T_r - 1/T)/KT} \qquad (2)$$

$$I_{ph} = (I_{SC} + K_1(T - T_r))\lambda/100 \qquad (3)$$

Where I_{or} is the reverse saturation current at the reference temperature T_r, E_{go} is the band-gap energy of the semiconductor used in the cell, I_{SC} is the short circuit cell current at the reference temperature and insolation, K_1 is the short circuit current temperature coefficient and λ is the insolation in mW/cm^2.

In Fig. 1 the corresponding electric power generated by the cell is depicted, and the dependency of the maximum power operation point (MPOP) on the atmosphere conditions can be observed [5].

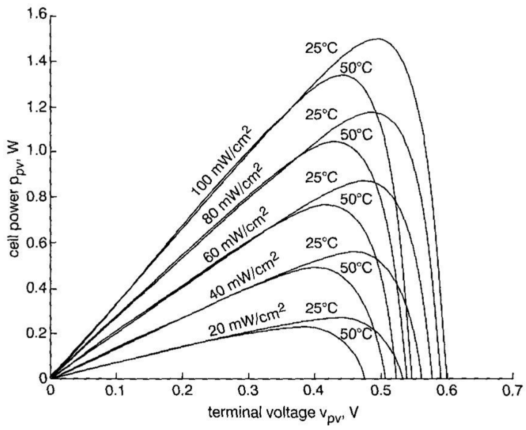

Fig. 1 Typical power-voltage curves of PV cell

The design and the operation of an efficient solar cell have two basic goals:

1. Minimization of recombination rates throughout the device.
2. Maximization of the absorption of photons.

It is evident that, despite the apparent complexity of the expressions describing the operation of solar cells, the basic operating principles are easy to understand. Electron–hole pairs are created inside the solar cell as a result of absorption of the photons incident on the solar cell from the sun. The objective is to collect the minority carriers before they are lost to recombination [6].

1.2 Irradiance Forecast Methods for Photovoltaic's

There are many different methods used to forecast irradiance values for photovoltaic panels to predict power generation. For very short-term forecast these steps should be followed with using weather data.

a) Spatial Averaging and Temporal Interpolation: Different spatial interpolation techniques have been investigated to optimize the forecast for a given site. The use of the arithmetic average of surrounding pixels is proposed, as the use of distance dependent weights does not improve the results. An analysis of the forecast accuracy in dependence on the number of grid points used for averaging revealed that with average values of 4x4 grid points best results are achieved.

b) Improved Clear Sky Forecasts:
The quality of the irradiance forecast for correctly predicted clear sky situations is strongly dependent on the atmospheric input to the model. The ECMWF model considers aerosols using a worldwide climatology of the annual cycle of different aerosol types.

c) Post Processing with Ground Data:
In a last step to derive an optimized forecast of hourly values of the global irradiance, it is investigate the application of a post processing

procedure to correct for systematic deviations. For that purpose, results analyzed the forecast in dependence on the cloud situation and the solar zenith angle [7].

2 System Description

In this study, resistive load is directly fed by PV panel. PV is polycrystalline panel which characteristic's is described in Table 1.

Table 1 Polycrystalline PV Characteristic

Voc	20.8 V
Isc	3.3 A
Vp	17.0 V
Ip	3.0 A
Pp	51 W

Rating at $1000 W/m^2$ irradiance, temperature $25°C$
(Direct Current Values)

In experiment system current and voltage values measured with power analyzer. Power analyzer is connected PC via RS232 serial port. All measurements are recorded at PC with software. Against the power outage PC and power analyzer fed by UPS. For this purpose experiment set was setup as shown in Fig. 2.

Atmospheric Weather parameters measurements recorded with electronic weather station which is installed at the roof of the building. These parameters and PV output current, voltage and power values are merged in database file. These database files examined and several graphics plotted to understand correlation between these values for different weather conditions. Solar irradiance is depending meteorological conditions so PV output current and voltage is strictly related with it.

