Effect of Solar Radiation and Ambient Temperature on Solar Cell Performance

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Abstract—The effect of solar radiation and ambient temperature on the performance of a solar power system was studied under different daily weather conditions at Ambrose Alli University, Ekpoma, Nigeria (Lat. 6˚44.3’N, Long. 6˚4.8’E). This study was carried out experimentally by monitoring the changes in power output of the solar power system with ambient temperature during the month of October, 2017. Results showed that there is a direct correlation between the power output performance of the system and the ambient temperature. The results also indicate that the temperature must be taken into account when designing and predicting the performance of the solar power system in the area of application.

Keywords: Ambient Temperature, Solar Cells, Solar Power System, Solar Radiation

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1. Introduction

The environmental degradation resulting from the use of fossil fuels includes severe 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 surrogate sources of energy (Okundamiya, 2016; Okundamiya & Ibharunujele, 2019) such as more efficient conversion technologies and environmentally sustainable applications. The use of solar energy technology is an effective solution to some of the environmental problems created 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 (Okundamiya et al., 2014). Solar energy may be used to produce electricity using photovoltaic solar cells and heat in photo collectors by a photo thermal conversion process. Increasing efforts are directed towards reducing the installation costs and enhancing the efficiency of photovoltaic systems so that the system can be deployed at a large scale (Okundamiya & Omorogiuwa, 2015). Photovoltaic solar cells are semiconductor devices (p-n diodes), which directly convert solar energy to electricity (Muneer et al., 2005). Silicon is frequently employed in the construction of solar cells. Solar cells operate as a quantum device substituting photons for electrons.
Photons from the Sun with sufficient energy close to the depletion region of a p-n junction produce electron-hole pairs. If these electrons have enough energy, they are liberated 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 (Okundamiya & Nzeako, 2011). 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). Other factors that affect the output characteristics of photovoltaic solar system includes; relative humidity, solar radiation, temperature, wind and rainfall.

This study is centred on the effect of temperature on solar cells performance at different weather conditions. The objectives are to determine the effect of solar radiation and temperature on solar cells performance at different weather conditions as well as the maximum charging current and charging voltage at different weather condition.

2. Methodology

The solar cell power conversion efficiency can be given as:

$$\eta_c = \frac{P_{\text{max}}}{P_{\text{in}}} = \frac{I_{\text{max}} \times V_{\text{max}}}{I(t) \times A_c} \quad (1)$$

Where $I_{\text{max}}$ and $V_{\text{max}}$ are the current and voltage for maximum power, corresponding to solar intensity $I(t)$ and $A_c$ is Area of solar cell.

The full factor (FF) parameter of solar cells can be expressed as:

$$\text{FF} = \frac{V_{\text{mp}} \times I_{\text{mp}}}{V_{\text{oc}} \times I_{\text{sc}}} \quad (2)$$

Where $V_{\text{oc}}$ and $I_{\text{sc}}$ are the open circuit and short circuit current, $V_{\text{mp}}$ and $I_{\text{mp}}$ are the voltage at a maximum power point respectively.

The voltage of the battery bank (12V-200Ah) was measured to ascertain the charging rate of the battery. The purpose was also to determine the maximum charging current and voltage at different weather conditions. A thermometer (model DM6902) was used to measure the ambient temperature of the solar panel. The solar photovoltaic (PV) array, made up of sixteen identical flat amorphous silicon solar modules, connected in series configuration mounted horizontally on a metal plate frame, which was raised above the roof-top of the Electrical /Electronic Laboratory, Ambrose Alli University. The specification of the PV module are as follows: Peak power ($P_{\text{mp}}$) = 220W, maximum power current ($I_{\text{mp}}$) = 6.29A, and maximum power voltage ($V_{\text{mp}}$) = 35.0V. The maximum output current and voltage of the PV system were measured and recorded at an interval of 15 minutes along with the corresponding voltage of the battery bank and the ambient temperature. Figure 1 shows the daily average variation of ambient temperature. As observed from the pattern of variation, the temperature varies with different weather condition during the day.
In the process of this study, several tests were carried out by monitoring the variation in power output of the photovoltaic system at different temperature. The results obtained from these tests were recorded, and graphs were plotted with information recorded. Comparisons were made based on the graphs obtained.

3. Results and Discussion

Figures 2 to 5 present the graphs of daily average voltage input produced by the solar photovoltaic system during the period of study (5th to 8th of October, 2017) against the ambient temperature. Generally, from the figures, panel voltage input produced, varied linearly with ambient temperature. Similarity in variation pattern of daily average of ambient temperature and that of the performance output of the system (see Figures 4 and 5), 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 creation 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 increases the power input, $P_1$ of the photovoltaic solar system since $P_1 = VI$.

![Figure 2](image-url)

**Figure 2.** Variation of daily average output power with ambient temperature for day 1 (October 5, 2017)
Figure 3. Variation of daily average output power with ambient temperature for day 2 (October 6, 2017)

Figure 4. Variation of daily average output power with ambient temperature for day 3 (October 7, 2017)

Figure 5. Variation of daily average output power with ambient temperature for day 4 (October 8, 2017)
The effect of temperature on the performance of the PV is shown in Figures 6 and 7. The change in temperature affects the power output from the cells. The voltage is highly dependent on the temperature and an increase in temperature causes a decrease the voltage (Figure 6). Figure 7 shows the effect of temperature on I-V characteristic of PV module at constant radiation (Qiang & Nan, 2010)

![Figure 6](image6.png)

**Figure 6.** Output I-V characteristics of the PV module with different temperatures

![Figure 7](image7.png)

**Figure 7.** Output P-V characteristics of the PV module with different temperatures
With decreasing temperature, the PV current decreases lightly but PV voltage increases clearly. As Figure 7 indicates, output power of photovoltaic module increases with decreasing temperature.

4. Conclusion

Effect of ambient temperature on the performance of a photovoltaic solar system was investigated. The results show that there is a direct correlation between the power output from the system and the ambient temperature of the locality. Thus, the application of photovoltaic technology in the conversion of solar energy to electricity is favourable 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 employed in designing and predicting the performance of the amorphous silicon photovoltaic solar system in the area of study.

Environmental conditions affects the performance of solar cells. The output parameters such as output voltage, current, power, and fill factor of solar cells is also affected by temperature. Experimental results showed that the most significant changed by temperature is voltage which decreases with increasing temperature while output current slightly increase by temperature. The effect of ambient temperature on the performance of a stand-alone photovoltaic solar system installed at Ambrose Alli University, Ekpoma Edo State was investigated. The results show that there is an indirect proportionality between the power output from the system and the ambient temperature of the locality. Thus, the application of photovoltaic technology in the conversion of solar energy to electricity is not more favourable during the period of very high ambient temperature than the period of low ambient temperature. The results indicated that PV solar panels must be installed at a place where they receive more air current so that the temperature remains low while the power output remains high.

References


