

Comparative Study of Solar Radiation Availability As It Affects Solar Panel Power Efficiency in Uyo and Port-Harcourt, Nigeria.

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Abstract: The effects of solar radiation on energy conversion efficiency of solar panel in Uyo and Port-Harcourt were investigated and the analysis compared. Solar radiation measurements as well as formal meteorological data were utilized. Data were also recorded from digital instruments used. Graphical analyses were made between solar radiation and current, voltage and efficiency. Results obtained show that solar radiation is directly proportional to current and efficiency but fairly stable with voltage. A comparative analysis show that an average of 87.8Klux of solar radiation $22.4 \times 10^{-1} A$ of current, 8.2V of voltage recorded 96.5% of power efficiency in Uyo. While 67.9 Klux of solar radiation, $15.1 \times 10^{-1} A$ of current, and 7.5V of recorded 65.9% of power efficiency in Port –Harcourt. This result shows that solar panel power efficiency is better in Uyo compare to Port-Harcourt.

Key words: Solar radiation, Solar panel, Power efficiency, current, energy conversion.

I. Introduction

The solar radiation spectrum describes cosmic, gamma and x – rays with wavelengths less than 0.001 μm , ultraviolet (0.001 – 0.4 μm), visible (0.4 – 0.8 μm), near infrared and far infrared (0.8 – 100 μm), microwaves (100 – 10 x 106 μm) and radio waves less than (10 x106 μm) (Megal, 1990)In this research, the visible, near and far infrared, of the spectrum are of great interest, as this is the region where solar panels respond to generate electricity.

The availability of solar energy is affected by location, latitude, elevation, seasons and time of the day. However, the biggest factors affecting the availability of solar energy are cloud cover, and other industrial and meteorological parameter and conditions which vary with location and time.

When solar energy impinges on a transparent medium or target it is partly reflected and absorbed, while the remainder is transmitted. This is what happens when solar radiation falls on a solar panel. The reflective values are dependent upon the optical properties of the transparent object and the solar spectrum (Wieder, 1982).Solar radiation is partially depleted and attenuated as it traverses the atmospheric layers, preventing a substantial portion of it from reaching the earth's surface. This phenomenon is due to absorption, scattering and reflection in the upper atmosphere within which cloud formations occurs and weather conditions manifest.

Three major atmospheric processes modify solar radiation passing through the atmosphere and destined for the earth surface. These processes occur when incoming radiation interacts with gases and suspended particles in the atmosphere. The process of scattering occurs when small particles and gas molecules diffuse part of the incoming radiation in random direction without any alteration to the wave length of the electromagnetic energy. Two major processes are involved selective and non – selective; scattering this depends on the size of the particles and molecules (Pidwirny, 2006).

Selective scattering is caused by smoke fumes, and gas molecules from industries and cars. It may range from 10% in the early morning. Non – selective scattering is caused by dust, fog and clouds with particle size more than 10 times the wavelength of the incident radiation (Pidwirny, 2006).

Scattering however reduces the amount of incoming radiation reaching the earth's surface. A significant portion of the scattered radiation is redirected back to space. This depends on the wavelength of the incoming radiation, the size of the scattering particle and gas molecules. The direct result of these scattering processes is our blue sky which corresponds to these wavelengths that are best diffused (Macree, 1998).

Absorption is a process by which solar radiation is retained by the particle or molecule and is converted into heat energy. The creation of this heat energy also causes the substance to emit its radiation. Absorption by thick cloud formation, gases, water vapour and particulate matter causes depletion mainly in the short wave region of the spectrum, this region is called the absorption band. The gases involved in this absorption are mainly ozone and carbon dioxide (Qualls, 1983).

The final process in the atmosphere that modifies incoming solar radiation is reflection. This is a process where sunlight is redirected 180° after it strikes an atmospheric particle. This redirection causes a 100% loss of isolation. Most of the reflection in our atmosphere occurs in the clouds when sunlight is intercepted by particles of liquid and frozen water. This occurs during rainy seasons. Thin clouds may reflect less than 20% of incident solar radiation, whereas a thick and dense cloud may reflect over 80%. (Acra, 2006).

In Nigeria, however, few studies have reported the measurement and analysis of solar radiation and its components. Akpabio and Udoimuk (2003), focused on the characteristic distribution of total diffuse and direct radiation at Calabar.

