Performance Analyses of PV Panel for Istanbul

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Abstract: - Renewable energy sources such as photovoltaic energy are considered promising in order to meet the continuously increasing demand for energy in the world. These sources have very attractive features. Clean and renewable energy production is getting more attractive due to global warming, environmental factors and decrease in conventional energy sources. Photovoltaic cells will be a good alternative against the conventional energy sources in the near future, with their decreasing costs and increasing efficiencies. Besides these benefits of photovoltaic systems they need to effective design before installing systems. In this study stand alone PV performance is tested experimentally for Istanbul-Goztepe.

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

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 in to 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).

Unfortunately, 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].

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

ISSN: 1790-5095

ISBN: 978-960-474-093-2

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 [3].

Basic structure of photovoltaic cell is shown in Fig. 1.

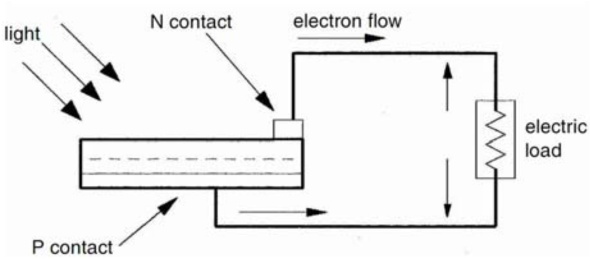

Fig. 1 Basic structure of photovoltaic cell

PV power technology uses semiconductor cells (wafers), generally several square centimeters in size. From the solid-state physics point of view, the cell is basically a large-area p-n diode with the junction positioned close to the top surface. Numerous cells are assembled in a module to generate the required power [1].

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.

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

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:

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

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

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.

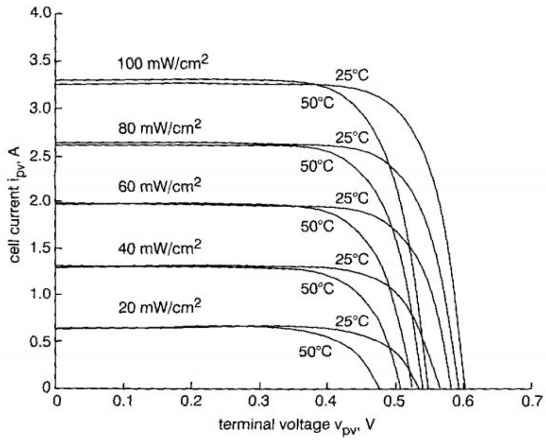

Fig. 2 Typical current-voltage curves of PV cell

In Fig. 2, the electric characteristics for a particular PV cell are presented using insolation as a variable parameter and considering two different values of temperature. In Fig. 3 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 [4].

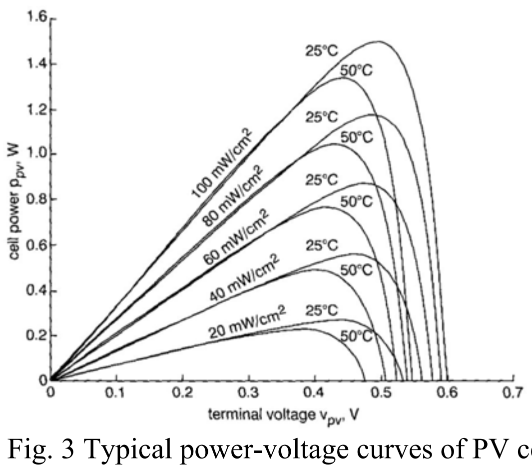

Fig. 3 Typical power-voltage curves of PV cell

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 [5].

2 Array Design Factors

Researches show that, there are several major factors influencing the electrical design of the solar array for the photovoltaic energy systems.

- Sun Intensity
- Sun Angle
- Shadow Effect
- Temperature Effects
- Effect of Climate
- Electrical Load Matching
- Sun Tracking
- Peak Power Operation

When designing a PV system, some factors discussed are considered at different points in the design process. Solar intensity depends upon the site location – its prevalent weather, pollution, latitude, and percent shade. Operating temperature depends on the site location as well, but a cooling system using chill water piping will mitigate the effects of heat on cell efficiency. Finally, the mechanical and electrical controllers affect the sites operating performance. The mechanical controller tracks sun position and cants the PV cells to minimize the sun's incident angle, and the electrical controller loads the cell appropriately to maximize its efficiency [1], [6].

3 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 $1000W/m^2$ 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. 4.

Solar irradiance measurements recorded with electronic weather station which is installed at the roof of the building. Solar irradiance values 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.

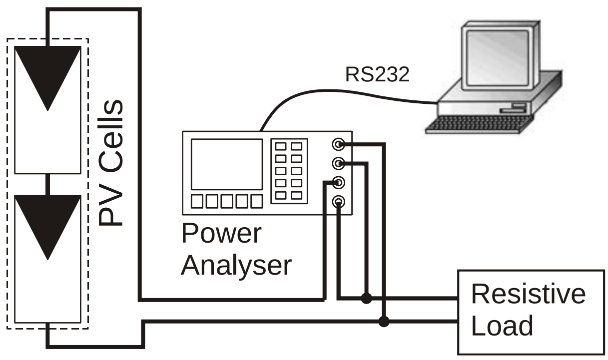

Fig. 4 Experimental setup for measurements

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.

