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# The Effect of Relative Humidity and Temperature on Polycrystalline Solar Panels Installed Close to a River

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author AON designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author JCO managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.*

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## ABSTRACT

The effect of temperature and relative humidity on photovoltaics installed close to Calabar River was investigated to evaluate their performance. The data used in the research was obtained by in-situ measurement approach using a KT-908 precision digital hygrometer and thermometer, and a $M890C^{+}$ digital multimeter. The result obtained shows a strong negative correlation for current, efficiency and relative humidity which indicates that high relative humidity adversely affects the performance of the photovoltaic. The results also show that voltage remains fairly stable between 65% to 75% relative humidity humidity and 33°C to 43°C (panel temperature), while efficiency increases with temperature up to the maximum

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operating temperature of the photovoltaic module before starting to decrease. Peak in efficiency was observed at a relative humidity value of 65% and module temperature of about 47°C at noon.

*Keywords: Relative humidity; ambient temperature; panel temperature; photovoltaic module.*

## 1. INTRODUCTION

Since the existence of man on earth, man has greatly relied on the use of fossil fuel for electricity and power generation. On a world scale, environmental problems including global warming due to extensive use of fossil fuels for electricity production and combustion engines have become increasingly serious in recent years. One of the viable solutions to tackling these environmental problems is by turning our attention to the use of renewable sources of energy to replace the use of fossil fuel for electricity and power generation. Solar energy which is clean, noiseless and pollution free is considered one of the most important sources among the renewable sources of energy.

Intensive efforts are being made to reduce the cost of photovoltaic cell production, improve efficiency and narrow the gap between photovoltaic and conventional power generation methods such as steam and gas turbine power generators. In order to decrease the cost of PV array production, different efforts have been made towards improving the efficiency of the system and collecting more energy per unit surface area [1].

Photovoltaic cells are solar energy applications and are used to convert the solar energy directly into electricity by pairs of semiconductor interacting with the effect of light [2]. The limited efficiency of the photovoltaic is the hindering reason for the widespread use of solar cells. The primary cause of the photovoltaic cell low efficiency is that it uses a small part of the energy in the solar spectrum [3].

Nowadays we get approximately 80% of our energy from non-renewable energy sources, e.g. fossil fuels. Pollutants and greenhouse gases increase when fossil fuels are converted into electricity or heat. Therefore the atmosphere is damaged and global warming developed. Fortunately, as the resources are limited, our dependence on fossil is close to its end.

Photovoltaic systems have been installed to provide electricity to billions of people that do not have access to mains electricity. Power supply to remoter houses or villages, irrigation and water supply are important application of photovoltaics for many years to come. In the last decade, PV solar energy system has shown its huge potential. The amount of installed PV power has rapidly increased. Nowadays, nearly 70 GW of PV power are installed worldwide [4].

Hussein and Miqdam [5] carried out a research in Sohar city on the effect of humidity on photovoltaic performance based on experimental study. Results indicated that Increasing relative humidity reduce the current. Increasing relative humidity from 67% to 95% reduced the current by 44.44%. In spite of high relative humidity of Sohar city the PV panel produced 62% of the maximum current in the worst condition. The voltage of PV dropped significantly with increasing relative humidity. Relative humidity has an adverse impact on solar radiation so that the resultant negative influence reflects on the PV cell output voltage.

Panjwani and Narejo [6] studied the effect of humidity ranges between (40 to 78%). The study results indicated that there is an estimated loss of about 15-30% of the PV power. Humidity brought down the utilized solar energy to about 55-60% from just 70% of utilized energy. The reason for this reduction resulted from the basal layer of water vapor lied at the front of the solar cell directly facing the sun.

Ike [7] investigated the effect of temperature on the performance of a photovoltaic solar system in eastern Nigeria. The results show that there is an indirect 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 not favorable 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.

Ettah et al. [8] carried out an investigation in Calabar (Nigeria) about the effect of relative humidity on the performance of solar panels. Their results demonstrate that low relative humidity between 69% and 75% favors an increase in output current from solar panels, with voltage stabilizing between relative humidity values of 70% and 75%, as well increases with a decrease in relative humidity.

