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The Effects of Solar Panel Temperature on the Power Output Efficiency in Calabar, Nigeria

E. B. Ettah[1*], E. E. Eno[1], A. B. Udoimuk[2]
1. Department of Physics, Cross River University of Technology, Calabar, Nigeria
2. Department of Physics, University of Calabar, Calabar, Nigeria

***Corresponding author**
Department of Physics, Cross River State University of Technology, Calabar.

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Abstract

Background: The current push for adoption of alternative energy sources necessitates research into parameters that would enhance the optimum harvest of the benefits of such efforts.

Purpose: To determine the effects of solar panel temperature on its efficiency in Calabar, Nigeria, by determining the output current and voltage changes due to solar panel temperature.

Materials and Methods: A modern digital thermometer, Model 220k type, and Alda ADV 890C digital multimeter, were used to obtain measurements of solar panel temperatures, current and voltage, respectively, in Calabar, Nigeria. Comparisons were made of the values of current and voltage obtained with solar panel temperature changes, and efficiency of the output of the solar panels determined by calculation using efficiency as given by Kachhava (2003).

Results: Results indicate that a maximum output current of 18.4×10^{-1}A was recorded at 42.8^{o}C. Beyond this temperature the output current dropped down to 12×10^{-1}A at 54.8^{o}C. The voltage output remained relatively stable as solar panel temperature increased. Power output efficiency dropped from 82.3% at 42.8^{o}C to 52.4% at 54.8^{o}C.

Conclusion: High solar panel temperatures may have adverse effects on solar panel efficiency. The result obtained in this study suggest a maximum operating temperature of solar panel in Calabar, Nigeria.

INTRODUCTION

Fossil fuel reserves, which for so long have provided most part of the energy sources of the world, are limited and are generally decreasing. Consequently, researchers need to develop more efficient ways of producing energy from available alternative sources especially as energy consumption in developed countries is growing at the rate of approximately 1% per year and developing countries at 5% per year [1].

In Nigeria, many communities do not have access to the national electricity grid. As at 1996, only about 40% of the national populations had been linked and these, largely in the urban areas[2]. As a result of the inadequacy in energy supply, it has become necessary that the abundant solar and other possible alternative energy sources in the country be harnessed to complement the conventional fossil fuel, reserves, gas and hydropower generation. The viable and reliable alternative energy option is the solar photovoltaic energy. This will make use of the abundantly available solar radiation in Nigeria.

The specifications given by manufactures of different types of solar panels are usually for standard Test condition (STC). These are obtained under simulated sunlight conditions. However, solar panels' performance varies with actual location and prevailing environmental conditions to which they are subjected. Such conditions as air mass, solar flux temperature and relative humidity have been reported [3].

Radiation from the sun absorbed by the earth warms it up and its temperature raises, this situation also occurs when radiation falls on solar panels. The performance of solar panels, in terms of power output, is a function of the availability of solar energy resource in the location. Solar intensity is high modulated due to the rapidly changing cloud cover and accounts for the rapidly changing temperatures [4].

According to Ettah[5], solar panel temperature increases more rapidly than ambient temperature. This is because low energy solar flux (photons) reaching the solar panel are absorbed as heat. Solar cells are encapsulated in black material which makes them good heat absorbers. The gap between the solar cell and glass casing of the panel encourages green house effect which equally adds to the temperature increase of solar panel. While this occurs, the ambient temperature remains relatively uniform throughout the day.

The solar cell is a PN junction divide which can be modeled as a diode with a photo generated current source in parallel. When this is done, the current I, flowing through the PN junction is given by equation 1[6].

$$I = I_o\left(\exp\frac{qv}{\eta KT} - 1\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where **Io** is reverse saturation current that is dependent on temperature, **K** is the Boltzmann's constant, **q**, the electron charge, **η**, a diode dependent ideality factor. Equation (1) shows the inverse relationship of current and temperature.

The aim of this paper was to investigate the effects of solar panel temperature on the power output efficiency of solar panels in Calabar, Nigeria.

Calabar is the capital of Cross River States, South South Nigeria. It lies on latitude 4^{O}. 30’ and 5^{O}.00 N and longitudes $5^{o}15$` and $8^{o}45$`E of the equator. The city has a uniform ambient temperature through the year with little variation. The mean ambient temperature is about 28 ± 2^{0}C, with no winter. Cloudiness and heavy precipitation help to moderate the daily temperatures. Regular land and sea breeze assist in maintaining a truly equitable climate [7]. Rich Sunshine is enjoyed in Calabar, with solar radiation in average of about 14.3 MJ/m^2 per day [8].

