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EFFECTS OF METEOROLOGICAL VARIABLES ON THE EFFICIENCY OF SOLAR PANEL

[1]Olayinka A.S, [1,]Ukhurebor K.E, [2]Ogunmola K and [3]Aruewamedo K*

[1]Department of Physics, Edo University Iyamho, Edo State, Nigeria
[2]Department of Physics, University of Ibadan, Ibadan, Nigeria
[3]Department of Basic Science, Benson Idahosa University, Benin City, Nigeria

Abstract

Energy from the sun is now a major focus of many researchers mainly due to the inadequacy of fossil fuels to meet the recent high demand of energy. In other to convert this energy into useful means, solar panel needs to be put in place. In this study, the effects of some meteorological variables on the efficiency of solar panel within Benin City, South-South region of Nigeria was investigated. The physical principles of mono-crystalline solar panel were examined with special reference to some meteorological variables. The value of the current and potential difference giving maximum efficiency for sunlight radiation was investigated for some meteorological conditions. It was observed that a solar panel with surface area of 0.0782 m^2 leads to maximum or near maximum performance in all cases. This again show that the intensity of the sun has a significant effect on the output of solar panel, but this is been interrupted by meteorological factors interacting with solar radiation from getting to the panel.

***Keywords*:** Atmosphere; Solar Energy; Radiation; Meteorological Variables; Climate Change

1.0 Introduction

Solar energy which is the energy from the sun is free, clean and inexhaustible sources of energy which cannot be completely obliterate [1]. This energy from the sun is now a major focus of many researchers because of the inadequacy of fossil fuels to meet the recent high demand of energy due to the advancement in technology. Also, the variations in climate are caused mainly by greenhouse gasses (GHGs) such as carbon (IV) oxide (CO_2), methane (CH_4) and nitrous oxide (N_2O); these gasses which are from the use of fossil fuels as a source of the world's greater energy source, allow solar radiation from the sun to pass through the atmosphere but do not allow the reflected heat from going back into space which leads to the rise in the earth's, hereby causing global warming temperature [1-3].

Radiation from the sun is the primary natural energy source of the earth. Climatic variables have major influence on these radiations. Variations in climatic variables can also lead to global warming, which is now a great treat in most parts of the world, Nigeria inclusive [3]. The conversion of solar energy to electrical energy through photovoltaic cells is now of great interest not only to developed nations but developing nations have also keen in as a result of the environmental and economical merits attached to it as an alternative source of energy which is cheap, clean and inexhaustible [1].

The solar energy that comes from the sun to the earth surface in one hour is approximately the amount of energy needed in the earth for one full year. The sun behaves as a black body radiator with a surface temperature of about 5800 K, which produces about 1367 W/m^2 energy density around the atmosphere [1, 4-5].

In the design and implementation of a photovoltaic (PV) solar panel the spectral factor should be taken into account, because having a thorough knowledge of the sun spectrum will help in understanding the effects of the atmosphere on the radiation, and this in turn will guide in the selection of the necessary materials that will best suit for the design and implementation of the solar cells [6]. These materials should have the capability to absorb the energy in the visible range which contains the highest energy density because almost all the entire spectrum at low temperature is found outside the visible range [6].

When global radiation which is the sum of the components from sunlight that contains beam of radiation enters the atmosphere, this might make some molecules in the atmosphere to cause three cases; absorb, scatter or makes the sunlight pass unaltered. The ultra violet part of sunlight is mainly absorbed by the ozone layer of the atmosphere while the CO_2 and water vapour constituents manipulate the visible and infrared parts. Bodies on the sea level of the earth might also reflect or absorb the sunlight. Air mass is a major factor that influence the amount of solar energy absorbed on the ground surface. As a result of the particulate nature matter in atmosphere and the distance of the path sunlight travels, the air mass 0 irradiance level – just above the atmosphere – drops from 1367 to 1000 W/m^2 corresponding to the air mass 1 – at sea level. Air mass 1.5 is addressed as the standard test condition in solar cell design [1, 7].

This study is aimed to examine how climatic conditions affect the efficiency of solar panel in converting solar energy to electricity, using different meteorological variables to investigate the resultant electricity production.