Omubo-pepple [9] using a B-K Precision module 615 Digital light instrument and PV modules in Port Harcourt carried out a research on the effect of solar flux and relative humidity on the efficient conversion of solar energy to electricity. Results obtained shows that current increases when relative humidity drops, which means low water vapor in the atmosphere, resulting to high flux which enhances high current production. Also a decrease in relative humidity leads to an increase in voltage as well as efficiency. Their results also show that solar panel operates optimally at lower temperatures. Lower panel temperature leads to a decrease in output current and an increase in output voltage which ultimately increases the output power as well as efficiency.

The aim of this research is to investigate the effect of relative humidity and temperature on the performance of photovoltaic installed for household use in atmospheres close to a river.

## 2. MATERIALS AND METHODS

### 2.1 Materials

a) A 130 watt polycrystalline solar panel with dimension of 1480*670*35 mm and capacities of 7.18A and 18.10V at maximum current and voltage respectively. Having 7.91A and 21.72V for short circuit current and open circuit voltage respectively.
b) Charge controller
c) 12 volts lead acid battery (75AH)
d) A digital hygrometer (KT-908) which is combined with a digital thermometer and an alarm clock is optimized to measure relative humidity (%) and temperature both in degrees (°C) and Fahrenheit (°F). it has a high stability and a multifunctional display. The device has accuracy up to ±2°F or ± 1°C for temperature and ±5% for relative humidity.
e) A digital multimeter ($M890C^+$) for measuring voltage and current, and also fitted with a K type thermocouple for measuring temperature in Celsius.

### 2.2 Methods

The solar panel was placed horizontally flat facing the sun on a platform one metre high above the ground. Connecting cables were connected to the output terminals of the solar panel. From the output terminals of the solar panel the cables were connected to the charge controller. The output of the charge controller was then connected to the battery for charging the battery which powered the load through an inverter.

Measurements were taken at an interval of 30 minutes from 6.00am to 6.00pm for a period of 60 days (30 days in April and 30 days in May). During measurements, the voltage and current from the panel were measured using the digital multimeter. The ambient temperature was read directly from the digital thermometer while the solar panel temperature was measured using the temperature sensing probe fixed on the solar panel. The time of day was recorded and the relative humidity measured and read directly from the digital hygrometer.

From the readings obtained, the power from the solar panel was determined using equation (1). The maximum power that the solar panel can give out can be calculated using equation (2). The normalized power output efficiency was calculated using equation (3) as shown by [10]. It has been shown by [7] that the open circuit voltage and short circuit current depend on parameters like solar irradiance and temperature as indicated in equations (4) and (5).

**Measured Power:**

$$P_{mea} = V_{mea} \times I_{mea} \quad (1)$$

**Maximum power:**

$$P_{max} = V_{max} \times I_{max} \quad (2)$$

**Normalized power output efficiency:**

$$\eta_p = \frac{P_{mea}}{P_{max}} \times 100 \quad (3)$$

**Open circuit voltage:**

$$V_{oc} = \frac{KT}{Q} ln \frac{Isc}{Io} \quad (4)$$

**Short circuit current:**

$$Isc = bH \quad (5)$$

Where $P_{mea}$, $V_{mea}$ and $I_{mea}$ are the measured power, voltage and current respectively. $P_{max}$, $V_{max}$ and $I_{max}$ are the maximum power, voltage and current respectively that the module can give out. $I_o$ is the saturation current, Q is the electronic charge, K is the Boltzmann constant, T is the absolute temperature of the photovoltaic module, H is the incident light intensity and b is a constant depending on the properties of the semiconductor junction. Fig. 1 shows how the experimental setup of the photovoltaic system was done.

