Physical Science International Journal

Volume 27, Issue 1, Page 1-15, 2023; Article no.PSIJ.96048
ISSN: 2348-0130

Diurnal Analysis of the Performance of Photovoltaic Systems under the Guinea Savannah Atmosphere in Ogoja, Cross Rivers State, Nigeria

Armstrong O. Njok [a*], Effiong A. Archibong [b] and Gertrude A. Fischer [b]

[a] *Department of Physics, Faculty of Physical Sciences, Cross River University of technology (CRUTECH), Calabar, Calabar, 540252, Nigeria.*
[b] *Department of Electrical Electronics, Faculty of Engineering, Cross River University of technology (CRUTECH), Calabar, Calabar, 540252, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/PSIJ/2023/v27i1767

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/96048

Original Research Article

Received: 19/10/2022
Accepted: 28/12/2022
Published: 15/01/2023

ABSTRACT

A thorough experimental investigation was carried out to diurnally analyze the performance of photovoltaic systems deployed for domestic purposes under the guinea savannah atmosphere in Ogoja, Cross River State, Nigeria. In this study, the time of day to expect maximum efficiency from the photovoltaic (PV) module is shown, and the time of day that the panel temperature will exceed it maximum operating cell temperature is also shown. Instruments employed in the process include a digital solar power meter, digital hygrometer, digital infrared gun thermometer and a digital high precision photovoltaic panel maximum power point tracker (MPPT) to track and determine the maximum power, voltage and current produced by the photovoltaic module. The result shows that

**Corresponding author: E-mail: Njokarmstrong@unicross.edu.ng;*

the highest level of efficiency was attained at 14:30 which reveals that the climatic condition which occurs at 14:30 is the most favorable for PV systems deployed for domestic purposes at the location. The study shows that 42% and 40^{0}C is the best relative humidity and PV temperature level for optimum PV efficiency at this location. In addition, the temperature of the study location appears encouraging as on average, the panel temperature will rarely exceed the maximum operating cell temperature for months besides January and march in which a cooling mechanism to regulate the panel temperature may be needed to avoid a massive loss in efficiency. An altitude of 85m above sea level makes the location relatively favorable for receiving intense solar radiation. With 90% efficiency assured, the location can be seen as suitable for generating electricity via PV technology and installing solar farms for commercial purposes.

Keywords: Time of day; Ogoja; climatic factors; PV technology; efficiency.

ABBREVIATIONS

PV : *Photovoltaic*
V_{mp} : *Voltage at maximum power*
I_{mp} : *Current at maximum power*
P_{mp} : *Power at maximum power*
P_{mea} : *Measured power*
P_{max} : *Power at STC*
MPPT : *Maximum power point tracker*
STC : *Standard test condition*
Amp : *Ampere*
Fig : *Figure*

1. INTRODUCTION

The war between Russia and Ukraine has brought about a significant shortage in fossil fuel products worldwide leading to an untold spike in the cost of these products [1]. Electrical power generation through the use of fossil fuel by people in bucolic areas which has no access to grid electrification now finds it difficult to generate electricity as the price of fossil fuel product continues to surge [2]. Utilizing fossil fuel products for the generation of electricity has an undesirable effect due to the role it plays in contributing to climate change globally.

Energy security coupled with the impending collapse of fossil fuel reserves and the issue of global climate change have triggered technological advancement in renewable energy [3]. Irrespective of the fact that almost 80% of the world's energy is generated through fossil fuel [3], it is expedient to consider renewable energy as a solution towards combating the looming energy security threat. Renewable energy has become very valuable due to its unlimited nature coupled with its technology that has very little impact on environmental dilapidation. The available renewable energy sources include biomass, geothermal, solar thermal, tidal and wind, but intense devotion is directed towards solar energy [4].

In Nigeria, a grid electricity supply is irksomely epileptic. This epileptic nature has significantly contributed to the lethargic growth of the country's economy [5-6]. Moreover, with the current state of Nigeria and its policies that are politically driven because its economy is majorly driven by crude oil, the adoption of grid-tie photovoltaic systems to combat its epileptic power nature is not visible even in the foreseeable future. However, with the application of stand-alone/off-grid photovoltaic systems, electricity can be made available to rural settlements that are settled 200 kilometers from the closest electric grid connection, thus paving way for them to have access to clean electricity which will enable them pump clean water from underground aquifers for drinking or watering crops or cattle. In addition, stand-alone/off-grid photovoltaic systems can also pave way for electricity to be provided to stations for data surveying and transmission (meteorological, seismic and fires) and remote transmitter stations in mountain regions to enhance communication without building roads to deliver diesel fuel for its generator [7-8]. If Nigeria desires to realize the level of socio-economic development it craves, then its population must get sufficient and cost-effective supply of energy [9].

Since energy has become very valuable in our life, its supplies should be sustainable and easily accessible. The energy demand of the world today is escalating leading to enormous pressure on conventional sources. The pressure on the existing conventional sources plays a significant role in directing attention toward alternative sources of energy that sustainably ensure the availability of energy. The reliable option for a clean energy source, which can guarantee energy security coupled with its abundant nature is the sun's energy [10].

The Photovoltaic (PV) system which is designed for the generation of electricity through the PV effect is a well thought-out technology for the harvesting of solar energy [11-13]. The PV technology is dominant in the solar energy sector and has revealed that it can generate electricity for an extensive range of applications, scales, geographic locations and climates.

The operation of PV systems envelops different features which include solar cell technology, charge controller technology, battery type and inverter design. Regardless of these amazing features, PV systems are still affected by climatic factors including solar power, relative humidity, temperature variations, aging of the solar cell, dust accumulation and wind speed [14-16]. At the moment, the PV system's conversion efficiency is estimated at diverse efficiencies which lie between 7 and 40% [17-18], though they are designed and manufactured to function best in certain weather condition called standard test condition (STC). But when they are deployed for domestic purposes in a specific location or region, climatic factors such as relative humidity as well as temperature affect the efficiency of the system for that specific location or region. The shift or variation in the performance of a PV system for a specific location or region is a result of the changing weather conditions, hence, forcing PV modules to function under conditions different from the normal operating condition they were initially designed for.

PV system performance does not only depend on its amazing features but also on the climatic factors to which it is subjected, which is related to the actual location of installation [19]. One of such climatic factors as relative humidity plays a vital role in its performance. Since at every instant solar radiation intensity is changing continuously, then electricity production by PV systems will also be changing. Hence revealing that the energy generated by PV systems at any instant is still very much a function of climatic factors [20-21].

