

Performance Evaluation of a Photovoltaic System for Household in Asaba, Nigeria

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Abstract

The purpose of this article was to assess the performance of a photovoltaic system for homes in Asaba, Nigeria. Solar PV systems, their parts and components, and their working principle were all designed. The approach makes use of the creation of a process chart, which illustrates the arrangement of the components, their relationships, and the steps involved in accomplishing the study's goals. According to the load demand assessment, 4757 watts of power were needed daily. Consequently, we decided to develop a 5,000-watt inverter. According to the test results, the month of January 2024 had the highest daily power output, while the month of September 2024 produced the lowest daily power output. In this order, the average daily power output was reached: 8440.3 watts in January 2024 > 8440 watts in November 2023 > 7913.5 watts in December 2023 > 6453.59 watts in June 2024 > 6208.74 watts in July 2024 > 5242.5 watts in September 2024. Most significantly, each of these months' daily power output was more than the roughly 5000 watts needed to operate a contemporary three-bedroom apartment in Asaba without experiencing power outages.

Keywords: Photovoltaic System, Power Output, Off-Grid System, Solar Irradiance, Residential Energy Analysis.

Introduction

Climate change and global warming have been linked to urbanization and energy demand (Orhorhoro & Oghoghorie, 2024). Approximately 55% (4.2 billion) of the world's population, which is expected to increase to 6.5 billion (two thirds) by 2050, live in cities and account for over 80% of global GDP (REN21, 2023; USEIA, 2024). Concerns about climate change, environmental sustainability, and energy intensity resulting from human activity have made energy consumption more critical than ever in the twenty-first century, but green energy has proven important in addressing electricity issues (Madu, 2018a; Oghoghorie *et al.*, 2024). Green growth, which is based on sustainable socio-economic systems propelled by the switch from non-renewable (fossil) energy to renewable resources, is defined as economic progress that fosters development marked by environmental sustainability, lower carbon emissions, and social inclusivity. On a daily basis, however, a considerable amount of greenhouse gases is emitted into the atmosphere

due to the burning of fossil fuels (Igbagbon *et al.*, 2024b; Oloaluwa *et al.*, 2025). Additionally, this pollutes our surroundings, leading to major environmental issues (Madu, 2018b; Orhorhoro *et al.*, 2022; Orhorhoro & Oghoghorie, 2024). Furthermore, achieving sustainable development goals depends on providing sufficient and dependable energy services in an eco-friendly way while also meeting social and economic development needs (Orhorhoro *et al.*, 2017). Reducing poverty, boosting national economies, increasing living standards, and enhancing human welfare all depend on energy. The United Nations established sustainable development goals (SDGs) acknowledge the significance of energy, with the seventh of the 17 objectives focusing on guaranteeing that everyone has access to modern, cheap, dependable, and sustainable energy. The majority of global energy supply and consumption trends are unsustainable. The absence of a stable and secure energy source limits economic development in most parts of the world, particularly in sub-Saharan African nations (Madu, 2018c; Madu, 2018d; Orhorhoro & Oyejide, 2024). Additionally, in industrialized nations, there is a growing emphasis on encouraging energy efficiency in order to promote more sustainable consumption patterns and lower environmental pollution (Galvin, 2018; Ghosh, 2018; Wolske *et al.*, 2020; EC, 2021; USEIA, 2024). In contrast, the physical attributes of the home, the type of energy devices, the dwelling location, and the size of the household all have a substantial impact on household energy consumption in sub-Saharan Africa, which includes Nigeria (De Abreu *et al.*, 2021). In developing economies, household energy use is also significantly influenced by culture and living circumstances (Madu, 2018h; Madu, 2018j; Garba & Bellingham, 2021). Other studies have emphasized how household energy consumption is influenced by education (Ogwumike *et al.*, 2014), income or wealth status (Garba & Bellingham, 2021), and the type and accessibility of energy sources (Madu, 2018e; Alola & Yildirim, 2019). The different elements that influence household energy usage make it clear how difficult it is to promote widespread access to sustainable energy services in developing nations. However, alternative electric power supply sources like solar energy (SE), which is renewable, are needed to reduce the impact of global warming brought on by climate change (Obi *et al.*, 2019).

The photovoltaic (PV) effect, which produces the release of an electron when a photon—the fundamental unit of light—impacts a semiconductor surface like silicon, is the basis for solar energy. When sunlight strikes a solar panel, the photovoltaic cell absorbs the energy from the sun. Electricity flows as a result of the energy's creation of an electrical charge that travels due to the cell's electrical field. Semiconducting materials, such as silicon, are frequently used to make solar panels because of their ability to absorb photons and excite electrons that are drawn into electrical circuits by an electric field. Additionally, solar inverters' battery storage functions by storing extra energy produced by solar panels during the day for usage at night or on overcast days. While the excess energy is sent to the battery storage system, the solar inverter transforms the DC power from the solar panels into AC

power for instant consumption. The battery's charging and discharging are then controlled by the inverter, which makes sure that energy is released when it is needed. The inverter uses the energy stored in the batteries to offer a steady power source when the solar panels are not generating enough. This configuration maximizes the utilization of renewable energy sources, improves energy self-sufficiency, and lessens dependency on the grid. A schematic illustration illustrating PV theory and operation can be found in Figure 1.

