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DETERMINATION OF THE EFFECT OF TEMPERATURE CHANGES ON POWER OUTPUT OF SOLAR PANEL

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ABSTRACT

It is importance to state that the main limit of photovoltaic power output systems is low conversion efficiency of photovoltaic panels, which is strongly influenced by their operating temperature. Negligence in considering the photovoltaic panel temperature increases the financial risk of system installation. This present study investigates the effects of operating temperature on solar panel power output at Enugu State Nigeria. Experimental approach was adopted in the implementation of the work. Solar panel was positioned outside the Department of Electrical/Electronic Engineering workshop where it will not experience any obstacle from solar radiation intensity. The changes in power output of the solar panel with respect to temperature was measured and recorded. The results show that the power output of the solar panel varies as temperature changes.

KEYWORDS: Photovoltaic, temperature, renewable, Sunlight, Depletion-region

1. INTRODUCTION

It is very common in the recent days that people are now seeking for renewable energy in order to replace the current fossil fuels. This is due to the extinction of fossil fuel in the beneath surface of the earth and people cannot depend on it forever. One of the most potential renewable energy found is solar energy (Henry S, 2014). Solar energy is the radiant heat and light from the sun that has been used by humans since ancient times using a wide range of technologies. One of the wide applications of solar energy is photovoltaic (PV). PV is the field of technology and research related to the application of solar cells for energy by converting sunlight directly into electricity by the photovoltaic effect. Solar panels or photovoltaic arrays and solar modules are made by assembling of solar cells. Increasing efforts are directed towards reducing the installation costs and enhancing the performance of photovoltaic systems so that the system can be deployed at a large scale. However, PV solar cells are semiconductor devices which directly convert energy into electricity (Pradhan. A, 2013). Solar cells operate as a quantum device exchanging photons for electrons. Photons from the sun with sufficient energy near the depletion region of a p-n junction produce electron-hole pairs. If these electrons have enough energy, they will move to the conduction band, leaving holes in the valence band. The potential difference across the depletion region provides an electric field that pulls the electron to the n-region and hole to the p-region (Hart .G and Raghuuraman P, 2010) . The newly free electron can then flow from the n-region to the p-region and recombines with the newly created holes. In this way the energy of the incident photon is converted. The PV solar cells output performance varies with atmospheric factors. Since sunlight is intermittent, solar cells cannot produce energy at a constant rate and the power delivered at a certain instant is still very much a function of climatological factors (Abhishek.k.T and Aruna, 2017).

1.2 HOW SOLAR CELL WORK

When light shines on solar panel it generated electron-hole pairs across the whole device. If the device is open circuited, the electron hole pairs generated near the depletion region tend to recombine with the charge in the depletion region, thus reducing the depletion region charge and eventually reducing the depletion region. The reduction in depletion region is equivalent of applying a forward bias to the device i.e. this reduction in depletion region tends to develop a potential across the open terminals of the device. The maximum voltage that can be developed is the maximum forward drop across the device which theoretically is possible with the complete elimination of the depletion region (Green. A and Martin, 1982). This maximum voltage that can be developed across the open circuited device is called the open circuit voltage. If the device is short circuited, the generated holes and electrons produce a current corresponding to the incoming photons. This current is called the short circuit current Solar panels work best in certain weather conditions, but since the weather is always changing and as engineers are installing solar panels all over the world in different climate regions, most panels do not operating under ideal conditions. That is why it is important for engineers to understand how panels react to different weather conditions. With this knowledge, they can design ways to improve the efficiency of solar panels that operate in non-optimal conditions. In some cases, they can design cooling systems to keep the panels within certain temperatures. For example, solar power plants in extremely hot climates may pass a cool liquid behind the panels to pull away heat and keep the panels cool.