Numerous researchers have presented studies on the performance of PV systems under different climatic conditions, but much of the information accessible is only coherent for a particular region or location. Generally, there is a deficiency of germane information on the diurnal analysis of photovoltaic performance in Guinea Savannahs especially in Nigeria that can be efficiently employed in the design and sizing of PV systems. Different types of PV modules and systems have been studied in different climates of different geographic locations and taken into account by researchers [22]. Among all the key climatic factors, only solar power, relative humidity and temperature have been considered for this study.

PV module specifications by their various manufacturers do not truly conform to outdoor results when analyzing the performance of PV systems, hence climatic factors at the location of installation must be taken into consideration [23]. In the northern part of Cross River State, Nigeria, no such study on diurnal analysis of PV systems has been done before to confirm if the manufacturer specification conforms with the climatic conditions. In an actual scenario once the system is installed, it is very difficult to monitor the system performance as it can be easily affected by soiling, shade and so forth. But the performance of the system at any instant largely depends on climatic factors. For this reason, steps have been taken to analyze the performance of PV modules diurnally. Utilization of PV module in locations with very high relative humidity will adversely affect its efficiency because the module will not receive the recommended level of radiation for it to function optimally, since water droplets in the atmosphere will obstruct radiation from reaching it [24-28]. Also, operating PV modules in locations with very low relative humidity will enhance the module temperature to rise beyond its maximum operating cell temperature, hence module performance will be hindered [29-35]. Unawareness of which time of day PV systems in specific locations are most efficient and might need thermal regulation leads to improper maintenance of the system and even loss of a significant amount of energy. This study offers information that may enable users to healthier maintenance of PV systems and gain more power output.

This location is chosen for the study because of its elevation above sea level and its climate. This region often experiences epileptic power supply that has hinder the growth of socio-economic activities. A huge percentage of people in this region has difficulty or no access to grid electricity, which has led them to source for alternative form of energy. However, a percentage of the population in this region has adopted solar energy as a viable means for electricity generation but they complain of photovoltaic systems been ineffective in meeting their daily power needs, hence the need for this study to enlighten the population of when to expect maximum efficiency from PV systems and also to enable engineers into designing efficient PV systems for this region. The crystalline PV technology is the technology that is dominant in the Nigeria's market which has led to its wide usage in Nigeria, but the polycrystalline PV technology is the cheapest and most easily accessible, especially in this location.

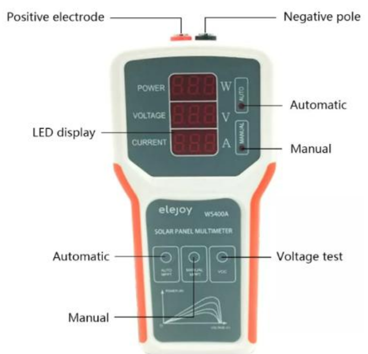
2. MATERIALS AND METHODS

2.1 Materials Employed in This Study

A polycrystalline PV technology of the model AF-130W manufactured by Africell solar with a rated maximum power of 130W. The electrical characteristics of the technology are presented in Table 1. An intelligent digital photovoltaic panel maximum power point tracker (MPPT) of the precision model WS400A was employed to track and determine the maximum power, current and voltage generated by the PV technology as revealed in Fig. 1a. A digital hygrometer of the model KT-908 as shown in Fig. 1b was employed for effective tracking of the humidity level at the surface of the PV technology. While the amount of solar power reaching the surface of the PV technology was monitored with the aid of a digital solar power meter of the model SM206 as displayed in Fig. 1c. The surface temperature of the PV technology was accurately determined with the aid of a digital infrared gun thermometer of the model GM320 as shown in Fig. 1d.

Table 1. PV technology manufacture specification

Electrical specification	Value
Maximum Power	130W
Current at Maximum Power	7.18A
Voltage at Maximum Power	18.10V
Short Circuit Current	7.91A
Open-circuit Voltage	21.72V
Number of cells	36
Module dimension	1480mm*670mm*
Manufacturer	35mm
Model	Africell solar AF-130W



(a) MPP tracker

(b) Hygrometer

(c) Solar power meter

(d) Infrared gun thermometer

(e) Solar charge controller

(f) Solar gel battery

(g) Inverter

Fig. 1. Instruments used in data acquisition / materials used for the experimental setup

2.2 Experimental Setup

The PV technology was installed horizontally flat facing the sun on a platform one metre above sea level. Cables were connected from the output of the PV technology to the input of a two-way switch. One output of the two-way switch was connected to the MPP tracker from which the maximum power points of the PV technology were tracked as described in Fig. 2. While the other output of the two-way switch led to the input of the solar charge controller (Fig. 1e). The output of the charge controller was connected to the solar gel battery (Fig. 1f) for smooth charging of the battery. Form the battery loads were powered via an inverter (Fig. 1g).

2.3 Measurement Procedure

Measurements were taken for a duration of four months (July to October) from 6:00 to 18:00 with an interval of 30 minutes between each measurement. In obtaining data, the time of day was noted, while the power, current and voltage from the photovoltaic module were ascertained with the aid of the intelligent PV panel MPP tracker. The humidity level, the surface temperature and the amount of solar power reaching the surface of the PV technology were measured through the digital hygrometer, digital infrared gun thermometer and digital solar power meter respectively.

2.4 Data Processing and Measurements

This study was conducted in real-time outdoor conditions with varying climatic factors. The open circuit voltage V_{oc}, the instantaneous voltage V_{mp} and Current I_{mp} at maximum power as well as P_{mp} under a particular real-time climatic condition were measured directly through the intelligent PV panel MPP tracker. The PV technology efficiency is considerably influenced by the voltage and current it can produce which in turn is affected by several climatic factors and maintenance. The current at maximum power I_{mp}, the voltage at maximum power V_{mp} and the open circuit voltage V_{oc} of the PV module are greatly influenced by several parameters, including design of the PV system, maintenance of the PV technology, and temperature (T), and can be determined via (1) and (2) respectively as shown by [36].

2.4.1 Load current

$$I = I_{ph} - I_0 \left(\frac{qV}{e^{K_B T}} - 1 \right) \quad (1)$$

2.4.2 Open circuit voltage

$$V_{oc} = \frac{K_B T}{q} ln \left(\frac{I_{ph}}{I_0} + 1 \right) \quad (2)$$

Where I_{ph} is the photogenerated current, I_0 is the diode reverse saturated current, q is the electron charge, K_B is the Boltzmann constant, T is the absolute temperature, and V is the voltage at the terminals of the PV module.