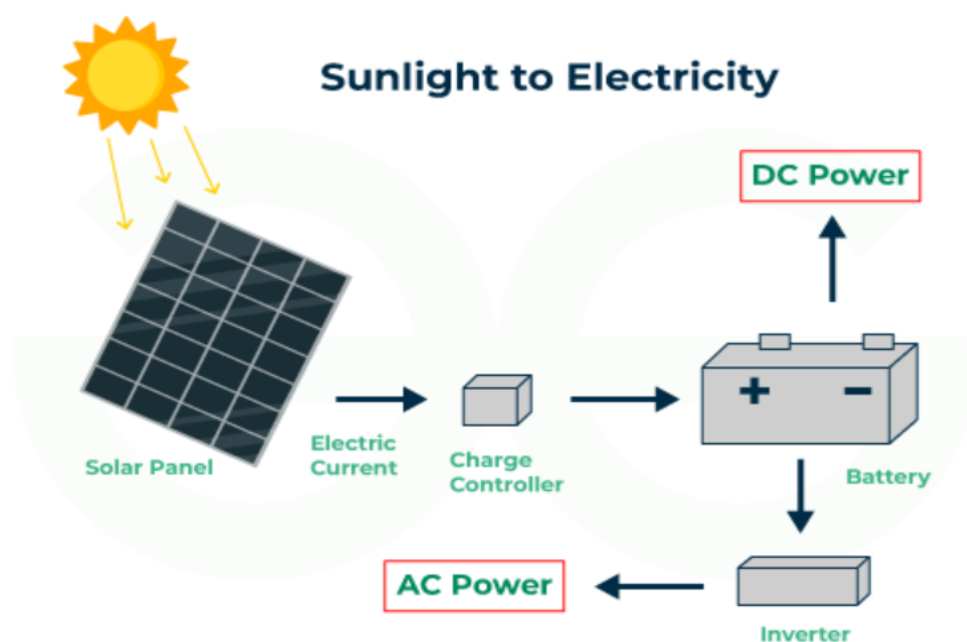


Figure 1. A schematic illustration illustrating PV theory and operation

In sharp contrast to the limited supply of fossil fuels, solar energy has grown in popularity as a renewable energy source in the twenty-first century due to its limitless supply and non-polluting nature. With solar photovoltaic technology, solar energy is used to directly generate electricity due to its vast technological potential and status as one of the cleanest energy sources (Akorede *et al.*, 2017; Egbon *et al.*, 2018). Out of all the renewable electricity generating technologies available, solar photovoltaic (PV) is thought to be the most environmentally beneficial and sustainable (Madugu *et al.*, 2020). Therefore, closing the energy gap, reducing climate change, and achieving green growth all depend on the rapid implementation of solar PV technology. Solar panels, inverters, charge controllers, cables, rechargeable batteries, and safety equipment like surge protectors are the components that make up solar power generation (Orhorhoro *et al.*, 2016a; Orhorhoro *et al.*, 2016b). The necessity for a charge controller stem from the possibility of overcharging caused by the sun's fluctuating strength during the day, especially in cases when the panels are connected directly to the battery (Orhorhoro *et al.*, 2016a). The advantages of solar power include low maintenance costs compared to using an AC generator or conventional power supply,

significant savings on power utility bills through power inverter optimization, the ability to reserve power for nights when there is no sunlight through battery storage, and the ability to charge batteries through PV panels, which further lowers power utility bills (Orhorhoro *et al.*, 2016a).

According to recent studies (Daioglou *et al.*, 2012; De Abreu *et al.*, 2021), the residential sector in Nigeria consumes the most electricity, accounting for roughly 59% of the nation's total electricity consumption (Madu, 2018g; Madu, 2018i). As a result, the sector can accelerate efforts to address the energy deficit and reduce greenhouse gas (GHG) emissions in order to mitigate climate change by implementing SE technology quickly. According to Mensah and Adu (2015), the proper implementation of residential SE technology necessitates integrated planning that includes specific laws, rules, and the development of a household energy consumption profile. The energy system's shift from fossil fuels to renewable energy depends on a better knowledge of home energy consumption. Determining the families' energy service needs is essential to assessing the home electricity demand for residential SE technology (Madu, 2018f; Saint *et al.*, 2021). A 3-kVA hybrid power supply system was created by Ogbekwe (2010) to support a computer lab experiment. The hybrid system was constructed using PWM charge controller standards and a 560 W, 24 V solar panel. It was shown that the method improved the consumer's power reliability when compared to alternative sources, like the delivery of electricity. The batteries were not adequately charged every day since the configuration that was made did not meet the predicted load. The chosen PWM controller was unable to convert the overvoltage to equivalent current in the same development. A grid-connected photovoltaic system was designed by Allouhi *et al.* (2016) and placed on a school building. The study compares the two types of solar panels under consideration in terms of technology, energy, and economic performance. The monthly yield of poly solar panels is higher than that of mono solar panels, according to a comparison. Because either of the two could malfunction, the system's dependability was not 100%, suggesting that backup was not included in the plan. The off-grid solar PV system, utility power source, and gasoline-powered generator would all be included in the proposed study project so that backup plans would be in place in case one of them fails. For use in university buildings, Ghenai and Bettayeb (2019) proposed a hybrid solar PV system design that combines grid-tied solar PV and fuel cells. Its goal is to construct a grid-connected renewable energy (RE) system that generates low greenhouse gas emissions and cheap energy costs by meeting building loads with a high penetration of RE. The percentage of fuel cells was found to be 32%, which is nevertheless detrimental to the surrounding environment because of the gas emissions that the fuel cells emit. In Pakistan, Michael (2012) designed and analyzed an off-grid solar system for a DC load. However, the design does not include AC loads, indicating that it was only implemented for DC loads. An off-grid solar PV system (also known as a stand-alone solar PV system) for residential usage is the subject of this study's performance analysis.

Solar energy and other renewable energy sources (RES) are gaining a lot of attention as an eco-friendly substitute for fossil fuels. A switch to cleaner energy sources is necessary due to the growing global energy demand as well as the detrimental ecological repercussions of using fossil fuels. The current analysis highlights the many benefits of solar energy, such as the potential to lower greenhouse gas (GHG) emissions, lessen reliance on scarce resources, and support energy defense. The creation and application of renewable energy technology have advanced significantly over the last few decades. An example of a potential solution for general use is solar photovoltaic (PV) innovation, which has witnessed significant cost reduction and efficiency improvement. Additionally, there is no data accessible on the ground because, despite the large number of photovoltaic installations in Nigeria, little has been done to estimate the precise energy requirements for houses throughout the country. Therefore, this study will ascertain the energy needs of a typical three-bedroom apartment in Nigerian cities, as well as the requirements for an inverter and battery. Additionally, a case study of 5 kVA off-grid solar PV systems in Asaba will be used to test a standard procedure for developing a solar-powered system in Nigeria homes.

Materials and Methods

Solar Energy System Suitability of the Study Area

Because of its constant exposure to sunlight, Asaba, the capital of Delta State, Nigeria, which is located at latitude 6.2036 and longitude 6.7365, is an ideal site for solar photovoltaic (PV) power generation (Aaron, 2024). Because Asaba is in the tropics, it has wet and dry seasons instead of the typical four-season cycle found in temperate countries. This means that Asaba receives a constant amount of sunlight throughout the year, which increases its ability to generate solar power efficiently. The dry season, when there is little cloud cover, runs from April to September, when solar radiation is at its greatest. This maximizes the amount of sunshine that PV systems can receive. However, regular maintenance, including routine panel cleaning, can guarantee optimal performance levels are maintained consistently, thereby increasing overall energy yield from installed PV systems. This is part of optimal installation practices, regardless of location specifics and potential environmental variables like dust accumulation on panels or occasional cloud cover during wet seasons. Since the tropics are situated between 23.5° North and -23.5° South of the equator, an ideal angle tilt towards the south of six (6°) degrees has been found to be the most effective orientation for maximum sun exposure capture throughout daylight hours across all seasons for fixed panel installations at this location specifically, given its latitude positioning relative to equatorial proximity (Aaron, 2024).