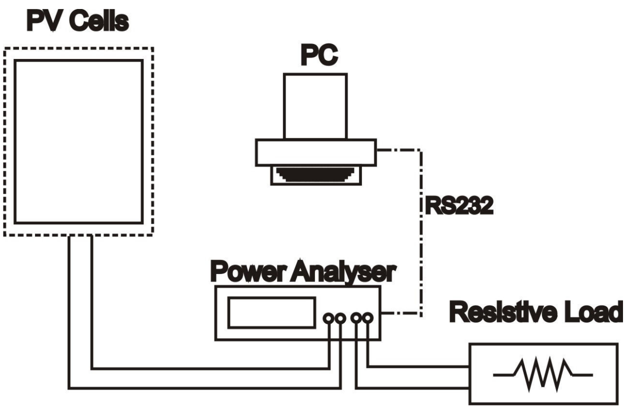

Fig. 2 Experimental setup for measurements

Resistive load is set of 18 parallel connected resistors. Each resistor 100Ω and 5W wire wound resistor. Ohmmeter measurements show that set resistance value is 5.5Ω including with contact resistance. Wire wound resistor used at load because long period load current exist in circuit which fed from PV [8].

3 Experimental Results

Experiments were done in Istanbul, Goztepe from 4 July 2008 to 12 March 2010. During twenty months period load voltage (V) and load current (A) measured with 2 minutes intervals. Weather station recorded parameters like outdoor temperature, air pressure, humidity, wind speed and solar radiation etc. with 5 minutes intervals and these measurements were recorded during the day (24 hour)[9],[10].

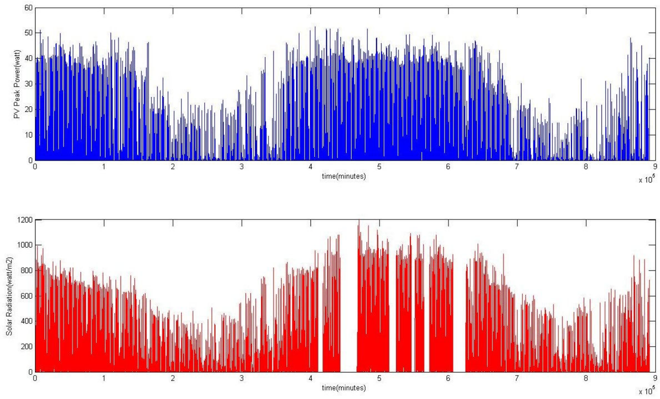

Fig. 3 Comparison of PV peak output power with solar radiance

In Fig. 3 comparison of PV peak output power with solar radiation is shown. Solar radiance directly effects PV system output power. But this direct effect is slightly changed especially in December, January, February and March. Because the cloud cover is so thick to effect direct solar radiation on pv cells surfaces.

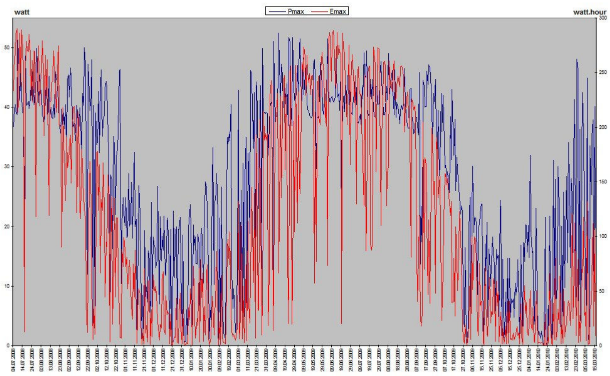

Fig. 4 Comparison of PV peak output power with produced electrical energy

PV Cells converted direct solar radiation to electrical energy depending on several environmental effects. Fig. 4 shows that differences between PV peak output and produced electrical energy for seasonal weather conditions.