According to [37] (2) can be approximated and reduced to (3)

2.4.3 Open circuit voltage approximated

$$V_{oc} = \frac{K_B T}{q} ln \left(\frac{I_{ph}}{I_0} \right) \quad (3)$$

According to [38], the photogenerated current I_{ph} is equal to the short circuit current I_{sc} and is

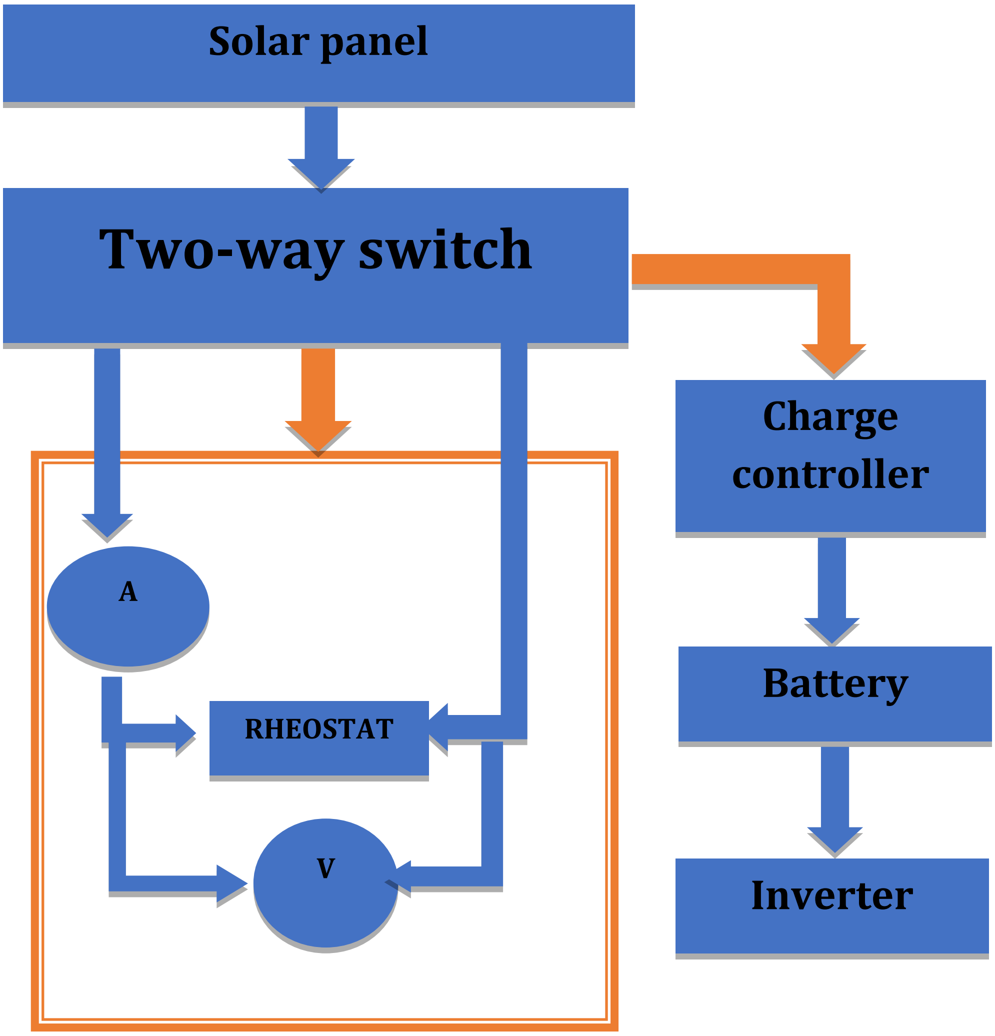


Fig. 2. Experimental setup

closely related to the photon flux incident on the PV modules and given as (4)

2.4.4 Short circuit current

$$I_{SC} = bH \tag{4}$$

Where H is the incident solar flux and b is a constant that depends on the junction properties of the semiconductor.

In contrast, from the data obtained, the normalized power output efficiency was computed by with (5) as shown by [39]. The efficiency of the PV technology at STC was confirmed via (6) as shown by [40].

2.4.5 Normalized power output efficiency

$$\eta_p = \frac{P_{mea}}{P_{max}} \times 100\% \tag{5}$$

2.4.6 Module efficiency

$$\eta_{Mod} = \frac{Power\ of\ photovoltaic\ module \times 100\%}{Area\ of\ photovoltaic\ module \times 1000W/m^2} \tag{6}$$

Where P_{mea} is the measured power at maximum power points, while P_{max} is the maximum power of the PV module (as specified by the manufacturer) at STC.

2.5 Study Area

Ogoja which has an elevation of 85m above sea level, is situated on longitude $8^0$47'57.23" E and latitude $6^0$39'30.24" N in Cross River State (South part of Nigeria). Ogoja has the tropical savanna climate prevailing, the raining season is warm, oppressive, and overcast. At the same time, the dry season is hot, muggy, and partially cloudy. Throughout the year, the temperature usually varies from *18.3°C* *(65°F)* to *32.2°C*

(*90°F*) and hardly drops below *15.56°C* (*60°F)* or rises above *33.89°C (93°F)* [41]. The mean temperature throughout the year in Ogoja is 26.78°C (80.2°F). The warmest month, on average, is March, with a mean temperature of 29°C (84.2°F). while the coolest month on average is July, with a mean temperature of 25.5°C (77.9°F). Throughout the year, the mean relative humidity is 76%, and the annual wind speed is 3.68m/s [42]. Furthermore, January is the least humid month with a mean relative humidity of 29%, while August is the most humid month with a mean relative humidity of 86% [43]. But the location of this study is the Cross River University of technology (CRUTECH) campus at Ogoja, with bearing of Longitude $8^{0}46'23.1"$ E and Latitude of $6^{0}37'35.4"$ N.

3. RESULTS AND DISCUSSION

This section presents the results acquired from experimental measurement and analysis, it is divided into four parts. The first part discusses the variations in the climatic condition during data acquisition in the study area. The second and third part presents the analysis of the voltage and current performance of the PV technology with different climatic factors at each time of day. The last part displays the level of efficiency attained by the PV technology throughout the day with varying levels of the climatic factors. it should be noted that the voltage, current and power used in the analysis of the results are the maximum voltage, current and power respectively that the modules produces instantly under a particular climatic condition.