Determination of the Photovoltaic (PV) System Temperature and Energy Production

Daily measurements of the solar panels' temperatures were made between the hours of six in the morning and six in the evening. Ten (10) 100-watt solar panels, a digital multimeter for measuring the voltage and current generated by the panels, and a UNI-T UT333 compact

digital thermometer for measuring the temperature of the PV solar panels make up the measurement apparatus, as illustrated in Figure 2.

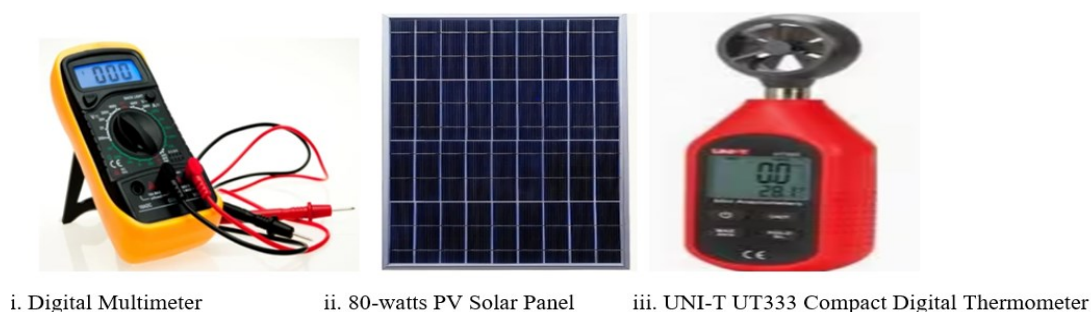


Figure 2. Equipment for the determination of the solar panel temperature and energy production

Description and Development of Photovoltaic Components

Figure 3 shows the contents of the process chart and the specifics of the photovoltaic components employed in this study. The following procedural steps were used throughout the entire research project: load estimation, inverter selection, battery-bank determination, solar panel design analysis, charge controller selection, cable and size selection, and system performance evaluation.

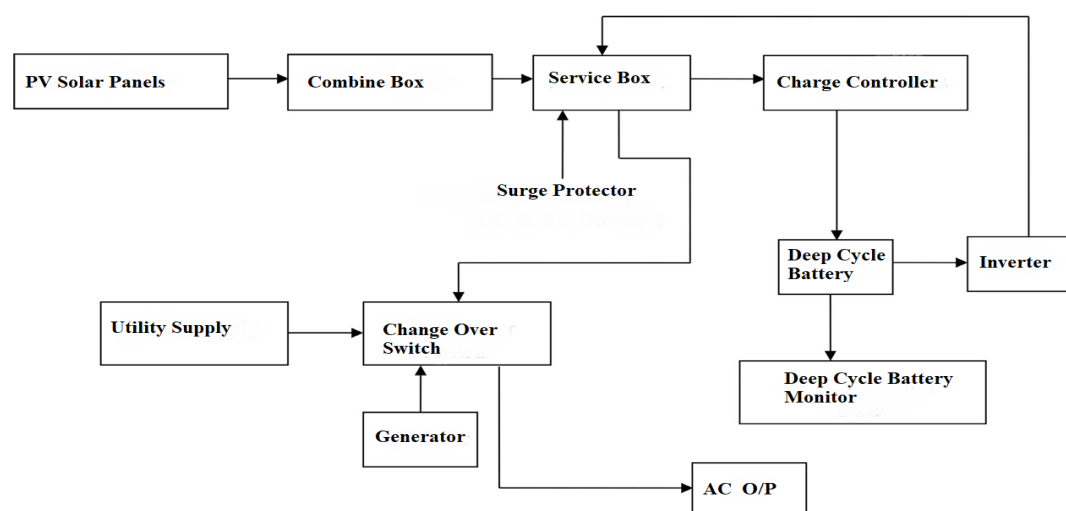


Figure 3. Process Chart of the Off- Grid Solar PV System

An array of panels, a charge controller, a battery, protection devices, and inverters make up the PV system's constituent parts. Lights, refrigerators, fans, stoves, and other electrical appliances or connectable equipment are examples of AC loads. A stand-alone solar PV

system's design and execution depend heavily on the calculation of a residential load. The average daily load consumption was determined using equation (1) (Madugu *et al.*, 2020).

$$A_{ED} = \sum_{i=1}^n \frac{L_{i.....n} \times N \times D \times H}{k \times 7} \quad (1)$$

When the average daily energy demand is denoted by AED; The inverter efficiency is denoted by K, the individual load W is indicated by Li...n, the number of individual loads is implied by N, the number of usage hours per day is represented by H, the number of usage days per week is implied by D. Depending on the manufacturer of the inverters, the power adjustment factor (K), sometimes referred to as inverter efficiency, can range from 0.8 to 1. In practice, however, k is assumed to be 1 (Akorede *et al.*, 2017). By listing all of the electrical appliances in a typical three-bedroom apartment in Asaba and estimating their energy consumption based on the normal run times for each device, the household's energy requirements were ascertained. The household's electrical appliances are listed in Table 1.

Table 1. Load Rating of a Typical 3 Bedroom Flat in Asaba

S/N	Equipment	Qty.	Rating (W)	Power (W)	Total Hourly Usage (Hrs.)	Total Energy Required (kWh)
1	Point light	20	6	120	12	1.440
2	AC (1.5HP)	1	1125	1500	8	9.000
3	Ceiling fans	6	120	720	12	8.640
4	Fridge	1	110	110	8	0.880
5	Freezer	1	140	140	8	1.120
6	Television	3	80	240	12	2.880
7	Water pump(1.5HP)	1	750	1125	2	2.250
8	Standing Fans	1	80	80	12	0.960
9	Computer	2	50	100	4	0.400
10	Decoder	1	12	12	12	0.144
11	VCD/DVD	1	10	10	8	0.080
12	Pressing iron	1	600	600	1/6	0.100
Total Load Rating				4757		27.894

DC can be converted to AC by the inverter. It is rated in KVA and regulates electric motor speed and torque. A 5KVA inverter is the one being used. In this work, a transformer converts the power inverter that uses 12V DC battery electricity to a modified sine wave voltage with 50 cycles per second to 220V. The inverter rating specification (X₂) and the total household wattage (X₁) are shown in equations (2) and (3) (Akorede *et al.*, 2017).

$$X_1 = \frac{A_{ED}}{\text{Total Hourly Usage}} \quad (2)$$

$$X_2 = \frac{\text{Total Energy Required}}{\text{Power Factor}} \quad (3)$$

The home needs 4.757 KW of power in total. A 5,000-watt inverter is therefore needed. A 15% fudge factor was employed to account for all losses in a system (Madugu *et al.*, 2020).

$$\text{Losses} = \frac{15}{100} \times 4.757 \text{ kW} = 0.7136$$

Therefore, the total power required = 4.757 + 0.7136 kW = 5.4706 kW.

