Effects of Ambient Temperature on the Performance of a Photovoltaic Solar System in a Tropical Area.

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ABSTRACT

The effect of ambient temperature on the performance of an amorphous silicon photovoltaic system (ASPS) was studied in a tropical area, Ogbomoso, Nigeria. This research was carried out by monitoring the variation in power output of the system with ambient temperature of the area for three years, 2006, 2007, and 2008. From the results, there is direct proportionality between the power output performance of the system and the ambient temperature. This was confirmed from the values of the correlation coefficient, R, when the power output of the system was correlated with the ambient temperature; they are 88%, 86%, and 89% for 2006, 2007, and 2008, respectively. The results also indicate that the ambient temperature must be taken into account when designing and predicting the performance of the ASPS in the area of the study.

(Keywords: photovoltaic, performance, temperature, modules, power, solar cells)

INTRODUCTION

The environmental degradation generated by the use of fossil fuels includes serious environmental problems such as acid rain, the greenhouse effect and ozone layer depletion, which in many cases are irreversible (Dincar, 2003). Research efforts are currently ongoing for the development of alternative sources of energy, more efficient conversion technologies, and environmentally sustainable applications. The use of solar energy technology is a viable solution to some of the environmental problems generated by the use of fossil fuels.

One of the promising applications of solar energy technology is the use of photovoltaic systems to generate electric power without emitting pollutants. Solar energy may be used to produce electricity using photovoltaic solar cells and heat in photocollectors by a photothermal conversion process. 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.

Photovoltaic solar cells are semiconductor devices (p-n diodes) which directly convert solar energy to electricity (Muneer et al., 2005). Silicon is frequently used in the fabrication of solar cells. 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. 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 photovoltaic 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 weather factors (Gxasheka et al., 2005). Solar radiation, temperature, relative humidity, wind speed and rainfall are among other factors that affect the output performance of the photovoltaic solar system.

The open circuit voltage and short circuit current depend on parameters like solar irradiance and the temperature as shown in the following equations:

$$V_{oc} = \frac{KT}{q} \ln\left(\frac{I_{sc}}{I_o}\right) \quad \textbf{(1)}$$

$$I_{sc} = bH \quad \textbf{(2)}$$

(Green et.al., 1982)

Where I_o is the saturation current, q is the electronic charge, k is the Boltzman constant, T is the absolute temperature, H is incident light intensity and b is a constant depending on the properties of the semiconductor junction, the geometry of the detector and size of the collector.

MATERIALS AND METHODS

Three functional 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 27W peak, 19v, model G100, ARCO. SOLAR INC, active area of $27cm^2$ and manufactured by BP solar system LTD. A 5.7kΩ 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.

Experimental Set-up

The photovoltaic solar system, array 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 Pure and Applied Physics Department building, Ladoke Akintola University of Technology Ogbomoso. The photovoltaic solar electricity array was capable of operating in the range of 70W – 80W, 12V – 19V (see Figure 1). To the PV solar array, a low resistance voltmeter was connected in series while a high resistance voltmeter was connected in parallel to the 5.7kΩ variable resistor using as a load. Figure 2 is a circuit model of the experimental set-up.

Figure 1: The Prototype of PV Solar Array of Stand-Alone ASPS.

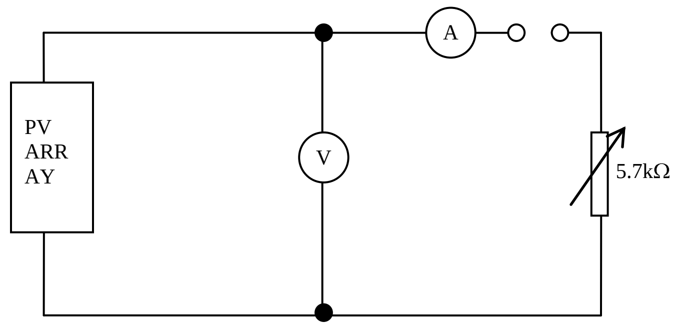


Figure 2: Circuit Model of the Experimental Set-up.

Measurements and Data Processing

Photovoltaic Output Parameters: Maximum output current and voltage of the photovoltaic solar system were measured and recorded everyday at interval of one hour using ammeter and voltmeter respectively. From these recorded values, daily average and monthly average values of the output currents and voltages were estimated.

Furthermore, daily average and monthly average values of maximum power outputs of the photovoltaic solar system were also computed. These are presented in Table 1.

Temperature: Daily ambient temperature was measured and recorded at intervals of an hour using a digital multimeter from the recorded values; daily average and monthly average values of the ambient temperature were determined and also presented in Table 1.