Fig. 5 Experiment system with resistive load

4 Experimental Results

Experiments were done in Istanbul, Goztepe from 4 July 2008 to 30 April 2009. During ten months period load voltage (V) and load current (A) measured with 2 minutes intervals. Weather station recorded solar radiance $\left(W/m^2\right)$ with 5 minutes intervals and these measurements were recorded during the day (24 hour).

Table 2 Measured and calculated values for PV

Months	Measured Radiance (W/m^2)	PV Out (Watt)	PV Area (m^2)	PV Out (W/m^2)	Efficiency
July	253.03303	10.34518	0.37310	27.72764	0.10958
August	218.28495	9.02500	0.37310	24.18921	0.11081
September	150.61792	5.49604	0.37310	14.73074	0.09780
October	110.98421	4.01652	0.37310	10.76527	0.09700
November	67.80347	1.69021	0.37310	4.53018	0.06681
December	45.68011	1.01086	0.37310	2.70934	0.05931
January	52.92944	1.13550	0.37310	3.04342	0.05750
February	68.30342	1.29547	0.37310	3.47217	0.05083
March	123.92272	3.65261	0.37310	9.78989	0.07900
April	200.07321	6.89843	0.37310	18.48948	0.09241

Experiment results are summarized at Table 2. In first two columns monthly average solar radiance $\left(W/m^2\right)$ and PV out power (W) are given. Third Column PV surface area $\left(m^2\right)$ (0.41×0.91) and fourth column PV output power which is calculated with $PV_{out}(W)\big/PV_{area}\left(m^2\right)$ are shown. Photovoltaic efficiency is found with $PV_{out}\left(W/m^2\right)\big/Radiance\left(W/m^2\right)$ formula.

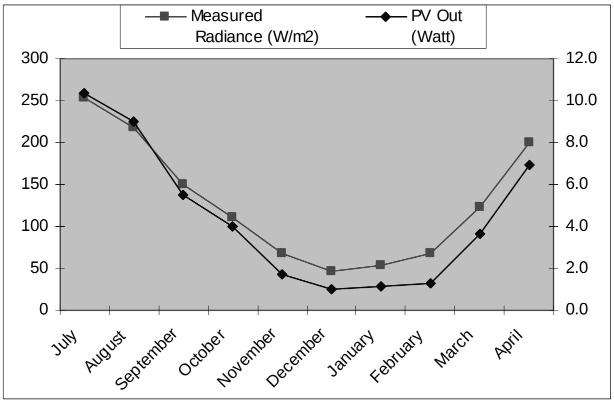

Fig. 6 Comparison of measured radiance and PV output power

In Fig. 6 comparison between PV out power and measured solar radiance is shown. Solar radiance directly effects PV system output power. But this direct effect is slightly changed especially in December, January, February and March. PV efficiency curve is declined (Fig. 7) these months which is drowned data's from Table 2.

Table 3 Solar radiance and sun hours' comparison

Months	Measured Radiance (W/m^2)	Min. Peak Sun Hours (h/day)
July	253.03	10.4
August	218.28	9.4
September	150.61	8.0
October	110.98	5.2
November	67.80	3.3
December	45.68	2.2
January	52.92	2.4
February	68.30	3.1
March	123.92	4.6
April	200.07	6.0

Minimum solar peak hour's data are taken from Turkish State Meteorological Service for Istanbul-Goztepe and measured radiance values are shown in Table 3 [7]. PV efficiency is affected negative from decreasing of Minimum solar peak hour's and solar radiance.

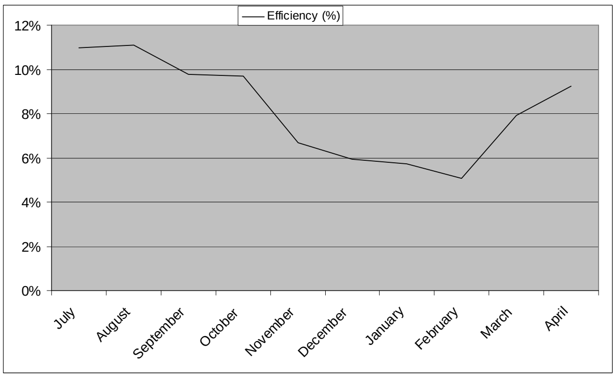

Fig. 7 Monthly efficiency graphic

5 Conclusions

In this study stand alone PV performance is tested experimentally for Istanbul. Stand alone PV system is loaded with resistive load and output power is observed continuously.

Experiment results have recorded during the 10 months period from July 2008 to May 2009. According to experiment results Climate effects on PV system putt forward briefly. PV efficiency is reached %11 which is highest value in August and lowest value is %5.08 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.

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