The above can be considered as the peak load. The base load is when most of the equipment are turned off and remaining only the freezer, 3 ceiling fans and three (3) energy bulbs.

Thus, power consumption for the base load: Freezer + 3(Point Light) + 3(Ceiling Fan) = 140 + 18 + 360 = 518 watts. Also, for inductive load, starting current (on inverter) is determined as (Akorede *et al.*, 2017):

$$I_s = 4I_p \quad (4)$$

Where I_s = Starting current on inverter; I_p = Running current

But,

$$I_p = \frac{P}{V} \quad (5)$$

$$I_p = \frac{518}{220} = 2.3545 \text{ A}$$

Also,

$$I_s = 4I_p \quad (6)$$

$$I_s = 4 \times 2.3545 = 9.418 \text{ A}$$

Starting power is given by Eq. (7).

$$P_s = V_s \times I_s \quad (7)$$

$$P_s = 220 \times 9.418 = 2,071.96 \text{ watts}$$

Since the sun doesn't constantly shine and the energy that is captured from it needs to be stored for a variety of uses, deep cycle batteries become essential in solar design and implementation. PV deep-cycle batteries typically go through charging and discharging procedures while in use. Equations (8) through (15) are used to determine the PV battery characteristics for solar power design and deployment (Adesina *et al.*, 2021).

$$B_1 = \frac{A_{ED}}{\text{Inverter Voltage}} \quad (8)$$

$$B_2 = \frac{B_1 \times DOA}{DOD \times 0.85} \quad (9)$$

$$B_3 = \frac{B_2}{\text{Ampere Hour capacity of selected battery}} \quad (10)$$

$$B_4 = \frac{\text{Inverter Voltage}}{\text{Selected battery voltage}} \quad (11)$$

$$B_5 = B_3 \times B_4 \quad (12)$$

$$B_6 = K \quad (13)$$

And, $K = B_3 \times \text{Ampere hour capacity of selected battery}$

$$B_7 = \frac{B_6 \times \text{Nominal Voltage}}{100} \quad (14)$$

$$B_8 = \text{No. of Batteries Required} \times \text{Cost per Battery} \quad (15)$$

In this case, B_1 stands for the average daily ampere-hour demand, B_2 for the necessary battery capacity, B_3 for the number of parallel batteries, and B_4 for the number of series batteries. Days of autonomy (DOA), depths of discharge (DOD), total number of batteries (B_5), total battery ampere-hour capacity (B_6), total battery kilowatt-hour capacity (B_7), and battery cost are all implied. The battery setup is depicted in Figure 4.

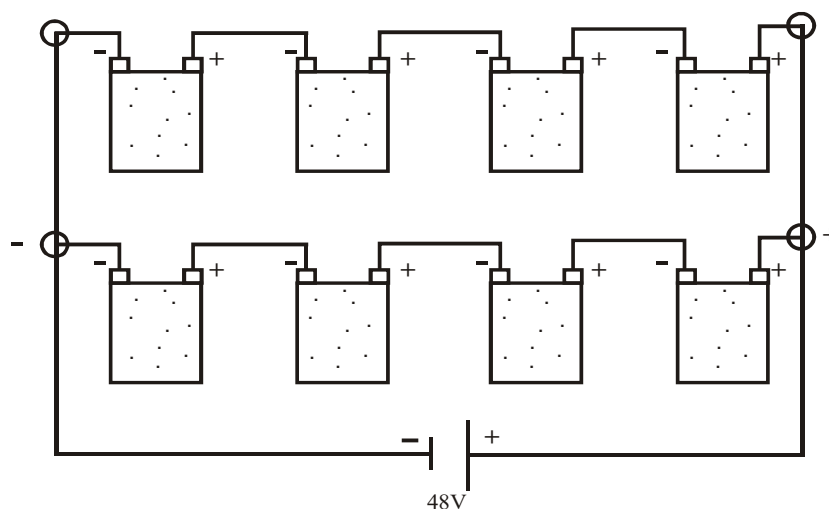


Figure 4. Batteries configuration

A PV system is made up of all these interconnected parts. In order to deliver DC and/or AC electrical needs, the off-grid solar PV systems (also known as standalone solar PV systems) were sized and developed accordingly. A charge controller, which is connected between the PV solar panels and the load, is one of the system's components that helps achieve maximum power production and matches the electrical load's impedance to the PV array's maximum power output. To achieve the desired increase in DC voltage, the charge controller and PV panels are connected in a series of four (4) before being connected in parallel, as seen in Figure 5

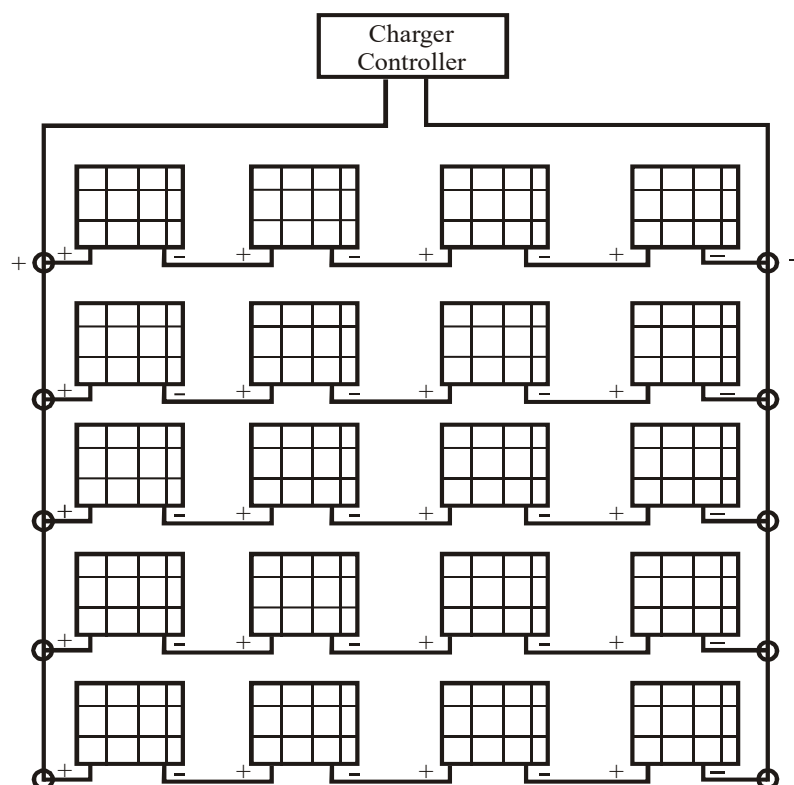


Figure 5. Configuration of PV Solar Panels

The solar irradiance and sunshine hours of the selected case study are used to calculate the number of solar panels or arrays needed. This procedure makes use of Equations (16) through (22).