3.1 Diurnal Analysis of Climatic Condition at the Site

Fig. 3 reveals fluctuating climatic condition at the location of study, i.e., solar power, relative humidity and temperature. It reveals high level of relative humidity during the morning which decreases towards noontime; which indicated that as solar power increased, relative humidity decreased. It was observed that the highest level of solar power should be expected at noontime which implies that the maximum efficiency of PV modules should be expected at this time. The figure further revealed that as early as 8:30 the solar power will be above 200W/m^2 which is the level of solar power required to generate voltage close to the maximum module voltage according to [21]. The figure also reveals that the highest panel temperature and lowest relative humidity level should be expected at 12:30 and 11:00 respectively, which indicates that the panel temperature might exceed the maximum operating cell temperature at this time. Hence a drop in efficiency should be expected if cooling mechanism is not incorporated in the PV system design. Temporary fluctuations of climatic conditions are normally caused by turbulence within the atmosphere.

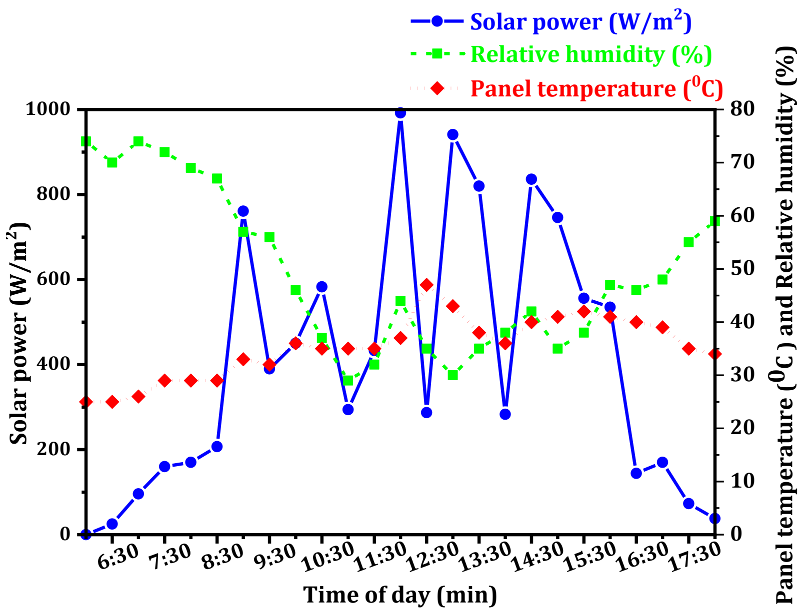


Fig. 3. Variations in Climatic factors at study location

3.2 Diurnal Analysis of Voltage Performance with Varying Climatic Factors

Fig. 4 displays the voltage behavioral pattern of the PV technology with respect to fluctuations in solar power. The figure reveals a rise in voltage between 6:00 to 8:30 before attaining stability with a voltage close to the PV voltage at STC (V_{mp}). This rise in voltage is accompanied with a corresponding rise in solar power from 0 to approximately 200W/m^2. Beyond 200W/m^2 the voltage remains almost stable and close to V_{mp} regardless of the amount of solar power reaching the surface of the PV technology [21].

Fig. 5 displays the voltage behavioral pattern of the PV technology with respect to fluctuations in relative humidity. The figure reveals a rise in voltage between 75 to 67% of relative humidity which occur between 6:00 to 8:30. Below 67%, stability in voltage close to V_{mp} was attained. While Fig. 6 which displays the voltage behavioral pattern of the PV technology with respect to its panel temperature reveals that the ripples found in the stable region of the voltage is simply due to the fluctuations in its panel temperature. Fig.6 further reveals that peak in panel temperature should be expected at 12:30 and above the maximum operating cell temperature.

Fig. 4 to Fig. 6 displays a favorable voltage response pattern regardless of the constant fluctuations in the climatic factors at the location of study and brought to light that generation of stable voltage via PV technology could be achieve with ease.

3.3 Diurnal Analysis of Current Performance with Varying Climatic Factors

Fig. 7 displays the current response of the PV technology with respect to fluctuations in solar power. It shows a rise and fall in current just as the solar power rises and falls which confirms that the level of current generated is highly influenced by solar power as shown in equation (2) by [36], which is also in agreement by earlier studies by [21] which reported that a direct relationship exist between PV current and solar power. In addition, the figure also brought to light that peak performance in current should be expected at 14:30.

Fig. 8 depicts the current generated by the PV technology with fluctuations in relative humidity. It shows that substantial amount of current above 3amps can be generated by the PV technology for relative humidity level ranging between 57% to 32% which occur between 9:00 and 16:00. Also, from the figure it was observed