**a). Solar panel on a platform 1m high.** **b). Grid connection**

**Fig. 1. The experimental layout**

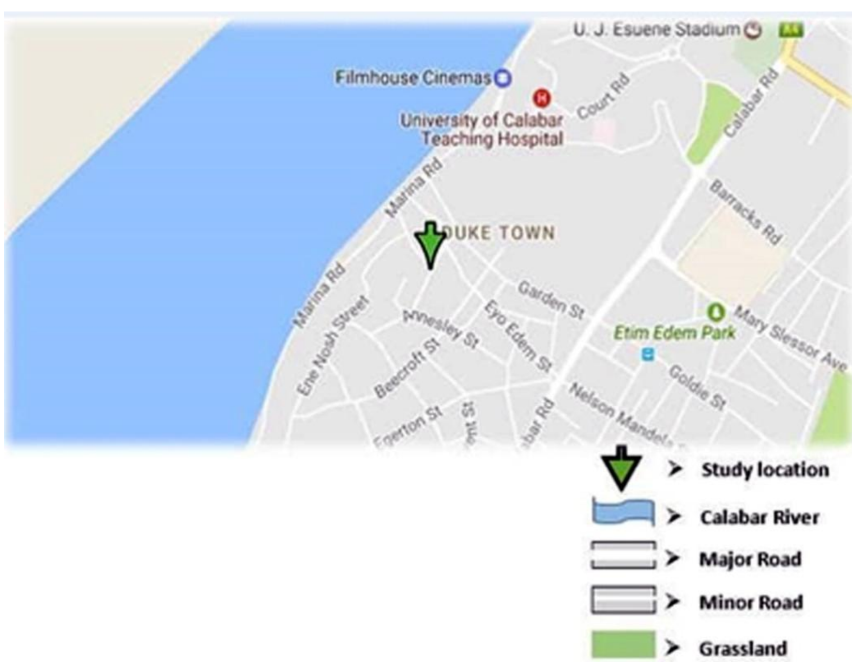


**Fig. 2. Map showing study location**

### 2.3 Study Area

Calabar, the capital of Cross River State is located in the southern part of Nigeria, located on Latitude 4°57'06''N and longitude 8°19'19''E at an elevation of 32 m above sea level experiences the tropical monsoon with a lengthy wet season spanning ten months and a short dry season covering the remaining two months. The harmattan, which significantly influences weather in West Africa is noticeably less pronounced in the city. Temperatures are relatively constant throughout the year, with average high temperatures usually ranging from 25 to 28 degrees Celsius. There is also little variance between daytime and nighttime temperature, as temperatures at night are typically only a few degrees lower than the daytime high temperature. Calabar averages just less than 3,000 millimeters (120 in) of precipitation annually. But the location selected for this study is on Latitude 4°57'38.6161" N and Longitude 8°18'58.482" E, it is about 500 metre away from the Calabar River as shown in Fig. 2.

## 3. RESULTS AND DISCUSSION

Table 1 show the summary of the data obtained from in-situ measurement.

Fig. 3 shows a very strong negative correlation between ambient temperature (°C) and relative humidity (%). The meaning is that as relative humidity increases, ambient temperature decreases; this conforms to our calculated result of statistical correlation.

Fig. 4 clearly shows a positive correlation between panel temperature and the ambient temperature. It shows that the air temperature surrounding the panel determines how hot the panel will get.

**Table 1. Summary of data obtained from in–situ measurement in April and May 2017**

| Statistic | Relative humidity | Ambient Temp | Panel temp | Voltage | Current | Power | Efficiency |
|---|---|---|---|---|---|---|---|
| Minimum | 59.059 | 27.293 | 25.200 | 3.076 | 0.001 | 0.003 | 0.00% |
| Maximum | 86.267 | 35.047 | 47.459 | 18.156 | 5.073 | 90.325 | 69% |
| Median | 70.235 | 32.112 | 39.282 | 17.829 | 2.714 | 48.672 | 37% |
| Mean | 70.488 | 31.741 | 37.633 | 16.913 | 2.536 | 45.206 | 35% |
| Variance (n-1) | 79.841 | 6.637 | 51.070 | 8.965 | 2.707 | 874.799 | 0.052 |
| Standard dev (n-1) | 8.935 | 2.576 | 7.146 | 2.994 | 1.645 | 29.577 | 0.228 |