MATERIALS AND METHOD

A general purpose digital thermometer, Model 220k, used with type k temperature probes was used to obtain solar panel temperatures. Before use, the probe and instrument were calibrated to zero ^{0}C following manufacturer’s guideline. The temperature probe was placed in an ice bath to stabilize the reading, and then the mode key was pressed to calibrate the reading to 0^{o}C. To obtain solar panel temperature readings, the probe was placed on the surface of the solar panel to take the temperature.

Voltage and current output readings were taken with an Alda Model AV 890C Digital Multimeter. This is an easy to use 3 ½ digital liquid crystal display (LCD) meter, designed to read resistance (R), voltage (V), current (I) and capacitance (C).

The Solar panels were designed with a glazed front and back. Glazing was with a low-Iron glass with a 4 mm thickness. The cell used in the study was a monocrystalline silicon type with an area of 1.9 m2. The panel had a surface area of 3.3 m2, and a solar temperature coefficient of 0.005/K. Its maximum output current and voltage were 2A and 8V, respectively.

The method of study involved the initial collation of current and voltage output data from the solar panel, using the digital multimetre (Alda Model AV 0890C). Solar panel temperatures were then measured at the surface of the panel with the model 220k type digital thermometer.

The solar panel and the thermometer where placed on the same horizontal test plane at the height of meter facing the sun. Instantaneous measurements were made at both stages at intervals of 5minutes averaged over 30minutes. This was done between the hours of 6.00am to 5.00pm for fourteen days to ensure effective and accurate data collection. Results collated were input into equation II, from Kachhava,[9] to calculate solar panel power efficiency output.

$$Efficiency = \frac{power\ of\ solar\ panel}{\text{Area of solar panel}} \times \frac{100\%}{1000W/m2} \ldots\ldots\ldots\ldots (II)$$

RESULTS

Plots of output current, voltage with solar panel temperature changes is shown in

Figures 1 and 2, respectively. Values of calculated solar panel efficiency percent (%) are presented in Figure 3.

Figure 1 shows that current output increased with the temperature of solar panel up to about 42.8^{o}C where current of about 18.4 x 10^{-1}A was recorded. Beyond this temperature current began to drop. The drop continued as the solar panel temperature rose up to 54.8^{o}C where a current output value of 12.4 x 10^{-1}A was obtained. This indicates a loss of efficiency by 32.6%.

From figure 2, the output voltage appeared to be relatively stable. Increase in solar panel temperature between 25^{o}C to 42.8^{o}C produced an output voltage of 8.3V, which dropped slightly by 0.4V at the temperature of 54.0^{o}C (value 7.9V).

Low solar panel temperatures yielded high efficiency % in the performance of solar panel. Beyond 42.8^{o}C, the efficiency % of the solar panel dropped. Figure (3) indicates that at 42.8^{o}C efficiency of 82.3% was recorded while at 54.8^{o}C it dropped to 52.4%. This showed showing a loss of nearly a third of the peak efficiency.