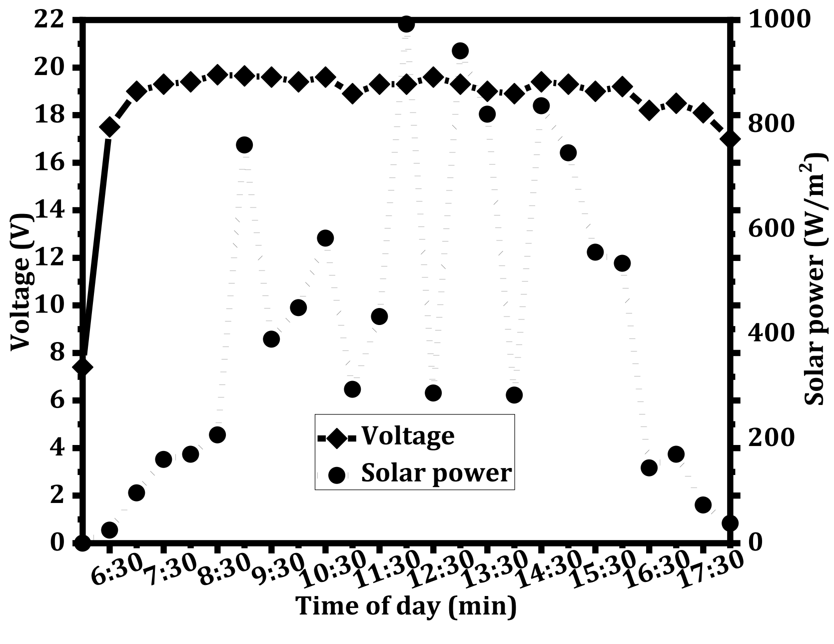


Fig. 4. Voltage produced and solar power received with respect to time of day

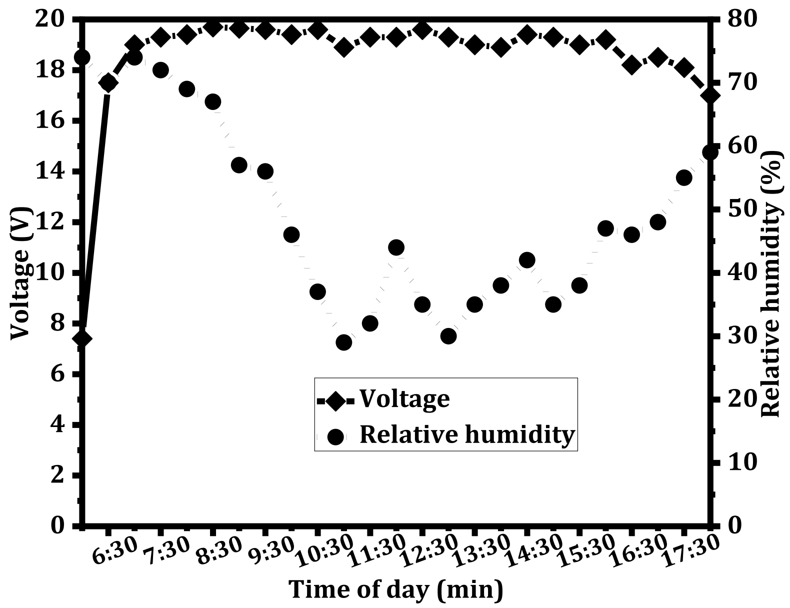


Fig. 5. Voltage produced and levels of relative humidity with respect to time of day

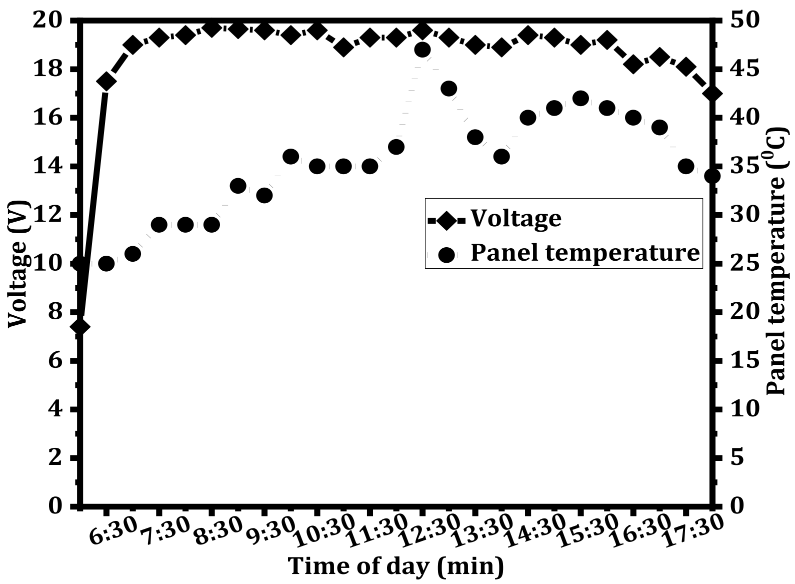


Fig. 6. Voltage produced and panel temperature with respect to time of day

that peak performance in current occurred at a relative humidity level of 42%, suggesting that 42% could be the most favorable level of relative humidity for peak current performance from photovoltaics in this location. While Fig. 9 which portrays the current generated by the PV technology with fluctuating panel temperature shows that the current generated is not largely influenced by the panel temperature as long as the temperature does not exceed the maximum operating cell temperature. From the figure it was observed that the maximum operating cell panel temperature was exceeded at 12:30 corresponding to a plummet in current which agrees with studies by [35] which report that panel temperature above the maximum operating cell temperature hinders the performance of photovoltaics.

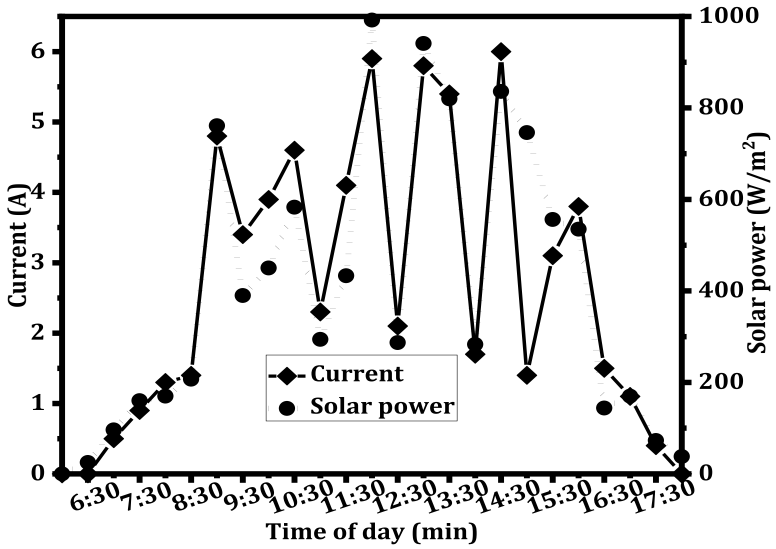


Fig. 7. Current generated and solar power received with respect to time of day

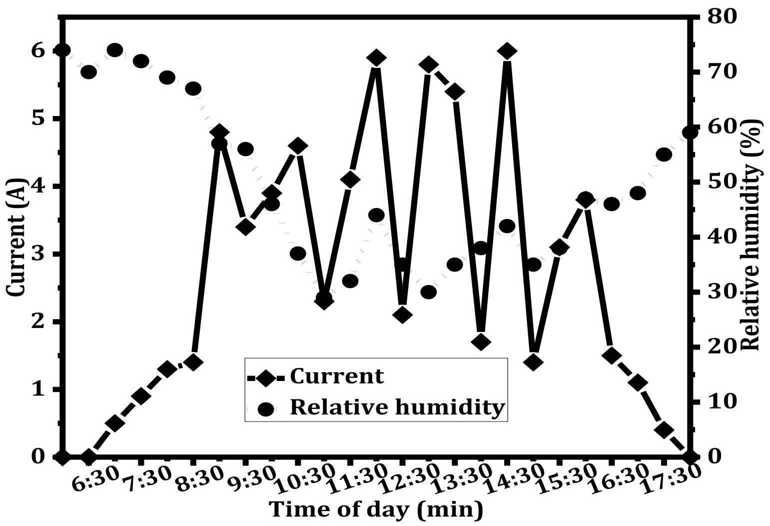


Fig. 8. Current generated and levels of relative humidity with respect to time of day

Fig. 7 to Fig. 9 reveals that despite the fluctuating climatic factors at the location of study a substantial amount of current above 42% of the maximum PV current could be harvested between 9:00 and 16:00.

