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# COMPONENTS DESIGN FOR A STAND-ALONE SOLAR-POWERED PHOTOVOLTAIC SYSTEM FOR VARIOUS NIGERIAN LOCATIONS

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## *Abstract*

*The majority, if not all, of the equipment in our homes and apartments can be powered by solar energy. Solar energy is a renewable resource. Other factors that make using solar energy so important in Nigeria include the country's climate, which is suitable for solar energy use, inconsistent electricity supply, delayed electricity supply projects for rural areas, etc. Designing, selecting, and figuring out the equipment ratings for a photovoltaic system is therefore important. The methods used to choose the different components of a stand-alone photovoltaic system were examined in this paper. The method was chosen to be applied to a typical Nigerian household in a highbrow neighbourhood. For the solar PV array, battery bank, voltage controller, and inverter to meet the design goals, measurements were taken and suitable brands were suggested. The household under consideration required 128 Poly-Luminous solar panels (250 Watts, 24 V, 8.31 A); 22 LiFePO4 batteries (48 V, 400 Ah, High Capacity, 20 KWH Energy Storage Battery); 5 ConextTM MPPT 60 150 solar charge controllers; and 1 Mercury 11 KVA Solar Hybrid Inverter in order to supply 82.3875 kWh/d of solar power to the household. The variables that influence the selection of each piece of equipment employed in the system's design and size were also discussed. Oversizing and undersizing of any piece of equipment were avoided to guarantee appropriate system design. Applications with higher or lower energy consumption as well as those in different regions can employ the same approach, which could be modified accordingly. Nonetheless, the design should adhere to these environmental parameters of these areas.*

## 1.0 Introduction

The energy needed to keep life in our solar system going comes from the sun. The sun provides the planet with enough energy each day to meet its needs (World Energy Council, 2013; Pourasl *et al.*, 2023). The direct conversion of sunlight into power is known as photovoltaic. For a variety of reasons, it is a desirable substitute for traditional electricity sources: it is dependable with low failure rates and anticipated service lifetimes of 20 to 30 years; it is also safe, silent, and non-polluting; it is renewable; and it is highly modular in that its capacity can be increased gradually to match with gradual load growth (Kurpaska *et al.*, 2018). It has no moving parts, is incredibly dependable and practically maintenance free, can be installed practically anyplace, and doesn't require any specialised training to operate. The amount of sunlight that reaches the planet varies depending on the season, location, weather, and time of day. Irradiation, measured in Wh.m-2 per day or, for example, kWh.m-2 per day, is the total energy on a daily or annual basis that represents the intensity of the sun (Ibrahim *et al.*, 2019).

The location of our home has a significant impact on the design of a photovoltaic system from several angles, including panel orientation, calculating the number of days during the year when the sun doesn't shine, and selecting the optimal tilt angle for the solar panels. This is because different geographic regions have different weather patterns. Installing photovoltaic panels atop a tracker that tracks the sun's movement increases energy collection, but it is a costly procedure. They often have a fixed location with an angle known as the tilt angle $\beta$ because of this. Seasonal fluctuations are reflected in this angle (Posadillo and Luque, 2008). For example, the solar panel needs to be positioned more horizontally in the summer and at a steeper angle in the winter. Nigeria is one of the biggest countries in West Africa, home to an estimated 227.713 million people (2024 estimate). With a GDP of over $477 billion, it is ranked first in Africa and thirty-one in the world (O'Neill, 2023). In addition to enhancing the country's current infrastructure, Nigeria has to develop solar and renewable energy sources in order to maintain economic growth, meet SDG7 targets, and raise the standard of living for its people.

Nigeria's energy grid still faces significant difficulties, despite the country having produced electricity since 1896. System instability, regular outages, and constant fluctuations characterise the grid supply. When it comes to generation, the prevalent traditional fossil fuel sources are impacted by a number of factors, including devaluation, inflation, and fluctuations in exchange rates; operational difficulties in the electricity sector, such as insufficient generation capacity to fulfil the nation's demand; and the requirement to recoup related costs. The transmission and distribution (T&D) sub-sectors have seen significant power losses due to antiquated and subpar infrastructure, which exacerbates the problems and cools the enthusiasm of the public and private sectors for additional capacity investment. Currently ranked as the 25th largest emitter of greenhouse gases, the government faces pressure from both local and international sources to reduce carbon emissions. This has created an urgency to find new and environmentally friendly ways to conduct structural development and alter the energy supply.