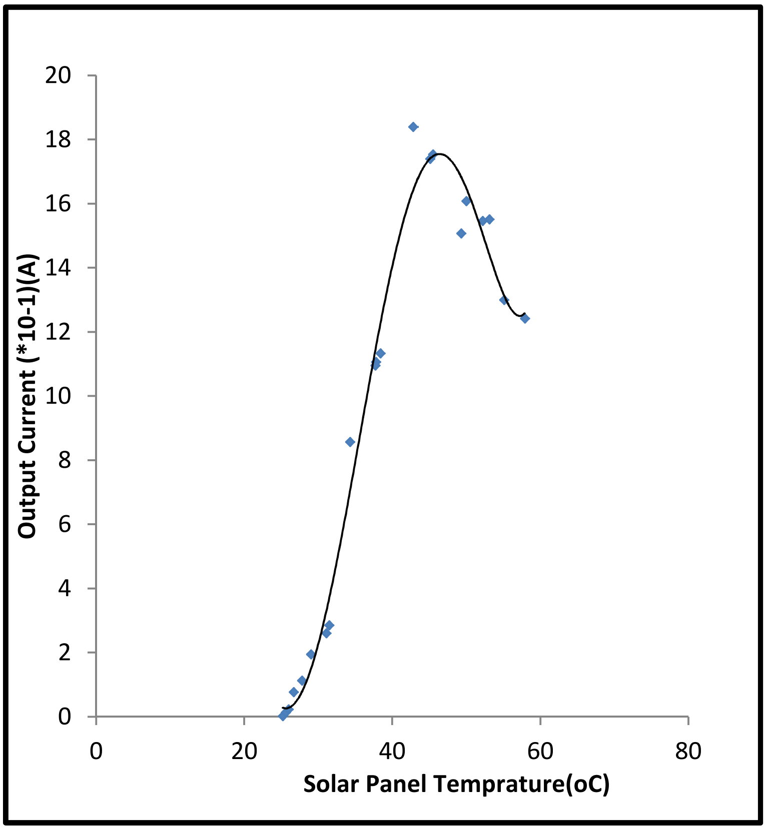

FIGURE 1: Output current variation with solar panel temperature

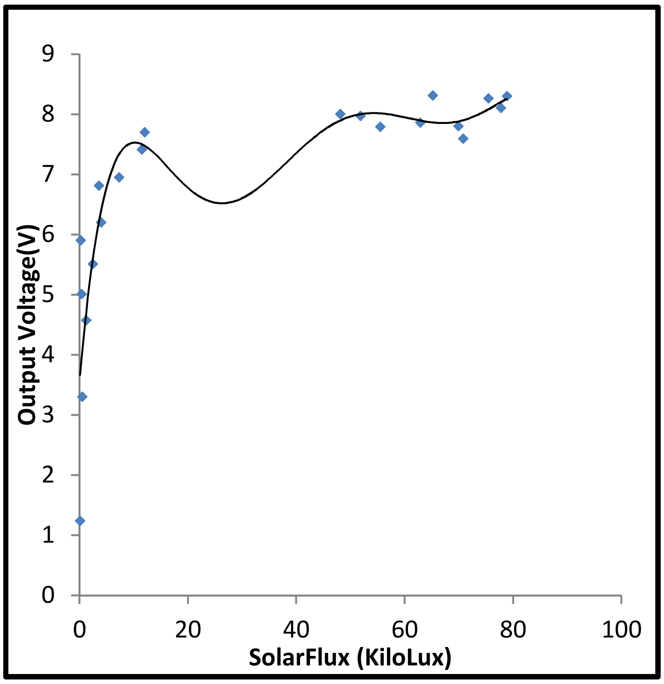

FIGURE 2: Output voltage plotted against solar panel temperature

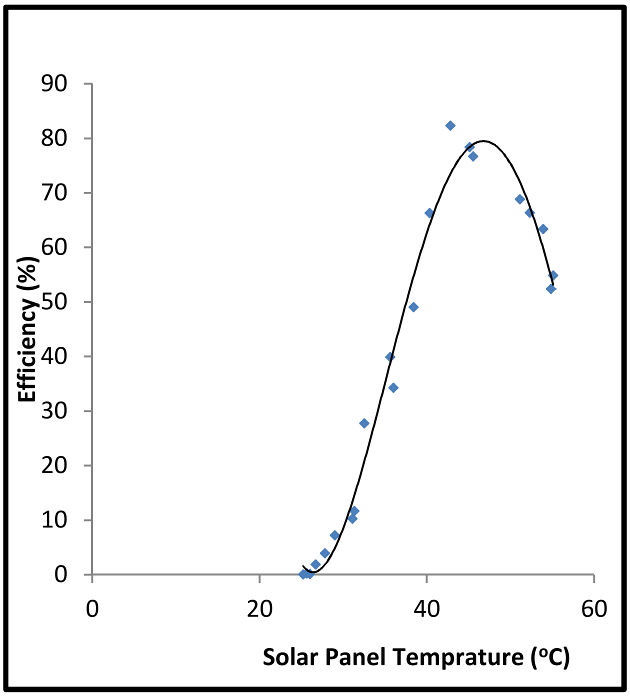

FIGURE 3: Variation of the efficiency of solar panel power output with temperature.

Discussion

When solar panels are exposed to the sun radiation solar flux falls on solar panel and the photons are absorbed at or near the P-N junction of the solar cell generating electron hole pairs. This depends on the sufficiency of the absorbed photon energy. The transition of electrons from the valence band to the conduction band creates a potential difference across the depletion region and thus an electric field, moving electrons to the negative region and holes to the positive region, respectively. The flow of free electrons to the p-region to recombine with the holes gives current. The conversion of solar radiation photons to photo electrons leading to the generation of electron-hole pair in the solar panels and the consequent increase in electron mobility makes panel temperatures to rise[10].

The effect of temperature on solar cell efficiency can be explained using equation 1. This effect comes in two ways. Firstly, there is the effect on the temperature component in the exponential term, and secondly, the effect on I_o. The increase in temperature reduces the magnitude of the exponent in equation 1, thereby increasing the value of I_o, but in proportion to the exponential decrement. The implication of this is that cells with higher values of V_{oc} (open circuit voltage) suffer smaller reduction in voltage with increasing temperatures.

Conclusion

The following conclusions were reached from this study.

1. Output current and efficiency are directly related and depend on temperature of solar panel
2. Output voltage of panel increases rapidly until it reaches near saturation where it is relatively stable even at high solar panel temperature
3. Low solar panel temperature enhances output current hence increase in efficiency. This means that high temperature of solar panels affect the efficiency of solar panels negatively.

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