$$\text{Photovoltaic module Capacity } (M_1) = \frac{X_1 \times 1.3}{P_1 + P_2} \quad (16)$$

And;

$$P_1 = SI \times f \quad (17)$$

$$M_2 = \frac{\text{Required PV module capacity}}{\text{Selected PV module wattage}} \quad (18)$$

$$M_3 = \frac{\text{Nominal battery voltage}}{\text{Selected PV module power voltage}} \quad (19)$$

$$Y_1 = \frac{B_2}{\text{Number of module per string}} \quad (20)$$

But,

$$Y_2 = Z_1 + Z_2 \quad (21)$$

$$Y_3 = \text{PV module Output Rating} \times \text{Panels required} \quad (22)$$

$$Y_4 = \text{Number of modules required} \times \text{Cost Per Module} \quad (23)$$

Where P_1 is the panel producing factor and P_2 is the peak solar hour. 1.3 = The system's specified energy loss; SI stands for solar irradiance; f is the panels' overall correction factor,

which Adesina *et al.* (2021) state is 0.62; M_3 denotes the number of modules required per string, while M_2 denotes the number of modules required to satisfy the requirement. Y_1 indicates the overall number of modules required, as well as the number of strings operating in parallel. The numbers Z_1 , Z_2 , Y_3 , and Y_4 stand for the number of modules per string, parallel strings, array output rating, and total cost of modules, respectively. The battery regulator, also known as the charge controller, sets a restriction on how quickly electricity may be supplied to or removed from the batteries. Additionally, it guards against battery overcharging and overvoltage, which can shorten battery life and performance or possibly cause the system to fail due to extreme heat. Additionally, it keeps the battery from deeply draining. As a result, it controls the DC voltage or output power of the solar PV panels' batteries. This output voltage is converted to the same DC voltage required for battery charging by the charge controller, which uses it as an input voltage. Equations (24) and (25) were utilized in the process of choosing a suitable charge controller.

$$I_1 = I_{sc} \times Y_1 \times 1.25 \quad (24)$$

$$I_2 = V_{oc} \times M_3 \quad (25)$$

Where I_{sc} implies PV module short circuit current; and V_{oc} represents PV module open circuit voltage.

Results and Discussion

The electricity production of a 5,000-watt photovoltaic (PV) system for a family in Asaba over a six-month period (November 2023, December 2023, January 2024, June 2024, July 2024, and September 2024) is shown in this section. The intermittent nature of solar energy in electrical conversion systems is better understood thanks to the diurnal PV system for temperature, current, voltage, and power (Adesina *et al.*, 2023). The performance evaluation of the findings was established based on the hourly study of the PV system data. A roughly 5,000-watt photovoltaic system was created and put in place for performance assessment after the various electric power-consuming appliances in Asaba were surveyed to determine the electric power requirements of different houses, as shown in Table 1. The residential loads were linked to the off-grid photovoltaic system, and its operating duration was determined. The solar charger was used to connect the fully depleted deep cycle batteries to the solar panels, and the batteries were watched until they were fully charged. The system turned on and was watched until it tripped off when the completely charged batteries were attached to the maximum permitted load of 4757 watts. The quantity of energy that was released from the batteries at full discharge determined how long it took to charge them. Over the course of six months of research, it was discovered that the PV could, for the first time, continuously power a contemporary three-bedroom apartment in Asaba that used about 5,000 watts of electricity per day without the deep cycle batteries running out. The relationship for daily temperatures over a six-month period is depicted in Figure 6.

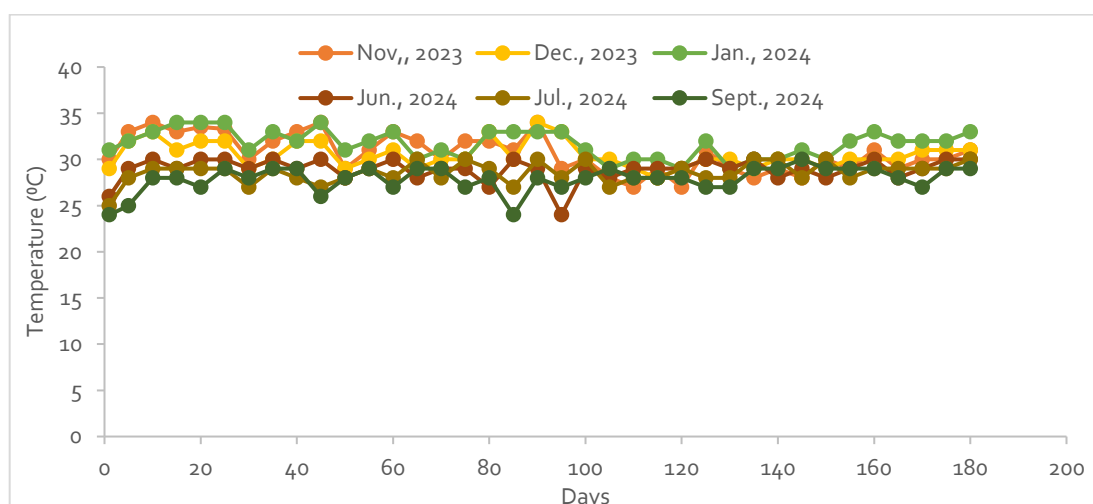


Figure 6. Comparative analysis of PS daily temperature readings

The graph indicates that the diurnal PS trend was lower in the months of June, July, and September, which are often associated with the wet season, and higher in the months of November, December, and January, which are typically associated with the dry season. Rain clouds reduce the amount of light that reaches solar panels by blocking direct sunshine. Given that solar panels depend on sunshine to produce power, this could result in a brief decrease in energy output. As a result, temperatures vary with the seasons, and temperature rises as the dry season approaches and drops during rainy season. Additionally, September 2024 saw the lowest ambient temperature of 24°C, while November 2023, December 2023, and January 2024 saw the highest ambient temperature of 34°C. The relationship between the average hourly voltage, current, and power production over a six-month period is depicted in Figures 7 to 12.