It is encouraging that in Nigeria, a country with an abundance of natural resources, renewable energy technologies, which are characterised by their declining costs, simple deployment, and rising capacities for enhanced resilience, have grown by double digits in recent years. These energy sources not only increase the nation's electricity capacity but also have some beneficial effects on its climate initiatives. These outcomes are essentially the direct result of the government's implementation of several renewable energy programmes and incentives.

Nigeria's geographic location makes it a particularly appealing place to install solar-powered equipment. Due to the established advantages of this energy source, there is a strong inclination for the deployment of standalone photovoltaic stations scattered over rural places. For the benefit of the residents in these locations, this topic needs to be specified. The methods used to design and choose the components of a standalone photovoltaic system depending on Watt-Hour requirement are introduced by the author in this study. Additionally, all of the elements that influence the size and design of each piece of equipment in the system have been listed. In order to guarantee an adequate, dependable, and cost-effective system design, oversizing and undersizing have also been avoided. The same techniques could be used and modified for applications requiring higher energy consumptions, as well as for various geographic areas; although, these places' specific design characteristics should be used.

There is now less than 4GW of energy generation capacity due to the status of the electrical market (Adoghe *et al.*, 2023; Trade, 2023; International Trade Administration, 2023). In metropolitan regions, the rate of electricity is 55%, whereas in rural settlements, it is 35% (International Trade Administration, 2023). This is taken to indicate that approximately 100 million people, or a large fraction of the population, do not have access to power. In addition, the country's deplorable grid system has made it necessary to increase the amount of power generated by fossil fuel generators. Due to this expansion, air pollution from generators has increased, endangering human health and the environment.

Nevertheless, because of its advantageous location on the equator, the nation receives an abundance of solar resources despite the precarious situation of electricity. This solar resource is dispersed throughout the nation. Table 1 shows the amount of solar radiation that each country's zones get. According to estimates, the yearly daily average of total solar radiation in Nigeria's coastal region is between 12.6 and 3.5 MJ/m2/day (or 3.5 kWh/m2/day), and between 25.2 and 7.0 MJ/m2/day (or 7.0 kWh/m2/day) in the northern region (Adun *et al.*, 2022). With lines pointing to the states in the region that are under consideration, Figure 1 depicts the solar radiation for the various regions of Nigeria.

**Table 1.** Solar radiation in zones in Nigeria (Osinowo *et al.*, 2015)

| Zones | $kWh/m^2$ | h/d | $kWh/m^2/yr$ | States |
|---|---|---|---|---|
| Zone I | 5.7–6.5 | 6 | 2186 | Borno, Yobe, Jigawa, Kano, Kaduna, Bauchi, Gombe, Adamawa, Plateau, and Katsina |
| Zone II | 5–5.7 | 5.5 | 2006 | Sokoto, Zamfara, Kebbi, Niger, Abuja, Nassarawa, Taraba, Kwara, Plateau, Katsina |
| Zone II | Less than 5 | 5.0 | 1882 | Oyo, Osun, Ekiti, Kogi, Benue |

The process for designing standalone PV systems was presented by numerous researchers (Aderamola, 2014, Dioha *et al.*, 2018; Olarewaju *et al.*, 2020). This study aims to present the methods used in the construction and equipment selection of a standalone solar system according to Watt-Hour demand.