Ettah *et al.*, (2011), investigated the relationship between solar radiation and current, voltage and solar radiation efficiency of solar panels in Port-Harcourt, Nigeria. Their results show that there is direct proportionality between solar radiation and output current as well as solar radiation and power efficiency of solar panels, implying that an increase in solar radiation availability will increase output current and hence power efficiency of solar panels and vice versa.

Their investigation also reveals that conditions such as thick cloud cover, air pollution due to gas flares from activities of oil industries, gas pollution from cars in the overpopulated city, production and servicing of oil companies peculiar in Port-Harcourt affect the availability of solar radiation, and hence will affect the power efficiency of solar panels negatively.

The main target of this paper is to investigate and compare the availability of solar radiation in Uyo and Port-Harcourt and determine its impact on the power efficiency of solar panels in these two cities.

II. Study Area

Uyo city is located at latitude 5°03'N and 7°57'E. It has a relatively flat, low-lying landscape. The most prominent feature of the physical landscape of Uyo is the ravine that lies in the north-eastern part of the city. The ravine contains small perennial streams. These are tributaries of the Ikpa River, which is the main water course in the vicinity of the city. Uyo lies within the Niger Delta and so enjoys a humid tropical type of climate with high rainfall, high temperatures and high relative humidity (Akpabio *et al.*, 2005).

The mean annual rainfall for Uyo city is about 215mm. The trend is for the monthly rainfall to run to a peak in July, and decrease in August (August break) and peak again in September before it finally decreases in December. The mean average temperature is about 29 ± 2°C. Relative humidity except for a short period of the season remains at an average of 70% to 80% throughout the year. Sunshine duration in Uyo is also high (Akpabio *et al.*, 2005).

Port-Harcourt is the capital of River State. It lies on latitude 4°45' and 4°60'N and longitude 6°50' and 7°30'E of the equator. It is bounded by Bayelsa state in the west, Abia state in the east, Imo in the north and the Gulf of Guinea in the south and lies along the Bonny River. Port-Harcourt has a population of about four million people (2007 population estimate). The climate condition is characterized by high temperature, high humidity and rainfall with high solar radiation. The climate is humid tropical. It is marked by wet and dry seasons. Mean ambient temperature is between 28 ± 2°C and 26 ± 2°C for dry and wet seasons respectively.

Relative humidity is above 80%. Mean annual sunshine in Port-Harcourt is about 1436 hours, while mean monthly values vary between 53.5 and 180.2 hours in the months of July and December respectively. Port-Harcourt experiences high rainfall almost throughout the year with over 80% occurring in the months of May to September with a peak in July.

The city houses the highest number of petroleum industries in Nigeria and has high gas emissions from these industries, gas flares and cars from the very high populated environment (Ebipade, 2008).

III. Materials And Method

A general purpose digital thermometer Model 220K, used with type K temperature probe was used to obtain solar panel temperatures. Before use, the probe and instrument were calibrated to zero °C following the manufacturer's guideline. The temperature probe was placed in an ice bath to stabilize the reading, and then the mode keys were pressed to °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 890 digital Multimeter. This is an easy-to-use 3.5 digital liquid crystal display (LCD) meter, designed to read resistance (R), Voltage (V), current (I) and capacitance (C) to ensure effective and accurate data collection. Results collated were input into equation (2), Kachhava (2003), to calculate solar panel power efficiency output

$$\text{Efficiency} = \frac{\text{power of Solar panel}}{\text{Area of Solar panel} \times 1000 \text{ W/m}^2} \times 100\% \dots\dots\dots (2)$$

The Solar panels were designed with a glazed front and back. Glazing was with a long –Iron glass with a 4mm thickness. The cell use in the study was a monocrystalline silicon type with an area of 1.9m². And a solar temperature coefficient of 0.005/K, its maximum output current and voltage were 2A and 8A, respectively.

The method of study involves the initial collection of current and voltage output data from the solar panel, using the digital multimeter (Alda Model AV 0890C). Solar radiation was measured with BK. Precision compact digital light meter (model 615).

The solar panel and the thermometer where placed on the same horizontal test plain at the height of meter facing the sun. Instantaneous measurements were made at both stages at intervals of 5minute averaged over 30 minutes. This was done between the hours of 6.00am to 5.00pm for fourteen days to ensure effective and accurate data collection.