1.3 MODELING OF SOLAR CELL

To understand the electronic behavior of a solar cell, it is useful to create a model which is electrically equivalent whose behavior is well defined. A solar cell was modelled by a current source in parallel with a diode. In practice no solar panel is ideal, so a shunt resistance and a series resistance component are added to the model *Krauter. S, 2004.* The circuit model of a solar cell is drawn in Figure 1(a)

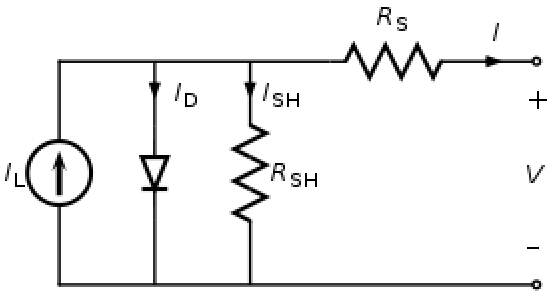

Figure 1(a): Solar cell model

From the circuit model in Figure 1(a), it is evident that the current produced by the solar cell is equal to that produced by the current source, minus that which flows through the diode, minus that which flows through the shunt resistor such that:

$$I = I_L - I_D - I_{SH} \qquad (1)$$

Where

I = output current of a solar panel (ampere)

I_L = photogenerated current (ampere)

I_D = diode current (ampere)

I_{SH} = shunt current (ampere).

The current through the circuit is governed by the voltage across them:

$$V_J = V + IRs \qquad (2)$$

Where

V_j = voltage across both diode and resistor

R_{SH} (volt)

V = voltage across the output terminals

(volt)

I = output current (ampere)

R_S = series resistance (Ω).

From the Shockley diode equation, the current diverted through the diode *Ike.C.U, (2013) is*

$$I_D = I_O\left\{\exp\left[\frac{V_j}{nV_T}\right]-1\right\} \quad (3)$$

where

I_0 = reverse saturation current (ampere)

n = diode ideality factor (1 for an ideal diode)

V_T = KT/q: the thermal voltage. At 25 °C,

From Ohm's law, the current diverted through the shunt resistor is:

$$I_{SH} = \frac{V_j}{R_{SH}} \quad (4)$$

Substituting equations (2), (3) and (4) into equation (1) produces the characteristic model equation of a solar cell, which relates solar cell parameters to the output current and voltage.

$$I = I_L - I_O\left\{\exp\left[\frac{V+IRs}{nV_T}\right]-1\right\} - \frac{V+IRs}{R_{SH}} \quad (5)$$

1.4 OPEN-CIRCUIT VOLTAGE AND SHORT-CIRCUIT CURRENT

When solar cell is operated at open circuit, I = 0 and the voltage across the output terminals is defined as the open-circuit voltage. Assuming the shunt resistance is high enough to neglect the final term of the characteristic equation, the open-circuit voltage V_{OC} is:

$$V_{oc} = \frac{nKT}{q}\ln\left(\frac{I_L}{I_O}+1\right) \quad (6)$$

Where,

q = charges

k = Boltzmann's constant

T = absolute temperature

Similarly, when solar panel is operated at short circuit, V = 0 and the current I through the terminals is defined as the short-circuit current (Jafari V.F, 2011). It can be shown that for a high-quality solar panel(low R_S and I_0, and high R_{SH}) the short-circuit current I_{SC} is:

$$I_{SC} = I_L \quad (7)$$

It is not possible to extract any power from solar cell when operating at either open circuit or short circuit conditions.

1.5 TYPES OF PHOTOVOLTAIC SOLAR CELLS

The main types of solar cells in use today are crystalline silicon, both single and multi-crystalline, and they are known as thin film solar cells, which include amorphous silicon, cadmium telluride, copper indium gallium diselenide **(CIGS),** and copper indium diselenide **(CIS)** Mahfoud .A etal (2015). Organic photovoltaic cells and dye-sensitized cells have been discovered. It is the connection of two or more cells either in series or parallel makes photovoltaic panel.

1.6 MATERIALS AND METHODS

Experimental method was used to generate the result of these practical results in table 1. Three flat plate photovoltaic solar modules of the same material were used for the study. Each solar module containing seventy two amorphous silicon solar cells, rated 30W peak, 21V, model G100, ARCO. SOLAR INC, active area of $30cm^2$ and manufactured by BP solar system LTD. A 6.1kΩ variable resistor was used as a load in the study. A low resistance ammeter, high resistance voltmeter, and five in one Auto Raging Digital Multi-meter (serial number M58209) were used for monitoring and measuring the output current, voltage and ambient temperature, respectively. The product of voltage and current was done to obtain power.