3.4 Diurnal Analysis of Efficiency Level Attained with Varying Climatic Factors

Fig. 10 depicts the efficiency level attained by the PV technology with respect to varying levels of solar power. The figure portrays triple peaks in efficiency above 85% occurring at 12:00, 13:00 and 14:30, revealing the period in which maximum load could be powered from PV systems. The figure also portrays that the highest level of efficiency should be expected at 14:30. It was observed that the period in which the triple peak occurred, the level of solar power at the location was close to 1000W/m^2. Although the time in which the highest peak in efficiency occurred does not tally with the time which the highest level of solar power was received.

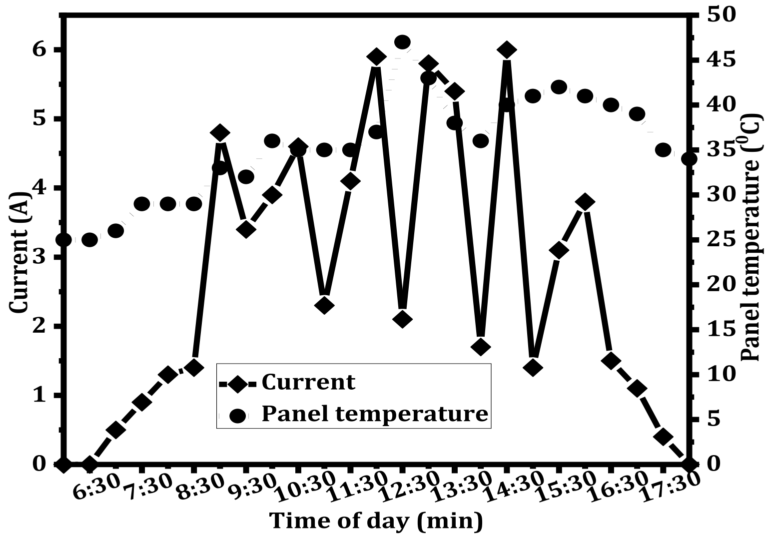


Fig. 9. Current generated and panel temperature with respect to time of day

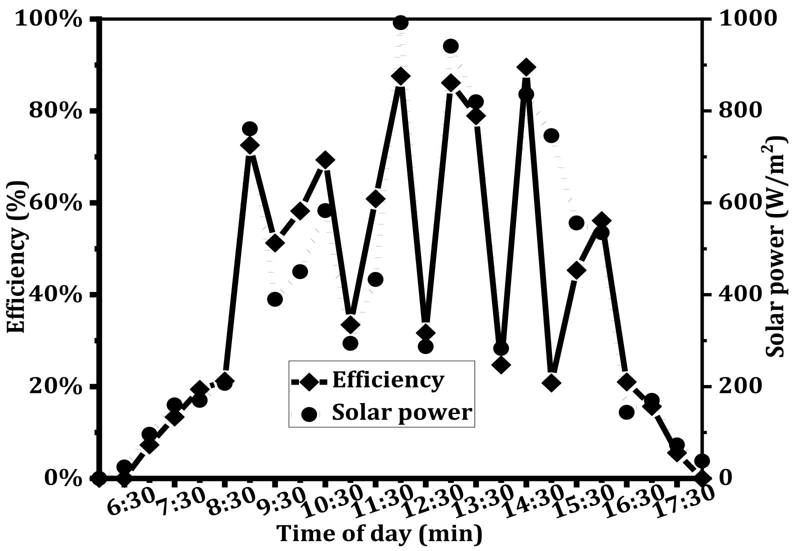


Fig. 10. Efficiency level and solar power received with respect to time of day

The levels of efficiency attained with their corresponding levels of relative humidity throughout daytime is displayed in Fig. 11. The figure reveals the levels of relative humidity that enhanced the PV technology to attain the peaks in efficiency. From the figure, it was observed that the triple peaks which occurred at 12:00, 13:00 and 14:30 was accompanied with humidity levels of 44%, 30% and 42% respectively, revealing that 42% is the most favorable level of relative humidity for optimum PV efficiency at this location. While Fig. 12 disclose the efficiency levels and the corresponding panel temperature throughout daytime. From the figure it was observed that the panel temperature exceeded the maximum operating cell temperature at 12:30, causing a steep fall in the efficiency. Furthermore, it was also observed that apart from 12:30, the panel temperature did not exceed the maximum operating cell temperature, bringing to light that a cooling mechanism might only be required at 12:30.

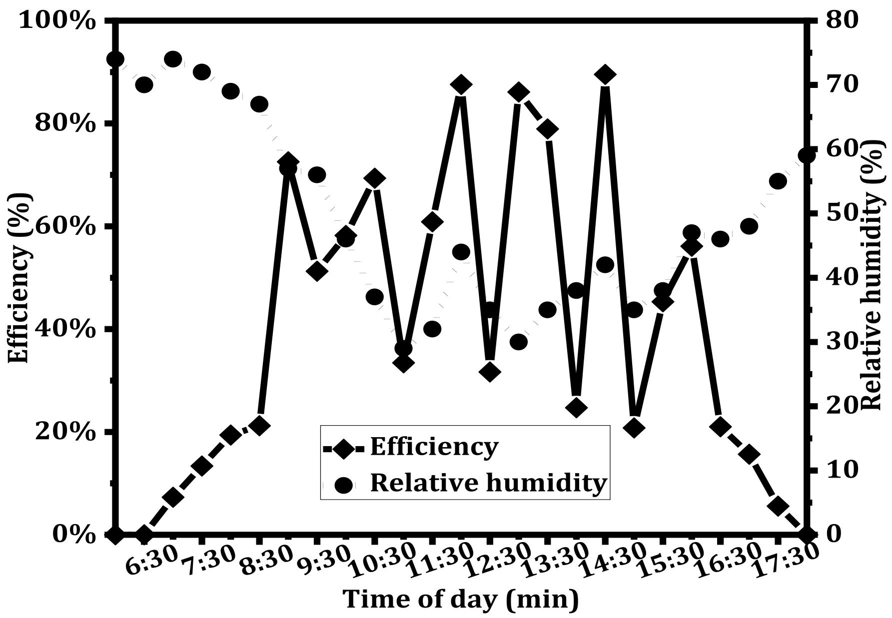


Fig. 11. Efficiency level and levels of relative humidity with respect to time of day