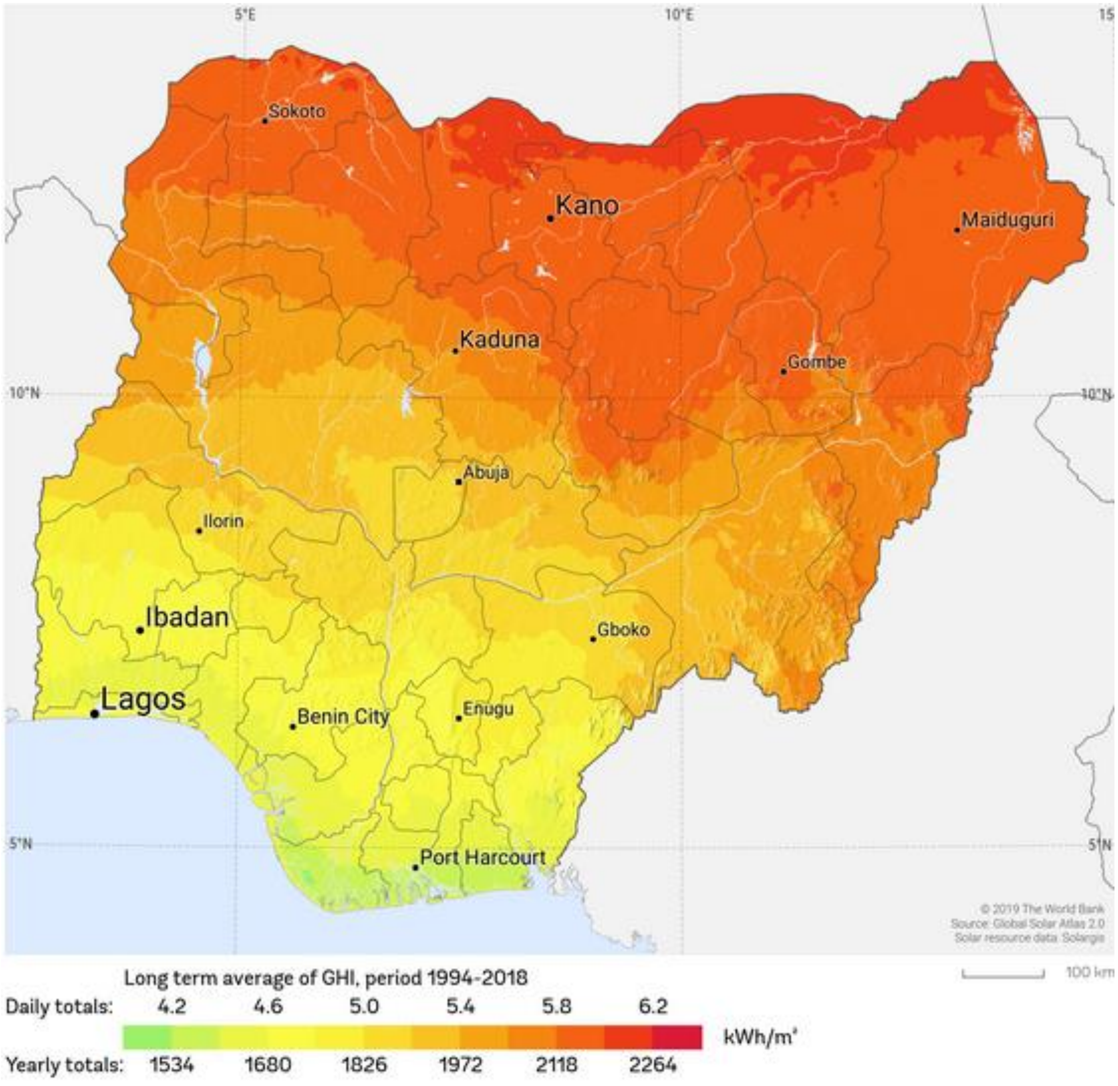


**Figure 1.** Solar irradiation in Nigeria (SOLARBUY, 2024)

## 2.0 System Description

### 2.1 Components of a Stand-alone PV System

An autonomous solar system that generates electricity to charge battery banks during the day so they may be used at night when the sun is not shining is known as a basic standalone photovoltaic system. Rechargeable batteries are used in standalone small-scale photovoltaic systems to store the electrical energy produced by photovoltaic panels or arrays. A collection of separate photovoltaic modules, also known as panels, with power outputs ranging from 50 to more than 100 watts apiece, typically operating at 12 volts, make up an off-grid or standalone PV system. The required power output is then obtained by combining these PV modules into a single array. Figure shows a stand-alone photovoltaic system.

In situations where, using other power sources to operate appliances, lights, and other devices is either impractical or not possible, standalone photovoltaic systems are the best option for isolated rural locations. In certain situations, installing a single standalone PV system is more economical than paying the local power company to extend their power lines and cables straight to the house as part of a grid-connected PV system.