1.7 EXPERIMENTAL SET-UP

The photovoltaic panel includes three flat amorphous silicon solar modules connected in parallel configuration. They were mounted horizontally on a metal plate frame, which was raised above the roof-top using an iron steel pole at the back of the Department of Electrical and Electronic Engineering workshop at Enugu State University of Science and Technology. The photovoltaic solar electricity array was capable of operating in the range of 80W – 100W, 12V – 20V. To the PV solar array, a low resistance voltmeter was connected in series while a high resistance voltmeter was connected in parallel to the 6.1kΩ variable resistor using as a load. Figure 1 shows the circuit model of experimental set-up. Thermometer was used to measure temperature of the photovoltaic panel.

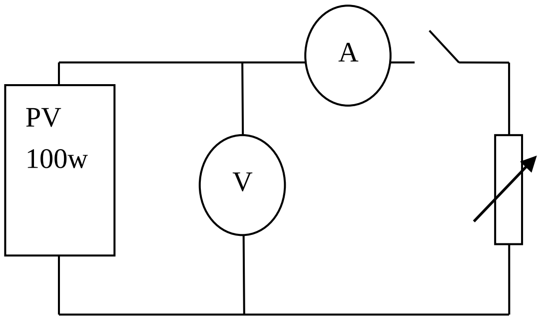

Figure 1: Shows the circuit model of Experimental set-up

Table1: The average monthly values of Temp. And power output of a solar panel for year 2014

MONTHS	Temp. (^{O}C)	PV Power Output(W)
January	34.20	70.20
February	33.10	68.60
March	35.00	72.10
April	32.40	68.20
May	30.10	67.40
June	29.20	67.20
July	28.00	66.80
Aug	28.60	67.00
September	29.00	67.60
October	30.10	68.00
November	32.00	67.80
December	33.20	68.40

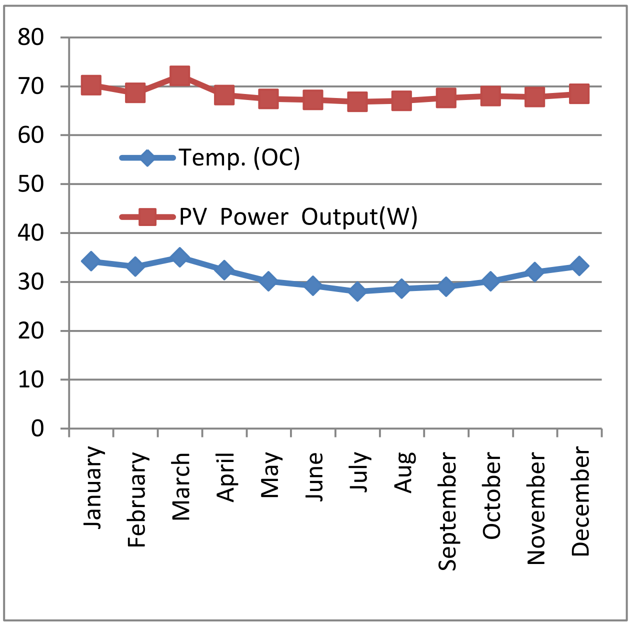

Figure 2: Shows the graph of temp. Vs power output of a solar panel for year 2014

Table2: The average monthly values of Temp. And power output of a solar panel for year 2015

MONTHS	Temp.(^{o}C)	PV Power Output(W)
January	34.30	70.00
February	33.60	69.40
March	34.60	71.10
April	33.10	68.30
May	32.00	67.8
June	30.20	67.20
July	29.40	67.00
Aug	29.60	67.20
September	29.00	67.40
October	31.20	68.60
November	33.30	69.00
December	33.60	69.80