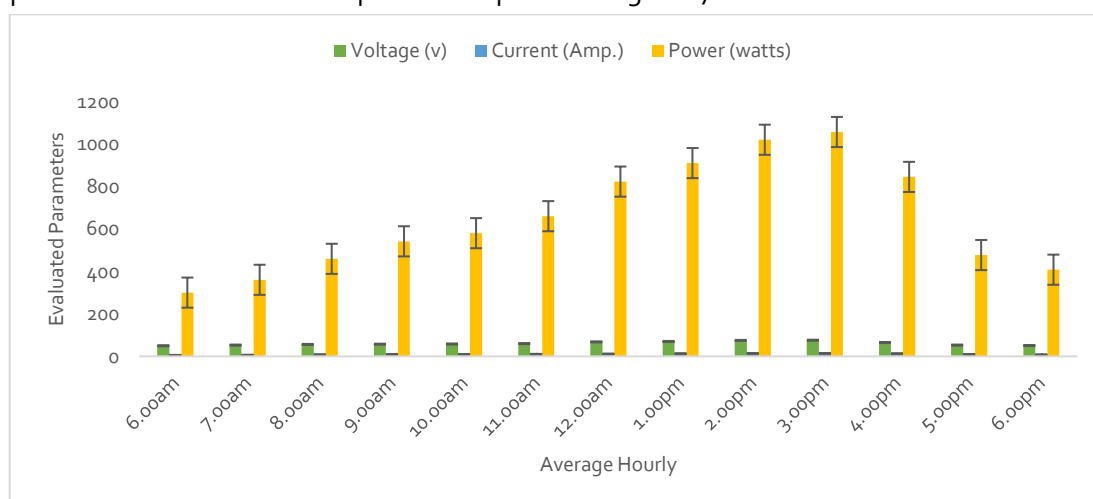


Figure 7. Average PS for household in Asaba obtained for hourly current, voltage, and power generation for the month of November, 2024

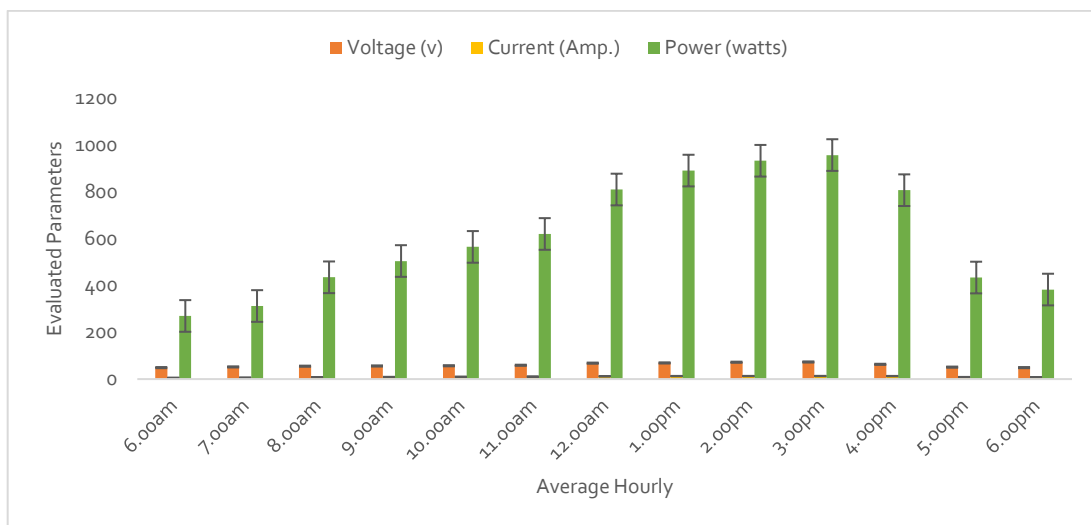


Figure 8. Average PS for household in Asaba obtained for hourly current, voltage, and power generation for the month of December, 2024

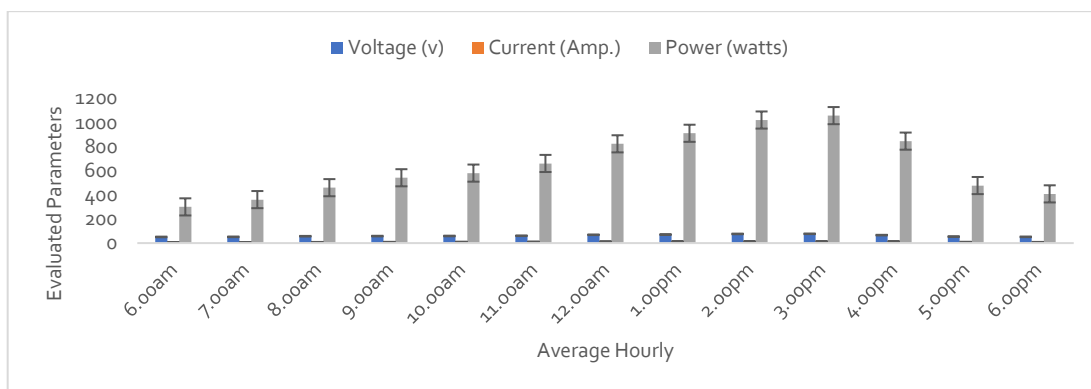


Figure 9. Average PS for household in Asaba obtained for hourly current, voltage, and power generation for the month of January 2024

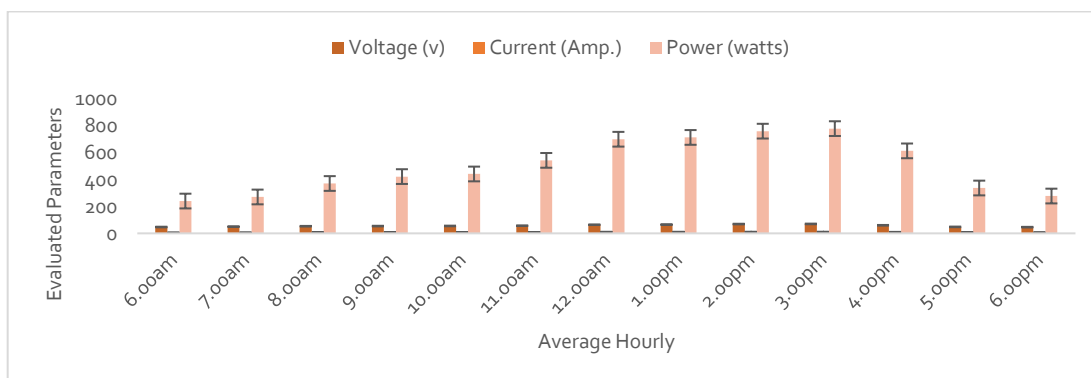


Figure 10. Average PS for household in Asaba obtained for hourly current, voltage, and power generation for the month of June, 2024

