



TEMPERATURE EFFECTS ON PV MODULE OPTIMAL PERFORMANCE

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ABSTRACT

This research was carried out to study the effects of Photovoltaic (PV) module temperature on its performance. The relationship between Module temperature and other parameters that determine the optimal performance were evaluated using Pearson product correlation in built in Microsoft Excel. The research has shown that PV module temperature among other factors has a great effect on the PV optimal performance.

Keywords: *Photovoltaic module, thermal degradation, performance, conversion efficiency.*

INTRODUCTION

The word 'photovoltaic' consists of the two words, photo and Volta. Photo stands for light (Greek phōs, photós: light) and Volta (Count Volta, 1745–1827, Italian physicist) is the unit of the electrical voltage. In other words, photovoltaic means the direct conversion of sunlight to electricity. The PV generates direct current (DC) electricity when sunlight falls on it (Gardas and Tendolkar, 2012). The history of photovoltaics goes back to the year 1839, when Edmond Becquerel discovered the photovoltaic effect, but in that century the technology was not available to exploit this discovery. The semiconductor age began about 100 years later (Green, 1982). After Shockley had developed a model for the p–n junction, Bell Laboratories produced the first solar cell in 1954 (Quaschnig, 2005). One of the most challenging factors in using photovoltaic systems is that the conversion efficiency of PV modules is still relatively low, say 15% (Musthafa, 2015). In Laboratories, efficiencies of up to 25% have been reached, but in commercial use the efficiencies reach only 14-17% (Quaschnig, 2005).



Figure 1: Typical Crystalline Silicon (cSi) Solar Photovoltaic Cell [Green, 1982]

Figure 1 shows a solid state semiconductor p-n junction device that converts sunlight into direct-current electricity through the principle of photovoltaic effect. Solar Photovoltaic cell is simply a P-N junction device (Gonzalez-Longatt, 2006), essentially a diode, which is composed of a p-type and an n-type semiconductor sandwiched together. An ideal diode under dark conditions i.e. (when there is no illumination) will have Current-Voltage (I-V) characteristic as shown in Figure 2 and 3. In this case, there will be no photons energy incident on the cells and no conversion takes place.

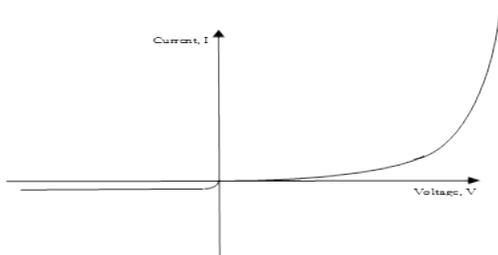


Figure 2: Ideal Diode under Dark I-V characteristics curve

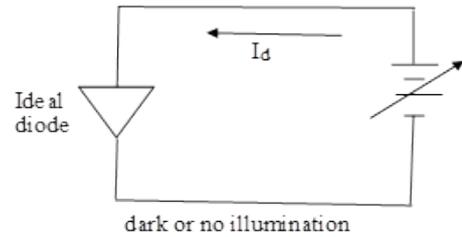


Figure 3: The equivalent circuit of an ideal diode with no illumination: [Green, 1982]

When a solar Photovoltaic cell is illuminated by sunlight, as shown in Figure 4, photons energy of the incident light is converted to direct current electricity through the process of photovoltaic effect of the solar cell. Incident light causes electron-hole pairs to be generated in the semiconductor and there is increase in the concentration of minority carriers (electrons in the p-type region and holes in the n-type region) in the depletion region.