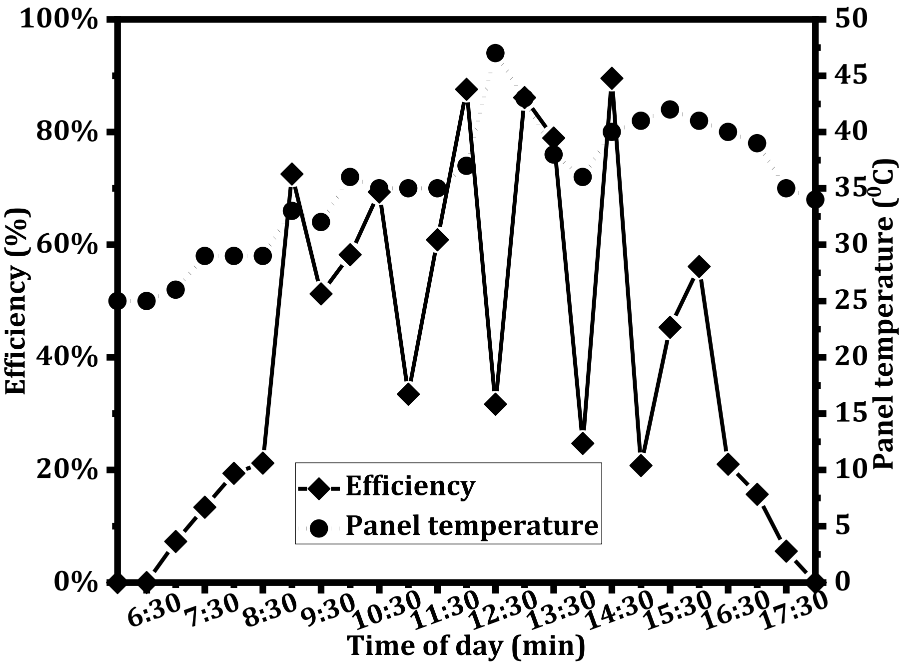


Fig. 12. Efficiency level and panel temperature with respect to time of day

4. CONCLUSION

In this study, the diurnal analysis of the performance of photovoltaic systems under the guinea savannah atmosphere have been investigated. The outdoor experimental measurement of the PV technology was carried out; analysis of the performance of the PV technology with the climatic factors at each time of day was done. From the results it is seen that the voltage parameter is less affected by fluctuations in climatic factors while the current parameter is mostly affected by fluctuations in solar power.

From the results, it might be expected that the PV technology should attained its highest level of efficiency at 12:00 since this is when the highest level of solar power was observed, but surprisingly, the highest level of efficiency was attained at 14:30 which reveals that the climatic condition which occur at 14:30 is the most favorable for PV systems deployed for domestic purposes at the location. The study reveal that 42% and 40^0C is the most favorable level of relative humidity and PV temperature for optimum PV efficiency at this location.

Furthermore, details of our study location revealed that January is the least humid month and March the warmest month. What this implies is that the solar power for this location during this period will certainly exceed 1000W/m^2 which should enable PV systems attain efficiency above 90%. On the other hand, it also gives insight that the panel temperature may exceed the maximum operating cell temperature more often during this period, hence a cooling mechanism to regulate the panel temperature should be incorporated into PV systems design and maintenance to avoid massive loss in efficiency. Moreover, with an altitude of 85m above sea level which makes it relatively favorable for receiving intense solar radiation, coupled with the fact that 90% efficiency is assured makes the location favorable for generating electricity via PV technology and installation of solar farms for commercial purposes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nerlinger M, Utz S. The impact of the Russia-Ukraine conflict on the green energy transition–A capital market perspective. Swiss Finance Institute Research Paper Series. 2022;22-49.
2. Steffen B, Patt A. A historical turning point? Early evidence on how the Russia-Ukraine war changes public support for clean energy policies. Energy Research & Social Science. 2022;91:1-10.
3. Andrea T, Pogrebnaya T, Kichonge B. Effect of industrial dust deposition on photovoltaic module performance: experimental measurements in the Tropical region. International Journal of Photoenergy. 2019;2019:Article ID 1892148:10.
4. Njok AO, Ogbulezie JC, Akonjom NA. Evaluation of the performance of photovoltaic system under different wavelengths from artificial light in a controlled environment.Journal of Applied Science and Environmental Management. 2022;26(6):1015-1020.
5. Akonjom NA, Umuji JI, Ekah UJ. Performance evaluation of polycrystalline modules in Guinea Savanna and Mangrove swamp. World Journal of Advance Engineering Technology and Sciences. 2021;4(1):11-21.
6. Ettah EB, Ekah UJ, Oyom E, Akonjom NA. Performance analysis of monocrystalline and polycrystalline solar panels in a Semi-Arid region. International Journal of Engineering Science Invention. 2021;1(7):10-14.
7. Alsharif MH, Kim J, Kim JH. Green and sustainable cellular base stations: an overview and future research directions. Energies. 2017;10(587):1-27.
8. Luque A, Hegedus S. Handbook of photovoltaic science and engineering, second ed. United Kingdom: John Wiley & Sons Ltd. 2011;1168.
9. Akonjom NA, Njok AO. Effect of meteorological parameters on the performance of photovoltaics installed under the Guinea Savannah Atmosphere in Ogoja, Cross Rivers State, Nigeria," Journal of Applied Science and Environmental Management. 2022;26(7):1299-1306.
10. Bhattacharya T, Chakraborty AK, Pal K. Effects of ambient temperature and wind speed on performance of monocrystalline solar photovoltaic module in Tripura, India. Journal of Solar Energy. 2014;2014:Article ID 817078:5.
11. Njok AO, Ewona IO, Akonjom NA. The effect of relative humidity on photovoltaics enhanced with automatic cooling mechanism. Unicross Journal of Science and Technology. 2022;1(1): 172-183.
12. Obeidat F. A comprehensive review of future photovoltaic systems. Solar Energy. 2018;163: 545–551.