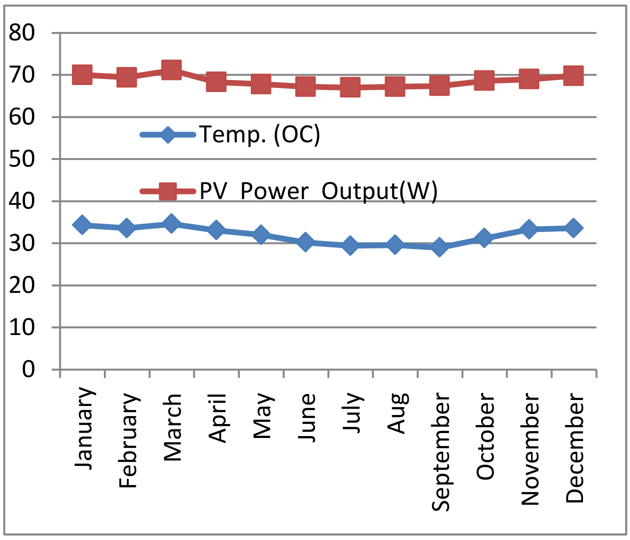

Figure3: Shows the graph of temp. Vs power output of a solar panel for year 2015

Table3: The average monthly values of Temp. And power output of a solar Panel for year 2016

MONTHS	Temp. (^{o}C)	PV Power Output(W)
January	36.00	73.00
February	34.20	72.20
March	35.10	72.00
April	33.00	71.00
May	30.80	70.40
June	30.60	70.40
July	29.60	69.80
Aug	28.40	68.00
September	29.80	68.40
October	30.00	70.10
November	31.10	70.20
December	32.30	71.40

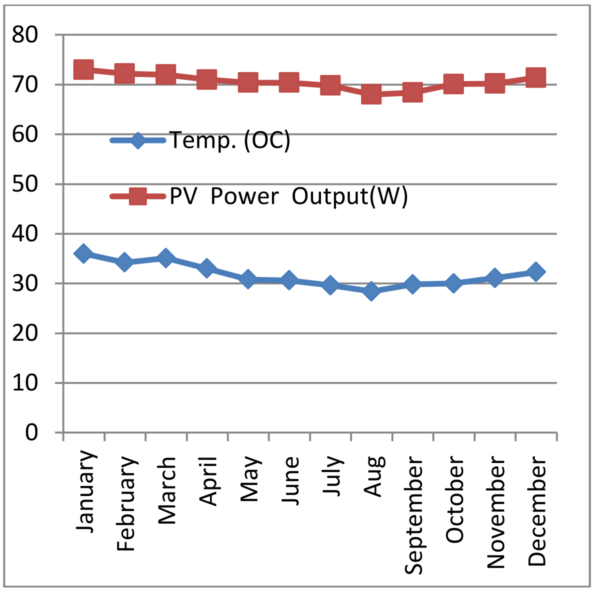

Figure 4: Shows the graph of temp. Vs power output of a solar panel for year 2016

RESULTS ANALYSIS

The results obtained from the experiment were presented in both tabular and graphical forms in other to bring out the detailed results. From Table 1, the monthly values of average Temperature and power output of a solar panel obtained in the year 2014 was presented. In Figure 2, the graph of table 1 was presented. It was observed that the power output of solar panel varies with temperature changes. Again in the year 2014, it was observed that the highest power output of a solar panel recorded was on match and the value was 72.10W at a temperature of 35^{o}C. Table 2 shows the average monthly values of data obtained in the year 2015. Figure 3 was the graphical representation of table 2. From the results, it was observed that the highest values of power outputs obtained in the year 2015 were in the months of November, December, January, February and March. The maximum values of power output in these months of the year were attributed to the high solar radiation intensity received, a period when the atmosphere is relatively clean and clear, as a result of little or no cloud, dust free and low humidity. Table 3 shows the average monthly values of temperature and power output of a solar panel in the year 2016 while figure 4 shows the graph of table 3. From the results, it is observed that, the power output of a solar panel changes with temperature.

CONCLUSION

Based on the results obtained, it is clearly shown that Temperature has great effect on the power output of a Solar panel. So it is advisable that when installing Solar panel on a roof, a space of few inches should be provided to allow air flow to cool the panel. Again the manufacture of solar panel should produce it with light cooled material to reduce heat absorption.

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