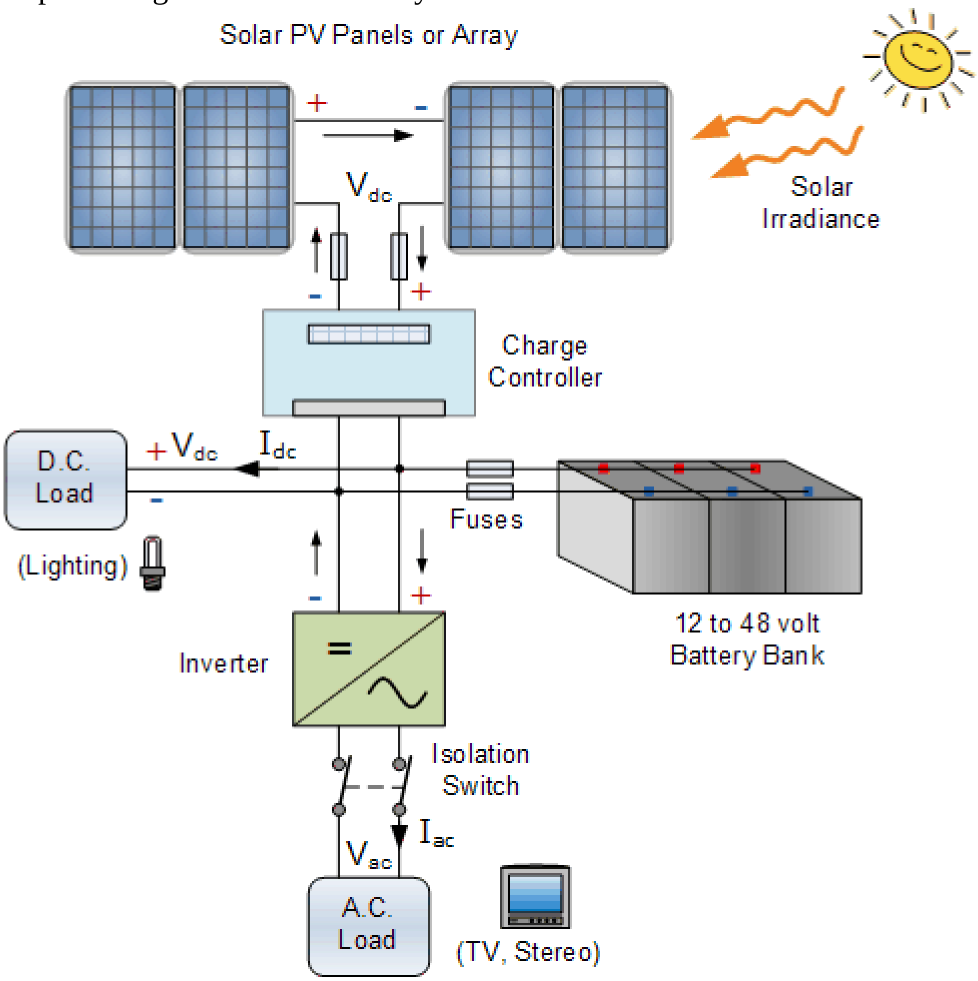


**Figure 2.** Stand-alone PV System (Alternative Energy Tutorials, 2024)

The solar array is the main component and most expensive part of a standalone PV system, however there are usually a few more parts that are required. Among them are:

1. Photovoltaic module: This semiconductor-based device turns sunshine into electricity. Sunlight is converted into DC electricity by the PV. As new technologies reach the market, single, polycrystalline, and amorphous silicon are the most widely used materials in PV modules.

2. Batteries: Depending on the design, batteries may be a required component or an optional add-on for any standalone photovoltaic system. The electricity generated by the sun is stored in batteries for use at night or in an emergency during the day. Battery banks can have a total capacity of many hundreds of amperes and a voltage of 12V, 24V, or 48V, depending on how the solar array is configured.

3. Charge Controller: A charge controller dissipates excess power into a load resistance in order to regulate and control the output from the solar array and prevent the batteries from being over-charged or over-discharged. Although they are not required in a standalone PV system, charge controllers are a good idea for safety reasons.

4. Fuses and Isolation Switches: These devices guard PV installations against unintentional wire shorting and enable the PV modules and system to be turned "OFF" when not in use, conserving energy and extending battery life.