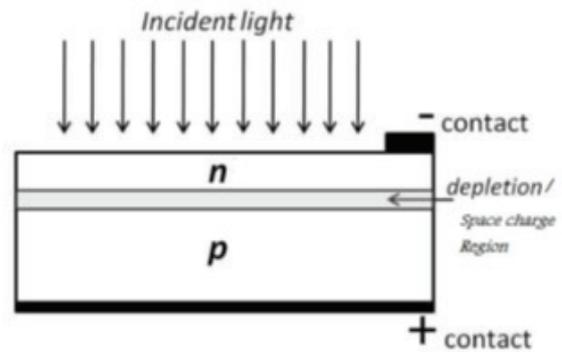


Figure 4: Incident light on a typical PN Solar Cell

[Nnadi (2012); Nobre *et al.*, (2012); Omubo-Pepple *et al.*, (2013); Samahdiya and Pandey (2016); Amuda *et al.*, (2017); Setiawan *et al.*, (2017)] shows the effect of climatic and environmental factors (such as ambient temperature, dirt and dust properties, shading, and acidic rain) on the performance of the PV module. From the above literatures, it was observed that the thermal response of the PV module is the major factor that affects the electrical power output. The PV module receives the incident irradiation; a portion of it is converted to electricity in proportional with the module efficiency. The rest of the incident irradiation heat up the PV module and thereby increases its operating temperature in relation to the PV material heat capacity (Amelia *et al.*, 2017). In this work, the relationship between module temperature and the parameters that determine the PV optimal performance was studied.

MATERIALS AND METHOD

A Monocrystalline Photovoltaic module with specifications shown in Table 1 was set up in an outdoor environment to expose it to real life operating conditions as shown in Figure 5.

Table 1: PV Module Specification at STC 1000W/m², A.M 1.5, 250C.

Maximum Power	150W
Maximum Power Tolerance	3%
Open Circuit Voltage	23.1 V
Short Circuit Current	8.99A
Maximum Power Voltage	18V
Maximum Power Current	8.34A
Weight	10.2kg
Dimension (mm)	1480 by 670 by 30
Maximum System Voltage	1000V
Maximum Overcurrent Protection rating	15A
Cell technology	Mono-Si
Module Application Class	A



Figure 5: View of the experimental set up.

The experiments were conducted between October 2017 and January 2018. The solar irradiance (W/m²) incidence on the horizontal surface was measured using solarimeter. The temperature of the module was measured using non-contact infrared digital thermometer and k-type thermocouple temperature data logger. Two different multimeters were used to measure the voltage and the current.

The maximum power delivered by the PV module was calculated from the product of voltage and current recorded.

The relationship between module temperature and the module parameters were compared using the in- built function of Pearson’s correlation coefficient in Microsoft Excel as shown in equation 1.

Pearson’s correlation coefficient ‘r’ can only take values between -1 and +1; a value of +1 indicates perfect positive association a value of -1 indicates perfect negative association, and a value of 0 indicates nonlinear association.

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}} \dots(1)$$

All measurements were saved to a Microsoft Excel file for further collation and analysis.

November and December was chosen because it is the hottest period of the year in this region. The time series analysis of the data was done and the result is as shown in the next section.

The photoelectric conversion efficiency was calculated using equation 2.

$$\eta = \frac{P_{max}}{G \times A} \dots\dots\dots(2)$$

Where η is the photoelectric conversion efficiency (%), G (W/m²) is the solar irradiance incident on the PV module, A (m²) is the surface area of the PV module. P_{max(W)} is the maximum power generated from the PV module. The maximum power generated is estimated by the product of the voltmeter and ammeter readings.

RESULTS AND DISCUSSION

From Figure 6, it was observed that as the module temperature increases, the open circuit voltage is slightly increasing alongside with solar irradiance within the period 8:00am – 11:20am when the module temperature was within the range of 27.7°C-48.6°C. The Open circuit voltage is maximum (20.6V) at temperature of 36.6°C. The Open circuit voltage begins to drop as the module temperature increases, while the temperature keeps increasing alongside with solar irradiance.

A correlation coefficient of 0.256 shows a poor linear relationship between the two variables. As shown in Figure 7, the short circuit current also increases as a result of a corresponding increase in solar irradiance. The current start decreasing from 2:10pm after reaching the peak of 60.4°C, till the rest of the day, in consonance with the module temperature and solar irradiance.

There is a linear relationship between module temperatures and current as shown in Figure 7, the correlation coefficient value of 0.93 further indicates a very strong relationship between the two variables. The module temperature is directly proportional to solar irradiance; i.e. an increase in solar irradiance leads to a corresponding increase in Module temperature as shown in Figure 8, the correlation coefficient value of 0.938 was gotten. This indicates a very strong relationship between the two variables. As the module temperature increases, the output power also increases. The correlation coefficient value of 0.923 indicates a very strong linear relationship between the two variables as shown in Figure 9.