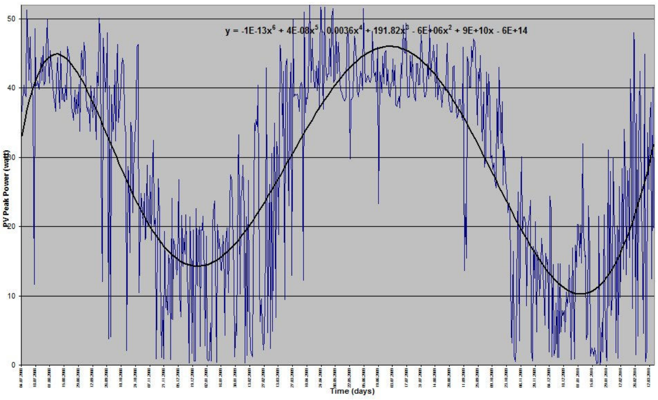

Fig. 5 Curve fitting graphic of PV peak power

Experimental results are recorded approximately 20 months period that begins on 4 July 2008 and ends on 12 March 2010. On Fig. 5 shows PV peak power and curve fittings graphic. The curve fitting results 6th order equation.

4 Conclusions

In this study electrical energy which is produced with stand alone PV performance is measured experimentally for Istanbul. Stand alone PV system is loaded with resistive load and output power is observed continuously.

Experiment results have recorded during the 20 months periods covers the different seasonal weather and atmospheric conditions. According to experiment results Climate effects on PV system putt forward briefly. PV peak electrical energy production is reached which is highest value in August and lowest value in February. Seasonal climate chancing is effected PV efficiency approximately % 50 percent.

Besides that PV efficiency is decreasing because of humidity, corrosion and equipment breakdown with time. For advanced studies to determining PV performance change depending on time, system will be followed and efficiency will be compared for same periods in several years.

References

[1] P.R. Mukund, Photovoltaic power systems. In: Wind and Solar Power Systems Design, Analysis and Operation. Taylor & Francis, (Chapter 9) 2006, pp. 163

[2] R. Faranda, S. Leva, Energy comparison of MPPT techniques for PV Systems, *WSEAS Transactions On Power Systems*, Vol.3, No.6 2008, pp. 446-455.

[3] T. Hiyama, K. Kitabayashi, Neural Network Based Estimation of Maximum Power Generation from PV Module Using Environmental Information, IEEE Transactions on Energy Conversion, Vol. 12, No. 3, 1997, pp. 241-247

[4] A. Luque, S. Hegedus, Handbook of Photovoltaic Science and Engineering, John Wiley & Sons Ltd, Great Britain, 2003.

[5] F. Valenciaga, P.F. Puleston, P.E. Battaiotto, Power Control of a Photovoltaic Array in a Hybrid Electric Generation System using sliding Mode Techniques, IEE Proc.-Control Theory Appl., Vol 148, No 6, 2001, pp. 448-455.

[6] N. Ekren, N. Onat, S. Saglam, Household Type Load's Effects on Photovoltaic Systems, WSEAS Transactions on Circuits and Systems, Issue 12, Vol. 7, December 2008, pp. 1020-1028.

[7] E. Lorenz, J. Hurka, D. Heinemann, Irradiance Forecasting for the Power Prediction of Grid-Connected Photovoltaic Systems, IEEE Journal of Selected Topics in Applied Observations and Remote Sensing, Vol. 2, No. 1, March 2009, pp. 2-10.

[8] Ş. Sağlam, G. Koçyiğit, N. Onat, Production Techniques of PV's and Polycrystalline PV Performance Analyses for Permanent Resistive Load, WSEAS Transactions on Circuits and Systems, Issue 7, Vol. 8, July 2009, pp. 589-598

[9] G. Cook, L. Billman, R. Adcock, Photovoltaic Fundemantels, DOE/Solar Energy Research Institute Report No. DE91015001, February 1995.

[10] Statistical data of Turkish State Meteorological Service, 2006.