13. Khan J, Arsalan MH. Solar power technologies for sustainable electricity generation - a review. Renewable and Sustainable Energy Reviews. 2016;55:414–425.
14. Adıgüzel E, Özer E, Akgündoğdu A, Yılmaz AE. Prediction of dust particle size effect on efficiency of photovoltaic modules with ANFIS: an experimental study in Aegean region, Turkey. Solar Energy. 2019;177:690–702.
15. Njok AO, Ewona IO. Diurnal analysis of enhanced solar photovoltaic systems using automatic cooling mechanism. World Journal of Advance Engineering Technology and Sciences. 2022;5(2):16-23.
16. Darwish ZA, Kazem HA, Sopian K, Alghoul MA, Alawadhi H. Experimental investigation of dust pollutants and the impact of environmental parameters on PV performance: an experimental study. Environment, Development and Sustainability. 2018;20(1):155–174.
17. Debbarma M, Sudhakar K, Baredar P. Comparison of BIPV and BIPVT: a review. Resource-Efficient Technologies. 2017;3(3):263–271.
18. Green MA, Hishikawa Y, Dunlop ED, Levi DH, Hohl-Ebinger J, Ho-Baillie AWY. Solar cell efficiency tables (version 52). Progress in Photovoltaics: Research and Applications. 2018;26(7):427–436.
19. Siddiqui R, Bajpai U. Deviation in the performance of solar module under climatic parameter as ambient temperature and wind velocity in composite climate. International Journal of Renewable Energy Research. 2012;2(3):486–490.
20. Gxasheka AR, van Dyk EE, Meyer EL. Evaluation of performance parameters of PV modules deployed outdoors. Renewable Energy. 2005;30(4):611–620.
21. Njok AO, Kamgba FA, Panjwani MK, Mangi FH. The influence of solar power and solar flux on the efficiency of polycrystalline photovoltaics installed close to a river. Indonesian Journal of Electrical Engineering and Computer Science. 2020;17(2):988-996.
22. Armstrong S, Hurley WG. A new methodology to optimize solar energy extraction under cloudy conditions. Renewable Energy. 2010;35(4):780–787.
23. Siddiqui R, Bajpai U. Statistical analysis of solar photovoltaic module output with temperature, humidity and wind velocity in composite climate. European Journal of Scientific Research. 2012;80(4):447–456.
24. Hussein AK, Miqdam TC. Effect of humidity on photovoltaic performance based on experimental study. International Journal of Applied Engineering Research. 2015;10(23): 43572-43577.
25. Muhammad AB, Hafiz MA, Shahid K, Muzaffar A, Aysha MS. Comparison of performance measurements of photovoltaic modules during winter months in Taxila, Pakistan. International Journal of Photoenergy. 2014;2014:Article ID 898414:8.
26. Chaichan MT, Kazem HA. Experimental analysis of solar intensity on photovoltaic in hot and humid weather conditions. International Journal of Scientific & Engineering Research. 2016;7(3):91-96.
27. Ettah EB, Udoimuk AB, Obiefuna JN, Opara FE. The effect of relative humidity on the efficiency of solar panels in Calabar, Nigeria. Universal Journal of Management and Social Sciences. 2012;2(3):8-11.
28. Omubo-Pepple VB, Tamunobereton-ari I, Briggs-Kamara MA. Influence of meteorological parameters on the efficiency of photovoltaic module in cities in the Niger Delta of Nigeria. Journal of Asian Scientific Research. 2013;3(1):107-113.
29. El-Shaer A, Tadros MT, Khalifa MA. Effect of light intensity and temperature on crystalline silicon solar modules parameters. International Journal of Emerging Technology and Advanced Engineering. 2014;4(8):311-318.
30. Tobnaghi DV, Naderi D. The effect of solar radiation and temperature on solar cells performance. Extensive Journal of Applied Sciences. 2015;3(2):39-43.
31. Rani SP, Giridhar SM, Prasad SR. Effect of temperature and irradiance on solar module performance. IOSR Journal of Electrical and Electronics Engineering. 2018;13(2):36-40.
32. Aish QM. Temperature effect on photovoltaic modules power drop. Al-Khwarizmi Engineering Journal. 2015;11(2):62-73.
33. Ike CU. The effect of temperature on the performance of a photovoltaic solar system in Eastern Nigeria. International Journal of Engineering and Science. 2013;3:10-14.
34. Amelia AR, Irwan YM, Leow WZ, Irwanto M, Safwati I, Zhafarina M. Investigation of the effect of temperature on photovoltaic (PV) panel output performance.

International Journal on Advanced Science Engineering Information Technology. 2016;6(5):682-688.

35. Ogbulezie JC, Njok AO, Panjwani MK, Panjwani SK. The impact of high temperature and irradiance source on the efficiency of polycrystalline photovoltaic (PV) panels in a controlled environment. International Journal of Electrical and Computer Engineering. 2020;10(4):3942–3947.
36. Kalogirou SA. Mcevoy's Handbook of Photovoltaics, fundamentals and applications, third ed, Academic Press, United Kingdom. 2018;1309.
37. Dincer F, Meral ME. Critical factors that affecting efficiency of solar cells. Smart Grid and Renewable Energy. 2010;1:47-50.
38. Ike CU. The effect of temperature on the performance of a photovoltaic solar system in eastern Nigeria. International Journal of Engineering and Science. 2013;3(12):10-14.
39. Verayiah R, Iyadurai A. A comparison study on types of PV for grid connected photovoltaic power. Indonesian Journal of Electrical Engineering and Computer Science. 2017;6(2):349-356.
40. Hoseinia H, Mehdipourb R. Evaluation of solar-chimney power plants with multiple-angle collectors. Journal of Computational and Applied Research in Mechanical Engineering. 2018;8(1):85-96.
41. Weatherspark, "Ogoja, Nigeria.
Available:https://weatherspark.com/y/58516/Average-Weather-in-Ogoja-Nigeria-Year-Round#:~:text=In%20Ogoja%2C%20the%20wet%20season,or%20above%2093%C2%B0F. Retrieved June 15, 2022.
42. Weatherbase. "Ogoja, Nigeria".
Available:https://www.weatherbase.com/weather/weathersummary.php3?s=604012&cityname=Ogoja%2C+Cross+River%2C+Nigeria&units=. Retrieved June 15, 2022.
43. Weather-atlas. "Ogoja, Nigeria".
Available:https://www.weather-atlas.com/en/nigeria/ogoja-climate Retrieved June 15, 2022.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/96048