Corresponding Author: Olayinka A.S., Email: ukhurebor.kingsley@edouniversity.edu.ng, Tel: +2348035383194

2.0 Materials and Method

Area of Study

The measurement was carried out at a residential building in Benin City, the capital of Edo State, South- South, Nigeria which is situated around 40 km north of the Benin River and 320 km by road east of Lagos and located within Latitude 6°20′29″N and Longitude 5°37′55″E with an elevation of about 88 m (288 ft) above sea level. It has an approximate population of 1,125,058 making it one of the largest and most ancient cities in South-South, Nigeria. The city operates on the West Africa time zone. The coordinates are given in the latest version of the World Geodetic System (WGS 84) coordinate reference system, which is used in mapping and navigation, including the Global Positioning System (GPS) satellite navigation system and the canonical form of latitude and longitude representation uses (°), (′) and (″) for degrees, minutes and seconds respectively [8-11].

Materials

The materials used for this study are solar panel with the following specifications:

Rating power at STC (W_p):	10 W
Rating power voltage (V_m):	13 V
Rating power current (I_m):	0.13 A
Open circuit voltage (V_{oc}):	17 V
Short circuit current (I_{sc}):	0.2 A
Nominal operating cell temperature (NOVT):	45 ^0C
Dimension of panel:	0.295 m X 0.265 m
Surface area of panel:	0.0782 m^2
Cell area:	0.0018 m^2
Solar type:	Mono-crystalline

Others are; Digital multimeter which is also known as Volt-ohm meter, wires, weather monitoring system and some software which include; Surfer, SalarCalc and MS Excel.

Procedure

The solar panel was displayed on a stand of about 3 m in height for the period under investigation. The measurements of the output voltage and current were taken with the digital multimeter at an interval of one hour for each day. In addition, some weather variables like temperature, atmospheric pressure, relative humidity heat index, wind chill and relative humidity were also acquired online (accuweather).

The solar radiation ($MJ/m^2/day$) for each day was generated from software known as SolarCalc.

The power intensity and efficiency were calculated using:

$$Power(P) = current(I) \times Voltage(V) \quad (1)$$

$$Efficeiency(E) = \frac{P}{A(1000\,W/m^2)} \times 100\% \quad (2)$$

$$I_p = \frac{P}{A}(Wm^2) \quad (3)$$

Where A is the surface area of the panel and I_p is the Intensity of the panel.

The approximation of the dew point temperature using the Thumb rule was carried out:

$$T_d = T - \left(\frac{100 - RH}{5}\right) \quad (4)$$

Also we can use a more elaborate formula;

$$T_d = T_n \frac{In\left(RH/100\right) + \left(MT/T_n + T\right)}{m - In\left(RH/100 - MT/T_n + T\right)} \quad (5)$$

Where T_d is the dew point, T is the temperature, RH is the relative humidity. For the temperature range –40 °C to 0 °C, T_n = 272.62 °C and m = 22.46 while for the temperature range 0 °C to 50 °C, T_n = 243.12 °C and m = 17.62.

The dew point value was approximated automatically from the computer using MATLAB after receiving the temperature and relative humidity values and was confirmed through online calculator [11-13].

Results and Discussion

In figure 1 it was shown that the ambient temperature and the dew point follow the same pattern throughout the days for the period under consideration with the peak at 12-3pm, while the wind speed was inversely related to the ambient temperature.

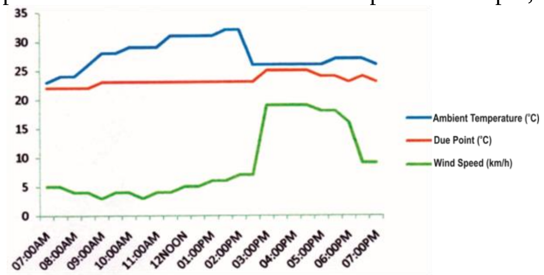

Fig. 1: Ambient Temperature, Dew point, Wind speed against Time

In figures 2 and 3, it was observed that the current and intensity output of the solar panel are directly proportional to the solar radiation. It was also observed that the radiations have little or no effect on the output voltage, this again confirmed the result of [14] that an increase in solar radiation has no effect on the output voltage; it remains relatively stable despite increase in radiation. The current has a direct relation with the intensity of the panel but the reverse is the case for voltage. Hence, the voltage does not contribute much to the intensity but the current does.