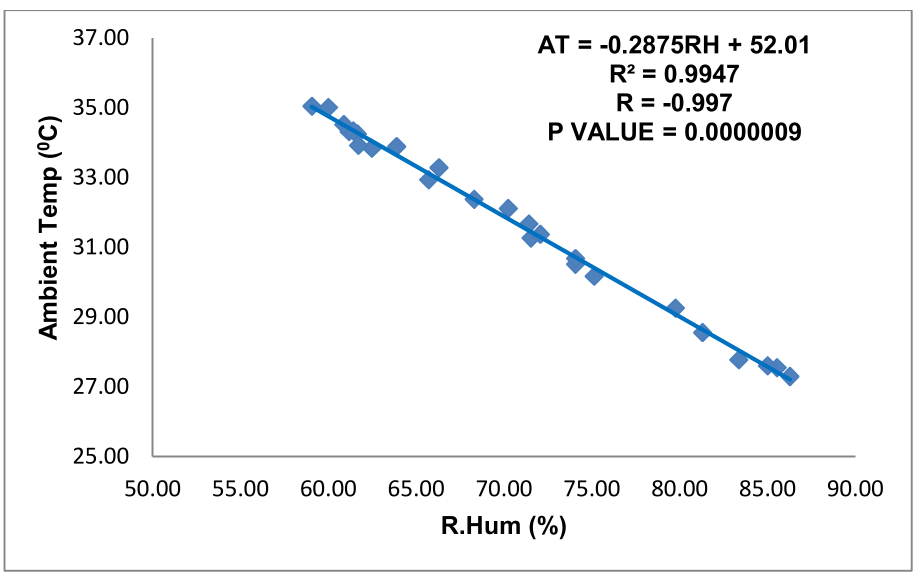


**Fig. 3. Ambient temperature (°C) against relative humidity (%)**

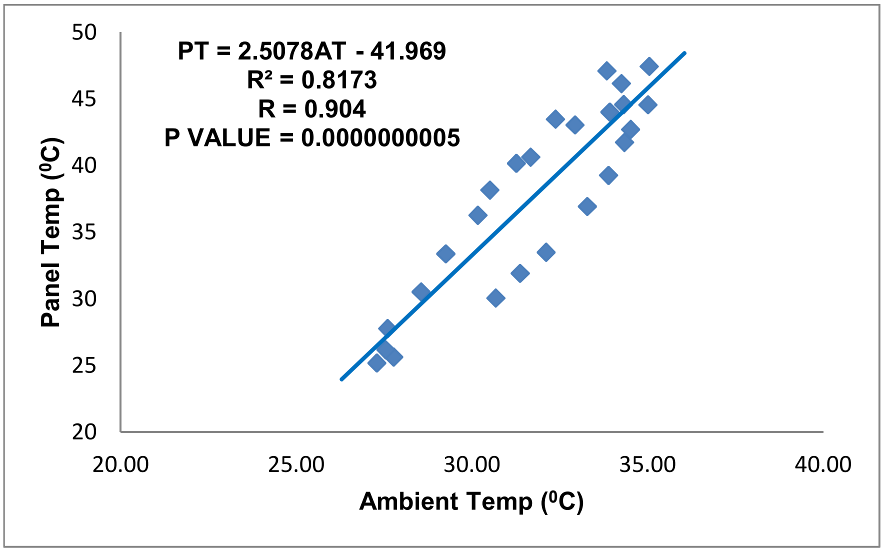


**Fig. 4. Panel temperature (°C) against ambient temperature (°C)**

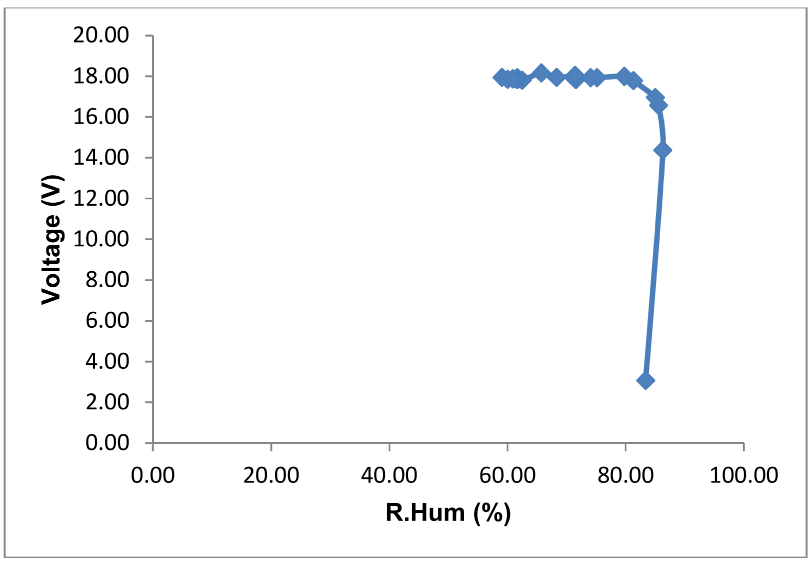


**Fig. 5. Voltage (V) against relative humidity (%)**

Fig. 5 shows that high relative humidity adversely affects the voltage performance of photovoltaics. It further reveals that the output voltage remains fairly stable between 65% to 75%. Beyond 75% the voltage begins to decrease to almost zero which is in agreement with studies by Ettah et al. [8].