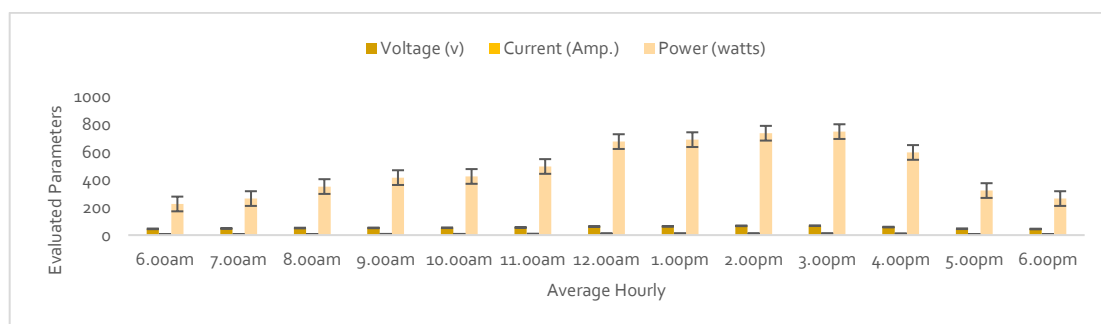


Figure 11. Average PS for household in Asaba obtained for hourly current, voltage, and power generation for the month of July 2024

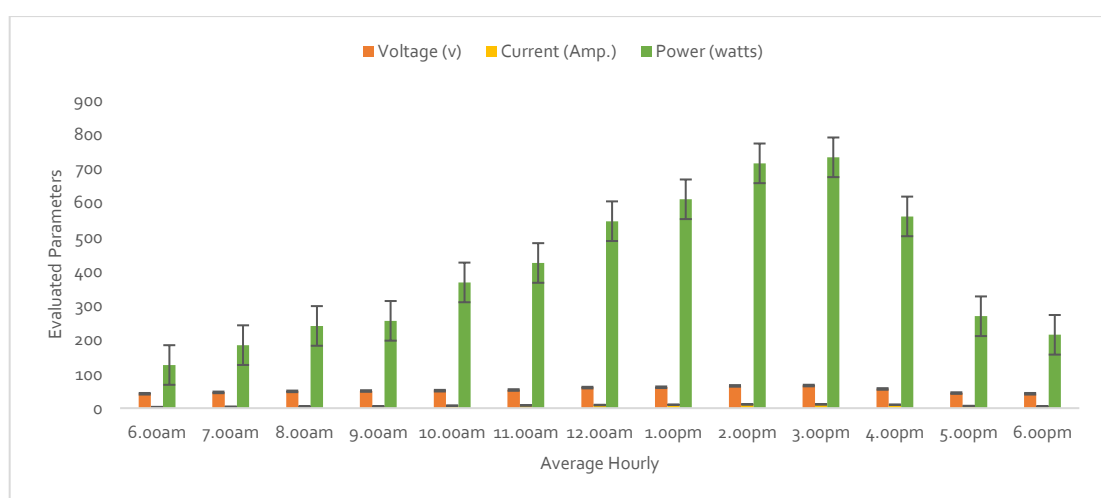


Figure 12. Average PS for household in Asaba obtained for hourly current, voltage, and power generation for the month of September, 2024

The graph provides evidence that the PV system produces the least amount of current and voltage and, thus, the least amount of power during the early (6am–7am) and late (5pm–6pm) hours of the day because there are no solar resources available. Nonetheless, the production of current and voltage increased steadily, reaching their highest daily levels between 2 and 3 p.m., which corresponded to the greatest power output. These results are consistent with the studies conducted by Adesina *et al.* (2023) and Gado *et al.* (2018). As a result, the relationship between sun irradiation and solar power generation is straightforward. The PV system peak values are recorded during the day's peak sunlight hours as shown in Figures 7 to 12. Additionally, there is reduced power output during the wet season days, which correspond to June, July, and September (Figures 10 to 12). This can be attributed to the effect of cloud cover. However, the maximum power output occurs during the dry season days, which are November, December, and January (Figures 6 to 8). This is due to the influence of sunny days. The average comparative assessment of voltage,

current, and power out during the six months of the study is displayed in Figures 13 to 1.5 Figure 13 illustrates that the average daily voltage is at its highest in January 2024 and its lowest in September 2024. Seasonal variation is also responsible for these numbers, with the wet season producing the least amount of voltage and the dry season producing the most.

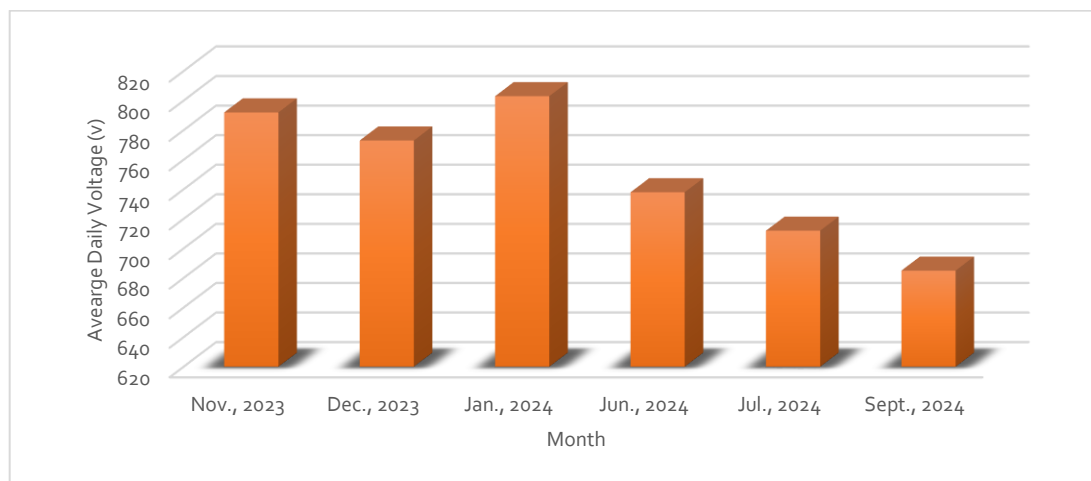


Figure 13. Comparative analysis of average daily voltage readings of PS for household in Asaba