Figure 10 indicated that as the module temperature increases, the conversion efficiency increases, the values reached maximum value between 11:00am and 2:00pm.

The correlation coefficient stands at 0.925 which show a strong relationship between the PV module temperature and the output efficiency as shown in Figure 10.

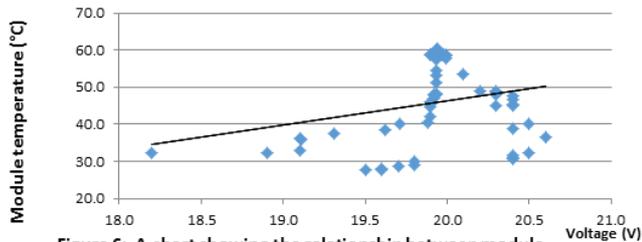


Figure 6: A chart showing the relationship between module temperature and Voltage

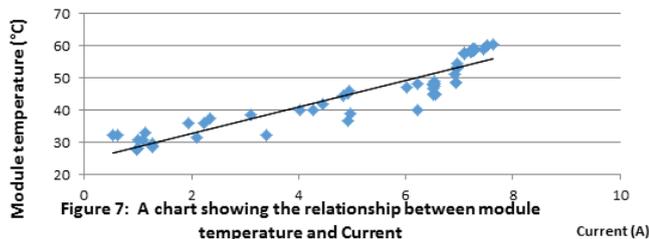


Figure 7: A chart showing the relationship between module temperature and Current

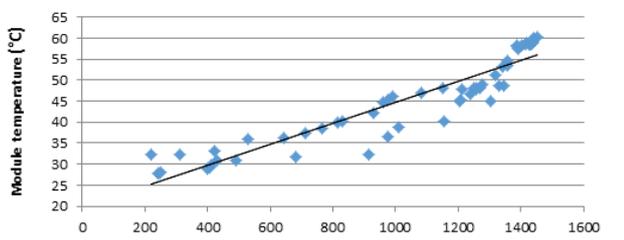


Figure 8: A chart showing the relationship between module temperature and solar irradiance

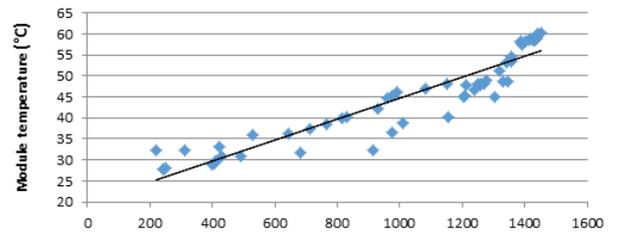


Figure 8: A chart showing the relationship between module temperature and solar irradiance

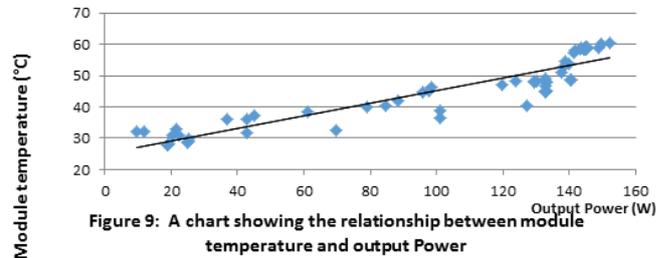


Figure 9: A chart showing the relationship between module temperature and output Power

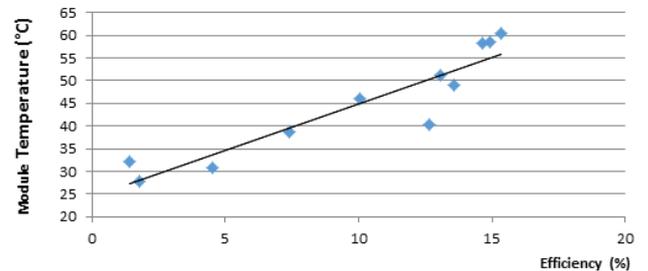


Figure 10: relationship between module temperature and efficiency

Conclusion

The research has shown that PV module temperature among other factors, has a great effect on the PV optimal performance.

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