Fig. 6 shows a strong downhill (negative) linear relationship between current and relative humidity. What this implies is that high relative humidity does not enhance current production from the solar panel but rather limits the amount of solar radiation that would have gotten to the panel to enhance current production. Fig. 6 is also in agreement with studies by Ettah et al. [8]. On the other hand, Fig. 7 also shows a strong negative correlation between efficiency and relative humidity which conforms to our statistical correlation. This is simply due to the adverse effect that high relative humidity has on voltage and current as shown in Fig. 5 and Fig. 6 respectively. This further show that high relative humidity adversely affect the efficiency of photovoltaics, which is in agreement with earlier studies by Ettah et al. [8].

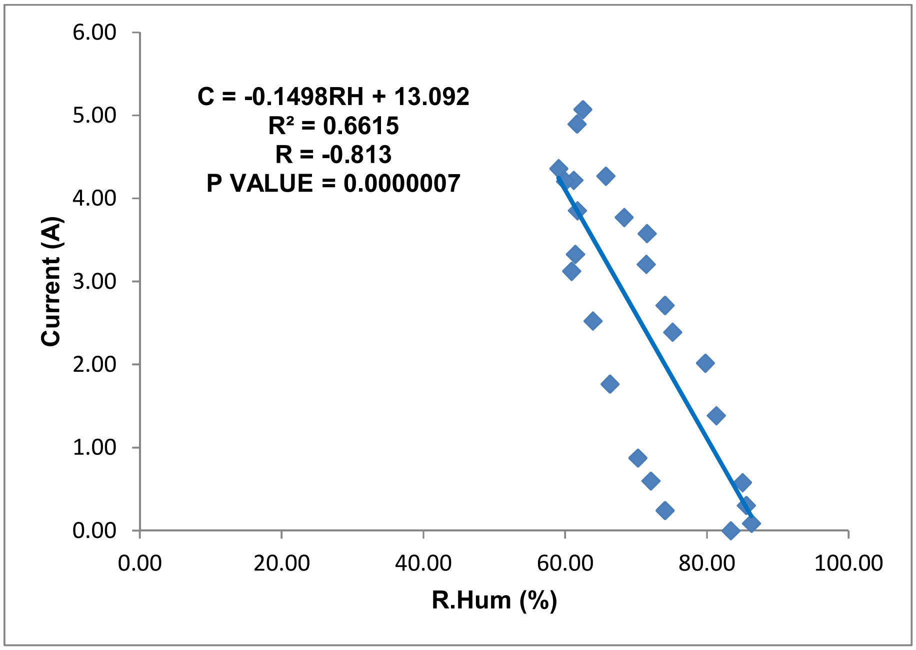


**Fig. 6. Current (A) against relative humidity (%)**

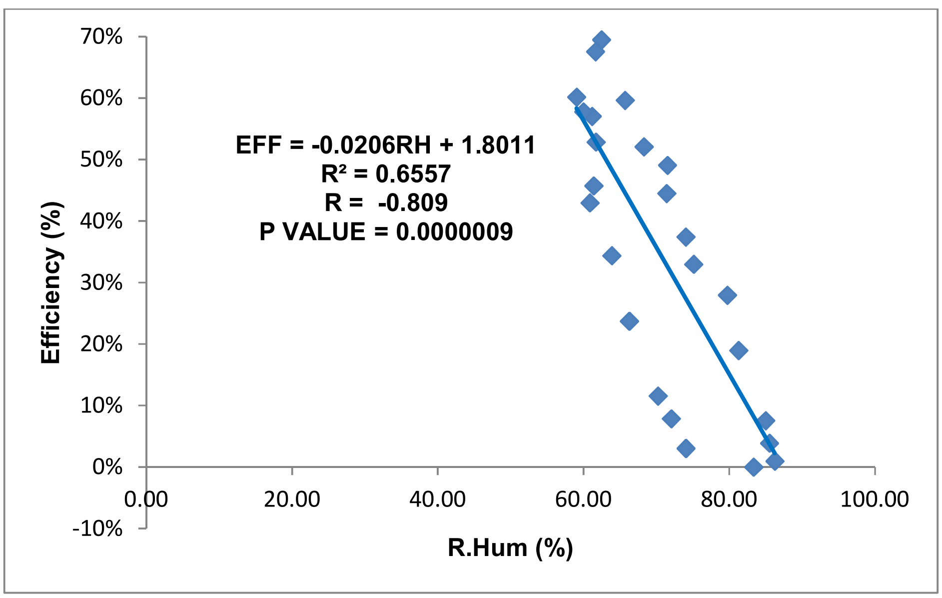


**Fig. 7. Efficiency (%) against relative humidity (%)**

Fig. 8 reveals that between 25°C and 33°C the output voltage from the panel increases. Between 33°C to 43°C the voltage remains fairly stable. Beyond 43°C voltage begins to drop indicating that temperature has significant effect on the voltage output, which is in agreement with studies by Omubo-pepple et al. [9].