5. Inverter: In a stand-alone system, an additional optional component is the inverter. The 12V, 24V, or 48V direct current (DC) power from the solar array and batteries is converted by inverters into 120 VAC or 240 VAC AC electricity and power for use in the home to power AC major appliances like TVs, washers, refrigerators, and so forth.

6. Electrical wiring is the last component needed for a photovoltaic solar system. For the needed voltage and power, the cables must be appropriately rated. Bell or phone cable that is too thin are not recommended.

The various parts of a solar PV system should be chosen based on the uses, site location, and system type. A balance-of-system made comprised of the following parts that when connected together, create a fully operational system that can supply electricity:

**2.2 Configuration of power electronic interfaces for stand-alone PV systems**

A storage device and its controller enable the stand-alone PV systems to sustainably meet the load power demands. When the power available from the PV panel is less than the required power at the load bus, the storage device with the controller should supply the power difference. The PV panel should supply the load power and use the extra power to charge the storage device when the PV panel's available power exceeds the required power. Figure 3 depicts a basic PV panel/battery connection configuration.

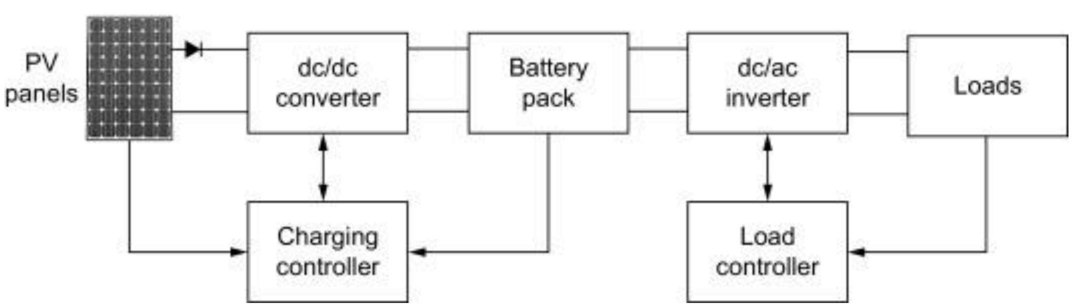


**Figure 3.** Stand-alone photovoltaic System (SCIENCEDIRECT, 2024)

## 3.0 System sizing

System sizing is the process of determining which photovoltaic system component has the proper voltage and current ratings to meet the facility's electricity needs while also figuring out the total cost of the system, including labour and shipping, from the design stage to the finished product.

### 3.1. Residence Device

The amount of energy that your appliances utilise must be known in order to determine the load in your home. For the majority of ordinary appliances and lighting, air conditioning is usually not necessary, although in tropical climates it might be. The energy consumption numbers for the majority of appliances and lighting are rather close to those indicated in Table 2. To determine the average energy consumption in Watt-hour per day, Table 3 below lists the electrical devices that are available at the residence along with their power ratings and times of operation throughout the day. The equipment sizes and ratings, beginning with the solar array and concluding with the system wiring and cost estimate as detailed below, are determined by taking the whole average energy usage into consideration.

**Table 2.** The kW/h consumed by domestic appliances

| Appliance | Power rating | Estimated Annual Consumption for a household of 5 |
|---|---|---|
| Television | 100 - 400 W, | 119 kWh per unit |
| Air conditioning | 900 - 2,000 W | 677 kWh per unit |
| Microwave | 900 - 1,500 W | 454 kWh per unit |
| Fridge | 200 - 400 W | 655 kWh per unit |
| Oven | 1200 – 3,000 W | 465 kWh per unit |
| LED light bulb: | 3 – 20 W. | 4 10kWh per household |
| Washing Machine | 300 – 500 W | 255 kWh per unit |
| Electric Kettle | 1200W – 1500W | 273.75 |
| Ceiling fan | 75W – 100W | 70.0 |