IV. Results.

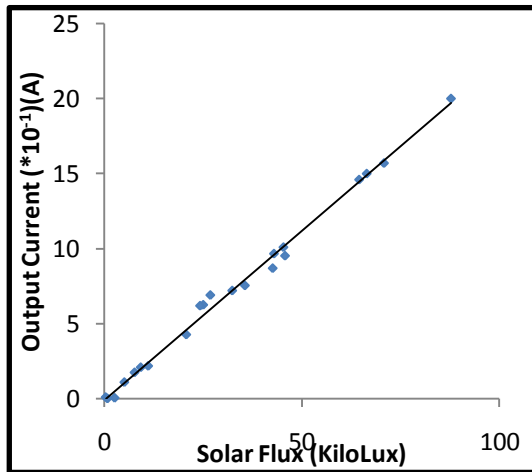


FIG 1A: GRAPH OF OUTPUT CURRENT AGAINST SOLAR FLUX IN PORT HARCOURT FLUX IN UYO

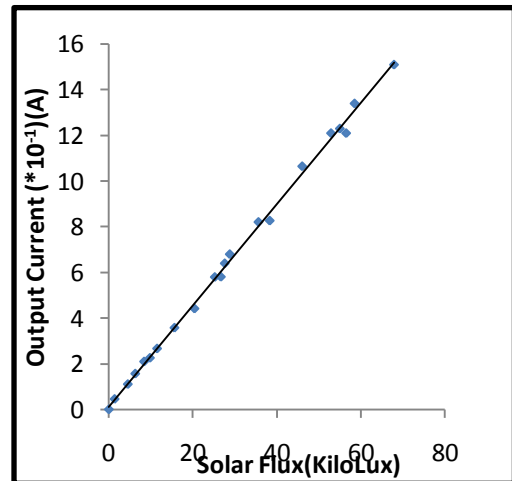


FIG 1B: GRAPH OF AGAINST SOLAR

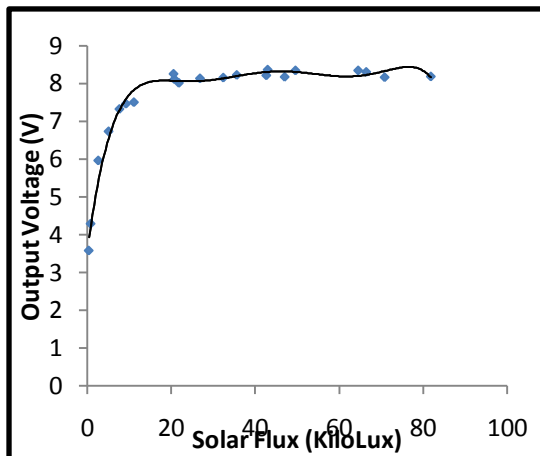


FIG 2a: GRAPH OF OUTPUT VOLTAGE AGAINST OUTPUT VOLTAGE AGAINST SOLAR FLUX IN UYO HARCOURT

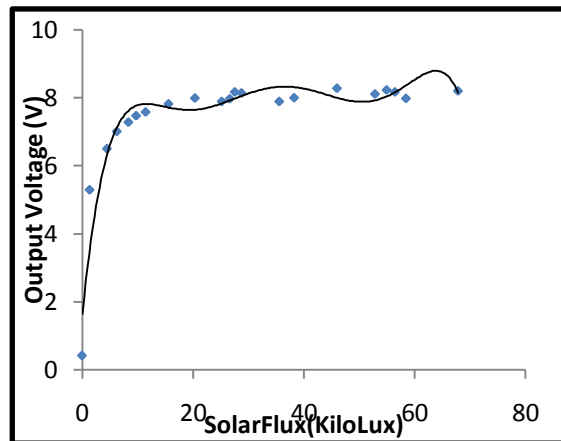


FIG 2b: GRAPH OF SOLAR FLUX IN PORT

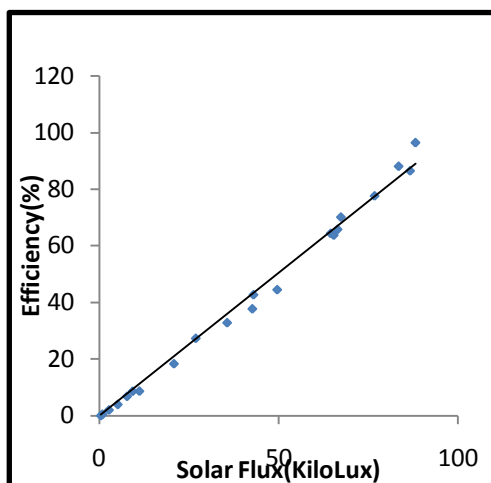


FIG 3a: GRAPH OF EFFICIENCY AGAINST AGAINST SOLAR FLUX IN UYO HARCOURT

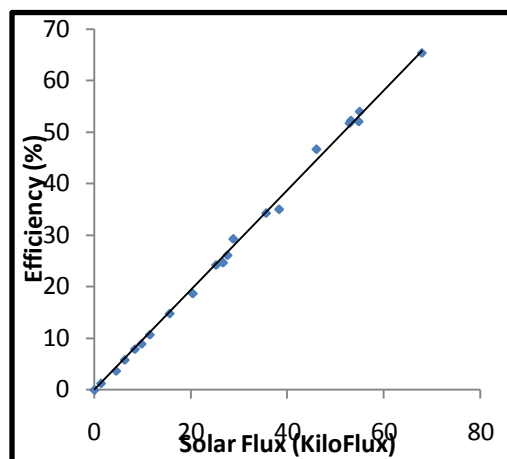


FIG 3b: GRAPH OF EFFICIENCY SOLAR FLUX IN PORT HARCOURT

V. Discussion

Effects of Solar Flux on the Efficiency of Solar Panel in Uyo.

Output current recorded in Uyo is relatively high, due to high solar flux observed. This is because of low relative humidity recorded, indicating clear sky. Figure 1a shows that output current is directly proportional to solar flux as indicated by the straight line graph pass through the origin. Solar flux of 87.8 klux recorded a current of $22.4 \times 10^{-1} A$.

Increase in solar flux has very little effect on the output voltage of solar panel. Figure 2ashows that solar flux between (11.2 and 70.9) klux generates output voltage between 8.1 and 8.2 V indicating output voltage stability despite increase in solar flux.

Figure 3a shows a straight line graph passing through the origin indicating proportionality between solar flux and efficiency of solar panel. This also indicates that rich solar flux increases output current which increases efficiency.

Efficiency of about 96.5% was recorded when solar flux was 87.8 klux and current of $22.4 \times 10^{-1} (A)$ was also recorded.

Effects Of Solar Flux On The Efficiency Of Solar Panel In Port Harcourt

Solar panel output current is directly proportional to solar flux since the graph is a straight line. Increase in solar flux is observed when relative humidity is low, less dust, haze and low air pollution. Figure 1b shows that output current of about $15.1 \times 10^{-1} A$ was recorded when solar flux was 67.9 klux.