Table 1: The Monthly Average Values of Ambient Temperature(^{o}C) and Power Output(W) of ASPS for the Year 2006, 2007 and 2008.

Month	2006		2007		2008	
	Ambient Temp (^{o}C)	Power Output (W)	Ambient Temp (^{o}C)	Power Output (W)	Ambient Temp (^{o}C)	Power Output (W)
January	30.3	61.2	.030.5	61.8	30.0	60.5
February	30.0	61.0	31.0	63.7	31.0	64.0
March	32.0	67.4	32.4	66.2	31.6	68.5
April	31.7	63.2	32.0	71.2	31.0	65.0
May	29.5	60.0	29.8	59.8	29.0	60.0
June	28.5	56.2	29.0	57.6	28.6	58.6
July	28.0	58.0	29.0	58.0	28.5	59.2
August	28.1	57.2	29.0	57.5	28	57.5
September	29.0	59.7	29.2	56.6	29	59.3
October	29.8	60.6	29.9	62.8	30	60
November	31.6	65.6	32	68.3	31.8	67.0
December	30.0	62.9	30	62.5	30.0	63.0

RESULTS AND DISCUSSION

Figure 3 shows the monthly average variation of ambient temperature for the year 2006, 2007 and 2008. From this pattern of variation, it is seen that the ambient temperature varies with the different months of the year throughout the period of study. Two distinct maximum values are observed, the first maximum value is in the month of December, January and February while the second maximum was obtained in the month of March, April and November. The maximum values of ambient temperature 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.

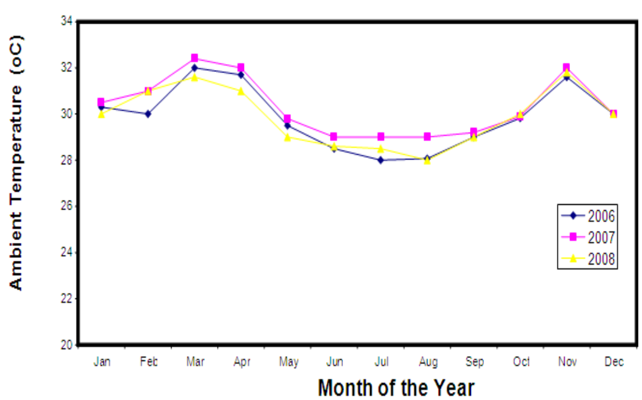


Figure 3: The Monthly Average Variation of Ambient Temperature for the Year 2006, 2007 and 2008.

However, little reduction in the maximum values of ambient temperature in the month of December, January and February compared to the months of March , April and November, was due to presence of scattering agents, especially Harmattan dust particles in the atmosphere.

In the case of the second main period (i.e. the month of May to October), minimum values of ambient temperature recorded were attributed to the reduction in intensity of solar radiation, due to rainy cloud, high humidity of air and air blowing from the ocean towards land.

Figures 5 to 7 present the graphs of monthly average power output produced by the photovoltaic solar system during the period of study against the ambient temperature. Generally from the figures, power output produced varied linearly with ambient temperature. Similarity in variation pattern of monthly average of ambient temperature and that of the performance output of the system (see Figures 3 and 4), confirmed the direct proportionality between the ambient temperature and the power output produced by the system. The explanation for this is that increase in ambient temperature increases the generation of electron-hole pair in the solar cell which thus results to increase in the mobility within the p-n junction leading to a larger photocurrent. This effect thus increase the power output, P_o of the photovoltaic solar system since:

$$P_o = IV \quad \textbf{(3)}$$

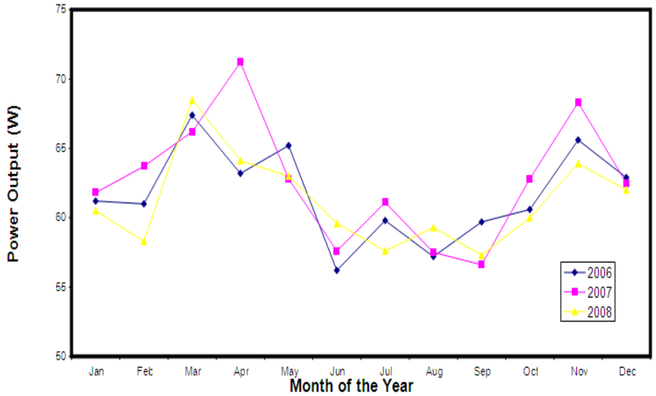


Figure 4: Variation in the Monthly Average of Performance Output of PV System with the Month of the Year.