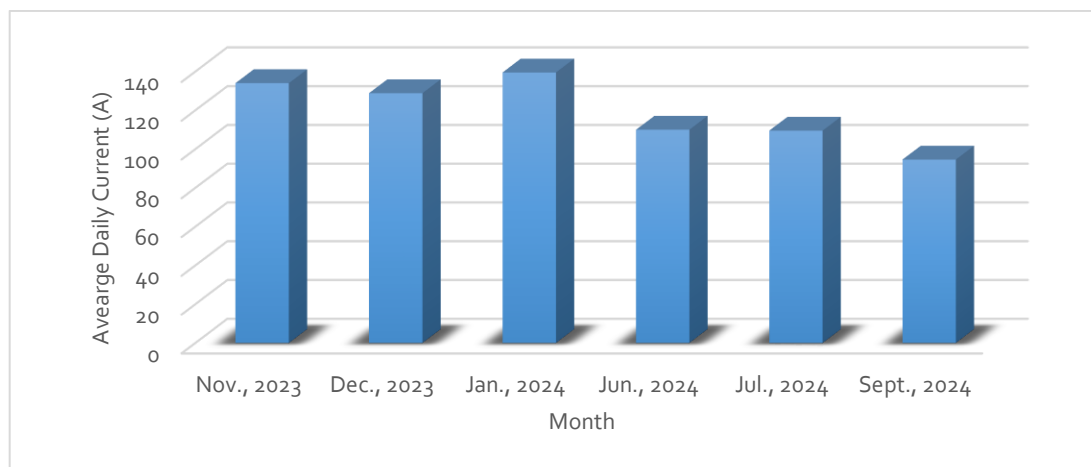


Figure 14. Comparative analysis of average daily current readings of photovoltaic system for household in Asaba

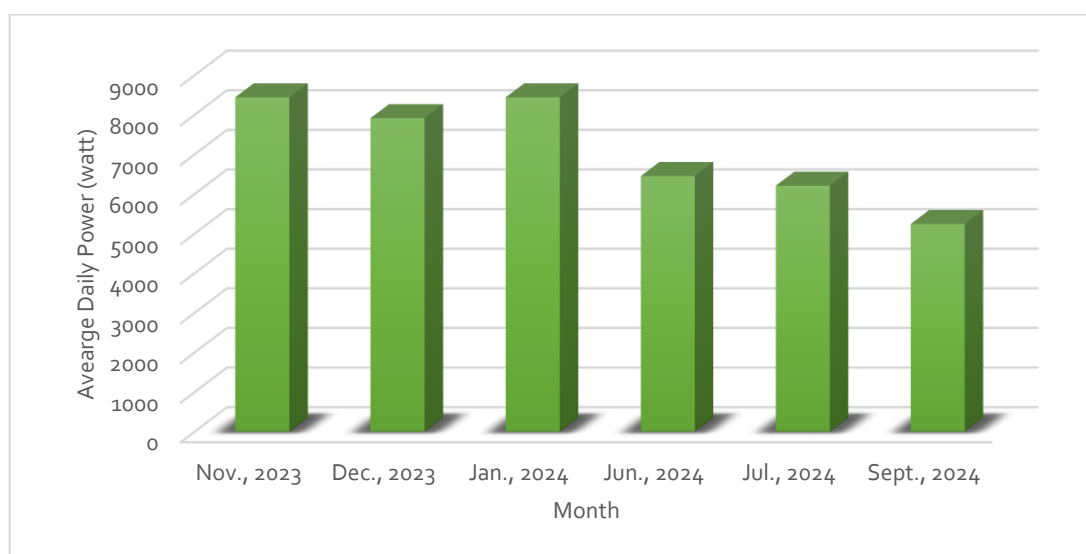


Figure 15. Comparative analysis of average daily power readings of photovoltaic system for household in Asaba

The minimum and maximum PV currents were generated in September 2024 and January 2024, respectively, as shown in Figure 13. Additionally, January 2024 was the month with the highest daily power generation, followed closely by November and December 2023 (dry season). The power output as calculated was in this order; January 2024 (8440.3 watts) > November 2023 (8440 watts) > December 2023 (7913.5 watts) > June 2024 (6453.59 watts) > July 2024 (6208.74 watts) > September 2024 (5242.5 watts), with the month of September producing the minimum daily power output. Besides, it is noteworthy that the daily power production generated in each of these months exceeded the approximately 5000 watts required to run a modern three-bedroom apartment.

Conclusion

Nigeria is a developing nation with a very low power generation output of less than 4000 MW. Nigeria has the potential to use solar power technologies to generate electricity due to its copious solar radiation. Due to Asaba's advantageous geographic position for PV system installation, this study found that an off-grid solar PV system can supply a residential building with continuous power. A solar panel that stores its charge in a block battery will provide all of the electricity required by the system. In Asaba, Nigeria, a residential building was supplied with power from the projected 5 kVA solar PV system. Additionally, September 2024 and January 2024 saw the lowest and highest PV currents, respectively. Furthermore, January 2024 had the largest daily power output, closely followed by the dry season months of November and December 2023. The maximum daily power output during this time was 8440.3 watts in January 2024 > 8440 watts in November 2023 > 7913.5 watts in December 2023 > 6453.59 watts in June 2024 > 6208.74 watts in July

2024 > 5242.5 watts in September 2024. It is noteworthy that the daily power production generated in each of these months exceeded the approximately 5000 watts required to run a modern three-bedroom apartment. Although the energy requirements for a typical three-bedroom apartment in Nigerian cities were established by this study, more research can be done on forecasting and prediction model techniques, managing PV energy demand, determining the average social behavior of Nigerian consumers to accept solar PV, and integrating solar PV energy into the circular economy.

Recommendations

Following the successful completion of the research on the assessment of a photovoltaic system's performance for homes in Asaba, Nigeria, we hereby suggest the following:

- i. To extend the active life of the PV system, heavy power-consuming household equipment like water pumping machines should be connected between 2 and 3 p.m., as this is when the production of current and voltage increased steadily and reached its highest daily levels, corresponding to the greatest power output, and
- ii. Also, since the least amount of power is obtained during the early (6am–7am) and late (5pm–6pm) hours of the day, household heavy power-consuming equipment can be turned off during this hour.

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