**Table 3.** Daily Energy Consumption for Residence Devices

| Type | Quantity | Watts | Total Watts (kW) | Daily Use (number of hours per day) | Watts-hour daily (kWh/d) | kW-hour daily (kWh) (Accounting for Losses) (x1.3) (kWh/d) |
|---|---|---|---|---|---|---|
| Energy efficient bulb | 10 | 15 | 0.325 | 12 | 3.9 | 5.07 |
| Fans | 5 | 65 | 0.255 | 6 | 1.53 | 1.989 |
| Television | 3 | 85 | 4.5 | 8 | 36 | 46.8 |
| AC | 3 | 1500 | 0.24 | 5 | 1.2 | 1.56 |
| Fridge | 2 | 120 | 1.5 | 10 | 15 | 19.5 |
| Pressing Iron | 1 | 1500 | 1.5 | 1 | 1.5 | 1.95 |
| Microwave | 1 | 1500 | 0.19 | .5 | 0.095 | 0.1235 |
| Laptop | 2 | 95 | 0.05 | 5 | 0.25 | 0.325 |
| DVD/Decoder | 2 | 25 | 0.45 | 6 | 2.7 | 3.51 |
| Water Dispenser | 1 | 450 | 0.4 | 2 | 0.8 | 1.04 |
| Washing Machine | 1 | 400 | 0.4 | 1 | 0.4 | 0.52 |
| Total | | | 9.81 | | 63.375 | 82.3875 |

Other factors that affect the annual power usage are as follows:

a. Number of household members: a higher number of household members means more time is spent cooking, more laundry is done, larger refrigerators, etc. Additionally, because homes are often larger, they will use more energy for air conditioning and heating.

b. Features of the dwelling: well insulated houses require less energy to keep the temperature at the right level. Less electric lighting will be required if the windows' orientation and type allow for greater light.
c. Lifestyle: As we have previously stated several times, lifestyle plays a major role in determining annual power consumption. Making every effort to maximise efficiency can help you actively cut back on energy use. This entails managing appliance use, avoiding standby, selecting energy-efficient appliances, and selecting energy-efficient programmes.

### 3.2 Solar Panel Needs

Demands for solar panels are determined by three primary factors. Production Ratio, Total Solar Panel Wattage, and Annual Energy Consumption are the three. Kilowatt-hours (kWh) are used to measure the amount of energy that a residence uses in a calendar year, or the total amount of energy used by all appliances and gadgets that need to be powered. While they offer the most power, premium solar panels are only a good fit for certain types of homes. A solar panel system should be chosen with the output in mind, as it is designed to meet your entire electrical needs. The power rating, or panel wattage, tells you how much electricity the panel can generate under perfect circumstances. According to Diemuodeke (2021) the majority of solar panels have an output of 250–450 watts (W). More electricity is produced by a panel with a higher wattage. A project's requirement for solar panels will be decreased if a high wattage is used. Higher-wattage solar panels are an option for homeowners looking to meet 100% of their energy needs (Diemuodeke, 2021). Lower-wattage panels make more sense if there are fewer energy requirements or if a partial conversion system is being explored.

The process of calculating the production ratio of a solar power system involves comparing the overall wattage of the system to its predicted power generation over time. It is challenging to determine this ratio precisely because the amount of sunlight your panels receive varies every day. However, by dividing the estimated annual production by the size of the system, you can get a rough idea.

The production ratio describes how much electricity your solar panel generates in your location under typical sunlight and weather conditions. The process of calculating the production ratio of a solar power system involves comparing the overall wattage of the system to its predicted power generation over time. It is challenging to determine this ratio precisely because the amount of sunlight your panels receive varies every day. However, by dividing the estimated annual production by the size of the system, you can get a rough idea. Production ratios in Nigeria vary from one to 1.6, depending on the location. for a system generating 10 kW and 15 kWh of electricity each year. 15 / 10 = 1.5 is the production ratio for this solar energy system. This scenario is applicable to residences in places like Kaduna that receive a lot of sunshine during the day. The output ratio could fall to 1.2 if you reside in a place like Lagos or Port Harcourt where clouds are common. Similarly, this is true for areas that are usually cloudy due to Saharan dust. According to Dioha and Kumar (2018), production ratios in the range of 1.0 to 1.3 are therefore anticipated for places like Sokoto and Maiduguri.