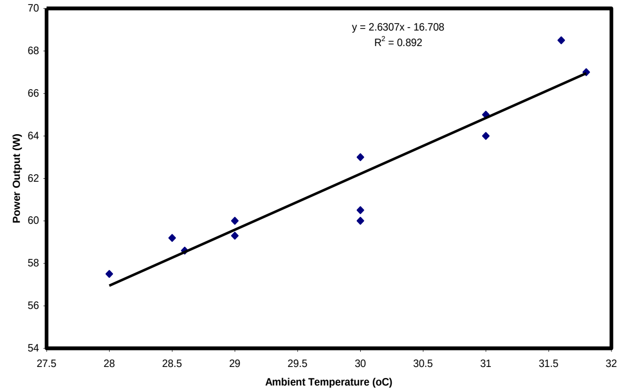


Figure 7: Graph of Power Output of the PV System with Ambient Temperature (2008).

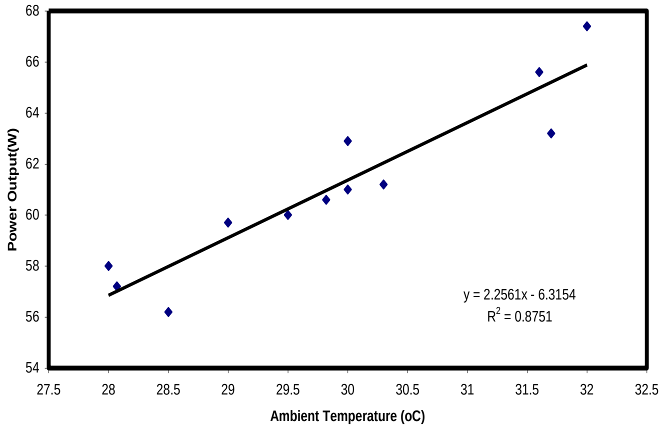
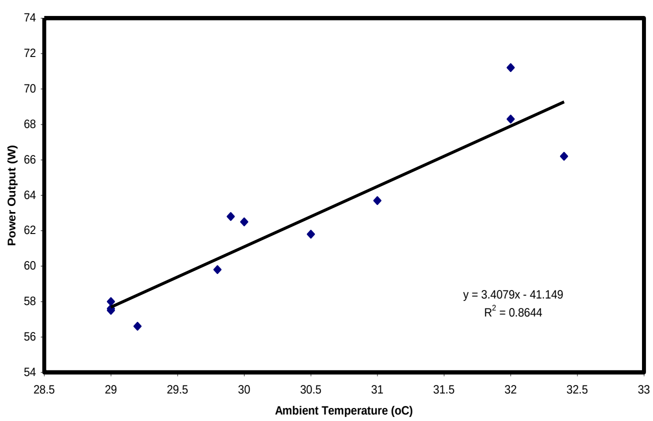


Figure 5: Graph of Power Output of the PV System with Ambient Temperature (2006).



It is also deduced from these figures that the power output performance of the photovoltaic system and ambient temperature are correlated. The regression equations obtained with the corresponding correlation coefficient R are:

For 2006,

$$y = 2.2561x - 6.3154, \quad R = 88 \quad \textbf{(4)}$$

For 2007,

$$y = 3.4079x - 41.149, \quad R = 86\% \quad \textbf{(5)}$$

For 2008,

$$y = 2.630x + 16.708, \quad R = 89\% \quad \textbf{(6)}$$

From the result above, it can be inferred that ambient temperature with the high values of correlation coefficient is good enough for predicting the performance output of the amorphous silicon solar cells in the area of study.

CONCLUSION

Effect of ambient temperature on the performance of a photovoltaic solar system was investigated. The results show that there is a direct proportionality between the power output produced by the system and the ambient temperature of the locality. Thus, the application of photovoltaic technology in the conversion of solar energy to electricity is favorable during high ambient temperature period than low ambient temperature period.

However, ambient temperature has a positive correlation with the power output produced by the system, hence; the temperature can be used in designing and predicting the performance of the amorphous silicon photovoltaic solar system in the area of study.

REFERENCES

1. Dincar, I. 2003. "The role of Energy in Energy Policy Making". *Energy Policy*. 30:137-149.

2. Gxasheka, A.R., E.E. Van Dyk, and E.L. Meyer. 2005. "Evaluation of Performance Parameters of PV Modules Deployed Outdoor". *Renewable Energy*. 30:611- 620.

3. Green, A. and Martin. 1982. *Solar Cells: Operating Principles, Technology and System Applications*. Prentice-Hall: Englewood Cliffs, NJ.

4. Muneer T., M. Asif, and Munawars. 2005. "Sustainable Production of Solar Electricity with Particular Reference to the India Economy". *Renewable Sustainable Energy Review*. 9:444-473.

SUGGESTED CITATION

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