Fig. 9 clearly shows a very high positive correlation between current and panel temperature. This very high positive correlation tells us that more current is produced as the panel temperature rises; this conforms to our statistical correlation and is also in agreement with studies by Omubo-pepple et al. [9].

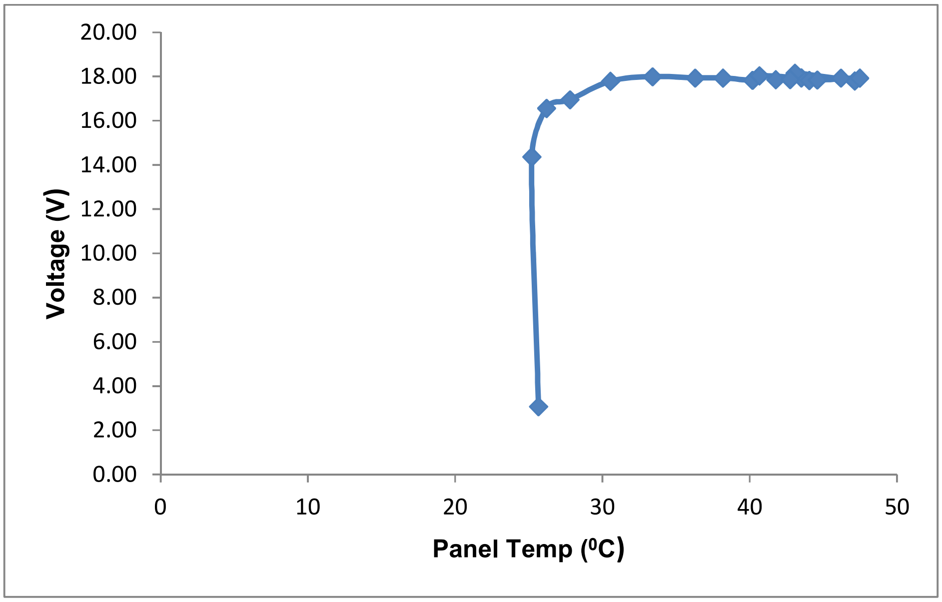


**Fig. 8. Voltage (V) against Panel temperature (°C)**

Fig. 10 shows that the efficiency of the photovoltaic increases as its temperature increases. It further reveals that this increase in efficiency as panel temperature increases is only up to the maximum operating temperature of the photovoltaic module. Above the maximum operating temperature of the photovoltaic module the efficiency of the system begins to decrease. Indicating that high temperature above the maximum operating temperature of the module does not enhance high performance.

Fig. 11 clearly shows a positive correlation between the efficiency of the photovoltaic and the ambient temperature of its surrounding. This result confirms that the temperature of the location in which a photovoltaic is installed has an effect on its efficiency.