Increase in solar flux has little effect on output voltage of solar panel. The graph in figure 2b shows that output voltage is stable despite increase in solar flux. For instance, increase in solar flux from 20.4 Klux to 67.9 Klux shows output voltage between 8.0V and 8.2V with a difference of .2V.

Efficiency and solar flux are directly proportional, just like output current and solar flux. These are shown in figures (1b) and (3b) which straight line graphs are passed through their origins further indicating that current output directly determines efficiency of solar panel.

Efficiency of about 65.4% was recorded when solar flux was 67.9 klux giving current of $15.1 \times 10^{-1} A$

Comparison of solar radiation availability and power efficiency of solar panels in Uyo and Port-Harcourt.

Solar radiation of 87.8Klux was recorded in Uyo this produced $22.40 \times 10^{-1} A$ of current translating to about 96.5% power efficiency. While solar radiation of 67.9Klux, produced $15.1 \times 10^{-1} A$ to 65.4% of power efficiency.

Port-Harcourt recorded 67.9Klux of solar radiation approximately 20 Klux less than Uyo, this is due to High relative humidity (cloud cover), gas flare from activities of oil industries and oil servicing companies. Air pollution from the cars, over populated city, generating set and fumes from other production companies. Ettah, (2007) and Ebipade, (2008).

According to Ettah, *et al*, (2011), in their work, the relationship between solar radiation and efficiency of solar panel in Port- Harcourt, also ascertain that solar radiation has direct proportionality with current and power efficiency, this implies that the high power efficiency in Uyo is due to high solar radiation availability

following low population density, less oil industries, zero gas flare and very few production industries as compare to Port-Harcourt.

VI. Conclusion:

A direct relationship has been observed between solar radiation availability and power efficiency of solar panel. This implies that where solar radiation is high, solar panel output current and power efficiency are high.

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