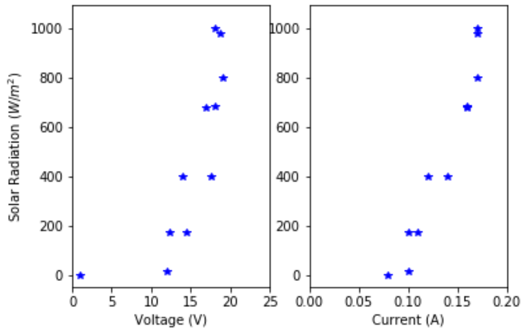

Fig. 2: Solar Radiation against Voltage and Current

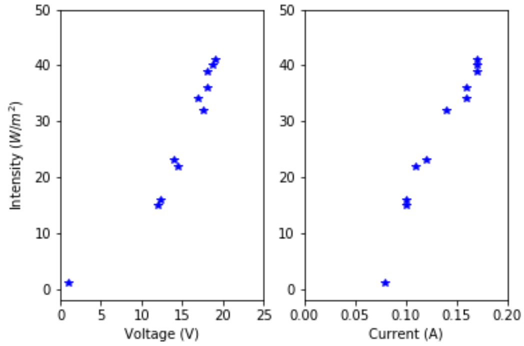

Fig. 3: Intensity against Voltage and Current

The current as seen in figure 4, shows that there is an effect of cloud cover and radiation on it. It was observed that at clear skies where the cloud cover is low, large current and radiation were recorded. The largest total average current was calculated to be by 12pm but in the daily measurement there were fluctuation due to the cloud cover. Large current was also measured between the 1-3pm. In addition to the cloud cover as observed in figure 5 where the relative humidity has a negative effect on the current produced; they are inversely proportional to each other, but has no effect on the voltage.

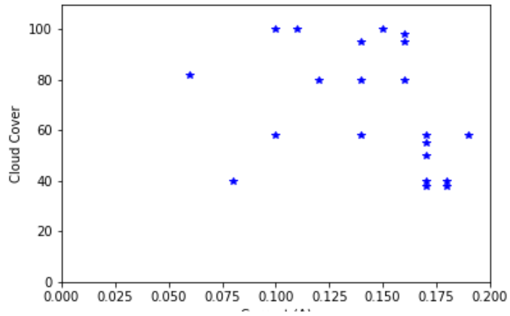

Fig. 4: Cloud Cover against Current

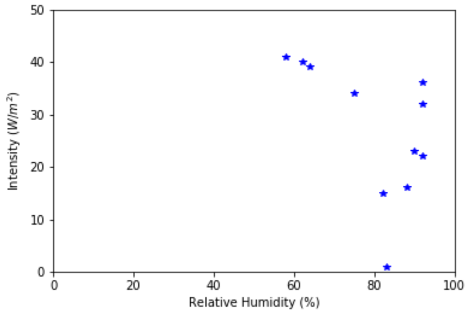

Fig. 5: Solar Radiation against Relative Humidity

The contour and 3D plot in figure 6 and 7 displayed the peak intensity at the highest value of visibility; at low intensity when the visibility is 15.

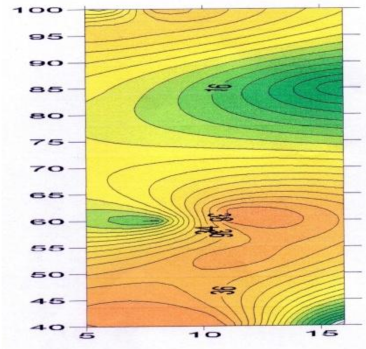

Fig. 6: Contour Plot of Visibility, Cloud and Intensity

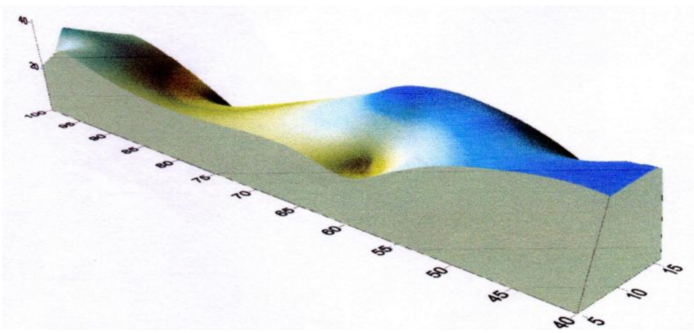

Fig. 7: 3D Plot of the Visibility, Cloud and Intensity

Conclusion

From the results obtained in this study, it will be in place to conclude that the intensity of the sun has a significant effect on the output of solar panel, which is also been interrupted by climatic factors like relative humidity and cloud cover of the area which interacts with the solar radiation from getting to the panel. Hence, the installation of PV system will best be in region with low relative humidity that is the tropic regions like the northern region of Nigeria. In case where the weather is not favourable, equipment which uses high potential difference and low current will be of great advantage in such cases, since radiation has no effect on the voltage of the solar panel.

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