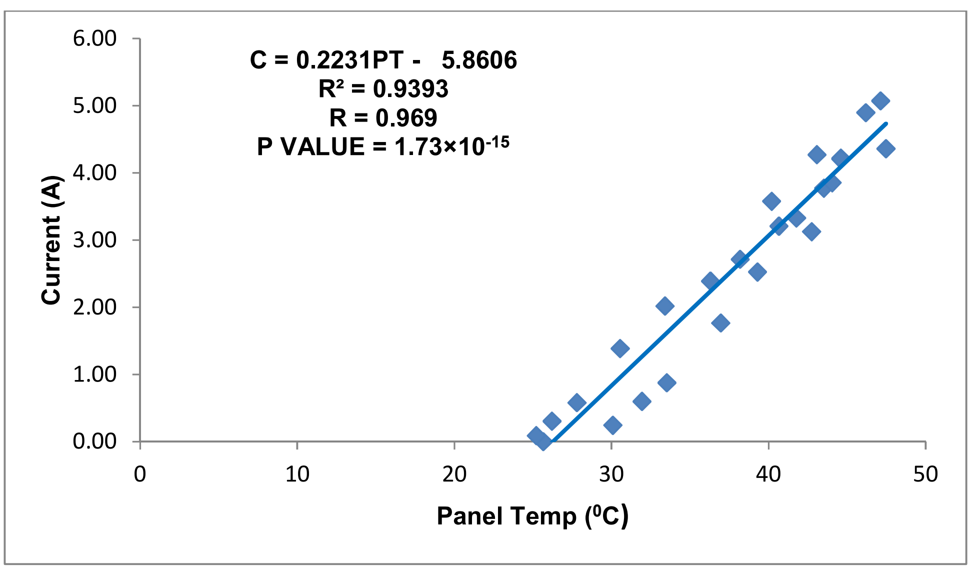


**Fig. 9. Current (A) against panel temperature (°C)**

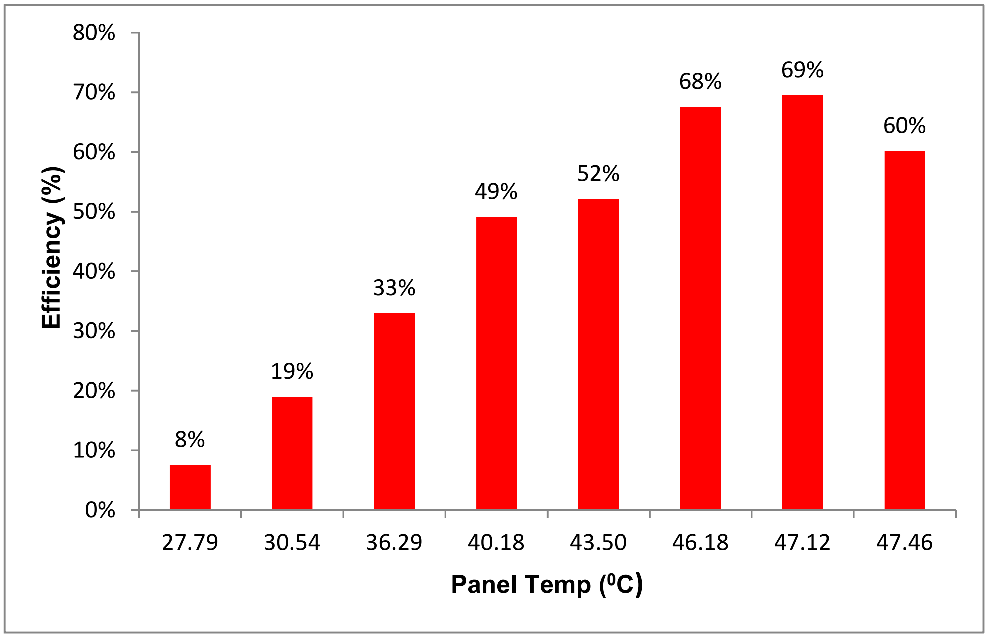


**Fig. 10. Efficiency (%) against panel temperature (°C)**

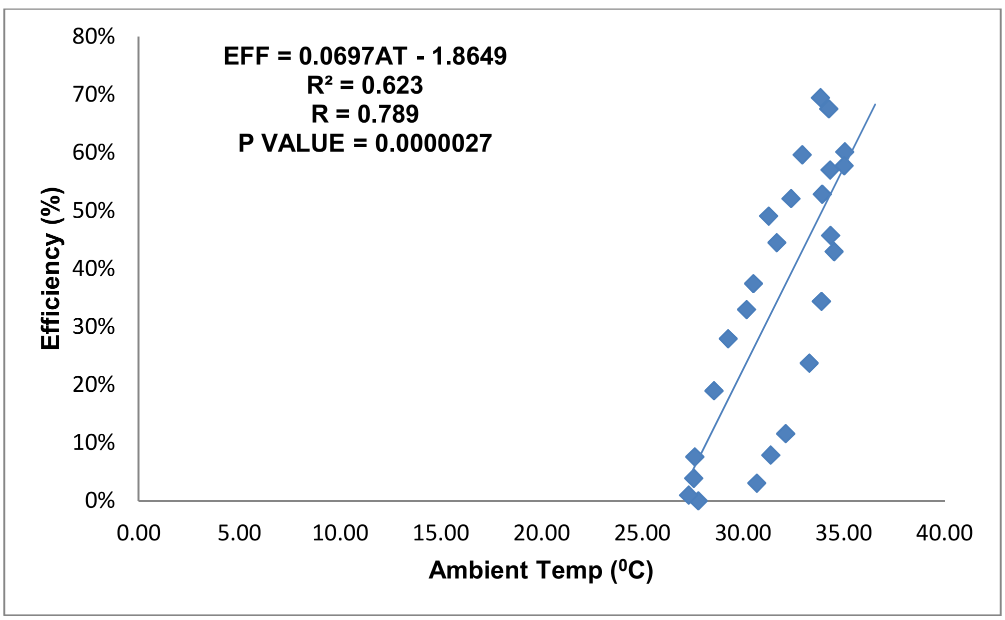


**Fig. 11. Efficiency (%) against ambient temperature (°C)**

Fig. 12 shows that during the early hours of the morning, the module temperature is lower than the ambient temperature. At noon the module temperature increases rapidly than the ambient temperature due to the high solar irradiation from the sun and rapid decrease in relative humidity. Towards sunset, the module temperature drops relatively faster than the ambient temperature. Fig. 12 also reveal that peak in efficiency is observed at a relative humidity value of 65% and module temperature of about 47°C at noon, indicating that these values of relative humidity and module temperature enhance the module performance.

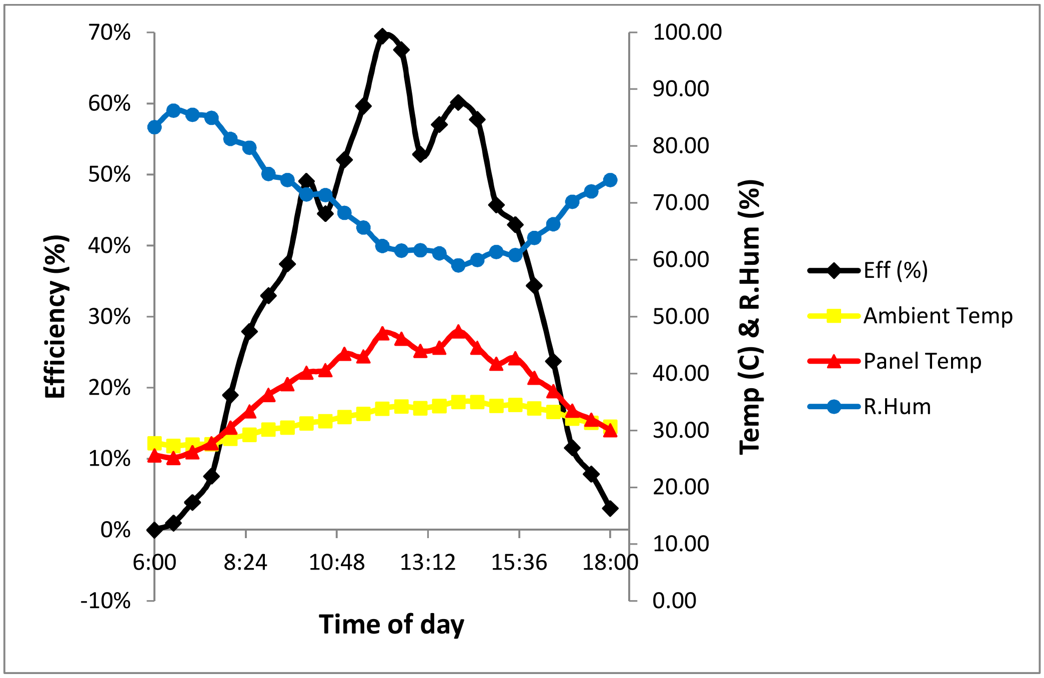


**Fig. 12. Efficiency (%) against time of day on the primary axis, temperature (°C) and relative humidity (%) against time of day on the secondary axis**

## 4. CONCLUSION

Our results shows that the output voltage from the photovoltaic remains fairly stable between 65% to 75% relative humidity and 33°C to 43°C as shown in Figs. 5 and 8 respectively. The result also shows a strong negative correlation for current, efficiency and relative humidity which indicates that high relative humidity adversely affects the performance of the photovoltaic.

Increase in current and efficiency is observed as the panel temperature rises. But this increase in efficiency as the panel temperature rises is only up to the maximum operating cell temperature of the module.

The photovoltaic module as well as the system will remain efficient if a means can be devised to keep the module temperature from exceeding the maximum operating cell temperature.

The application of photovoltaic technology in the conversion of solar energy to electricity within the location under study in the months of April and May can be said to be favorable.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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