### 3.3. Sizing of the solar PV array

Prior to sizing the array, it is necessary to calculate the system's DC voltage (VDC), average daily solar hour ($T_{min}$), and total daily energy in Watt-hours (E). After these variables are available, we proceed to the sizing procedure. Losses must be taken into account in order to prevent undersizing. To calculate the required energy $E_r$, divide the total power demand in Wh.day-1 by the product of the efficiency of all system components.

In order to prevent undersizing, we calculate the daily energy required from the solar array by first dividing the overall average daily energy demand by the system component efficiencies (Japan International Cooperation Agency, June 2010; Al-Shamani, 2015):

$$E_r = \frac{daily\ average\ energy\ consumption}{product\ of\ component's\ efficiencies}$$

$$= \frac{E}{\eta_{overall}} \qquad (1)$$

The previous value is divided by the average number of sun hours per day for the given location (Tmin) to determine the peak power.

$$P_p = \frac{daily\ energy\ requirement}{minimum\ peak\ sun - hours\ per\ day}$$

$$= \frac{E_r}{T_{min}} \qquad (2)$$

.

One can get the total required current by dividing the peak power by the system's DC voltage.

$$I_{DC} = \frac{Peak\ power}{System\ DC\ voltage} = \frac{P_p}{V_{DC}} \qquad (3)$$

In order to get the necessary voltage and current, modules must be linked in series and/or parallel Initially, the quantity of parallel modules equal to the total current of the modules divided by the rated current of each module, $I_r$.

$$N_p = \frac{whole\ module\ current}{rated\ current\ of\ one\ module} = \frac{I_{DC}}{I_r} \qquad (4)$$

Secondly, the quantity of series modules that is equivalent to the system's DC voltage divided by each module's rated voltage, $V_r$.

$$N_s = \frac{system\ DC\ voltage}{module\ rated\ voltage} = \frac{V_{DC}}{V} \qquad (5)$$

Finally, multiplying the series modules by the parallel ones results in the total number of modules, $N_m$:

$$N_m = N_s * N_p \qquad (6)$$

**3.4. Sizing of the battery bank**

The total power demand multiplied by the number of autonomy days determines the amount of approximate energy storage needed. The percentage of the battery that has been depleted in relation to its overall capacity is known as the depth of discharge. A solar battery with an 8 kWh capacity, for instance, would have a 75% depth of discharge if you were to drain 6 kWh from it.

$$E_{safe} = \frac{energy\ storage\ required}{maximum\ depth\ of\ discharge} = \frac{E_{rough}}{MDOD} \qquad (7)$$

The rated voltage of each battery Vb that will be utilised in the battery bank must be decided at this time. One way to calculate the battery bank's required capacity in ampere-hours is to divide the safe energy storage requirement by the DC voltage of one of the chosen batteries:

$$C = \frac{E_{safe}}{V_b} \qquad (8)$$

Another choice must be made for the capacity $C_b$ of each battery in the battery bank based on the number acquired for the bank's capacity. Batteries make up the battery bank. By dividing the battery bank's capacity (C) in ampere-hours by the selected battery's capacity ($C_b$) in ampere-hours, the total number of batteries is calculated:

$$N_{battries} = \frac{C}{C_b} \qquad (9)$$

At this point, figuring out the battery bank's connection is simple. The DC voltage of the system divided by the voltage rating of one of the chosen batteries determines the number of batteries in series:

$$N_s = \frac{V_{DC}}{V_b} \qquad (10)$$

The total number of batteries is then divided by the number of batteries connected in series to get the number of parallel paths, or $N_p$:

$$N_p = \frac{N_{battries}}{N_s} \qquad (11)$$

We move on to the following system component as soon as the battery bank's size is known.

**3.5. Sizing of the voltage controller**

The lifetime and efficiency of your complete battery-based photovoltaic (PV) system depend on the choice of an effective and well-designed charge controller. You can go closer to offsetting your use of traditional grid power or another source of energy by making the most out of the power that your solar modules generate. Additionally, by safeguarding your battery bank, you'll be shielding yourself from unanticipated and unnecessary replacement expenses. Current levels can rise due to a few things, like light reflection or the sporadic cloud effect. This happens frequently. As a result, we add a 25%–30% cushion to the charge controller amperage.

It regulates the flow of current in accordance with its function. Both the maximum current generated by the array and the maximum load current must be supported by a reliable voltage regulator. By multiplying the short circuit current of the modules connected in parallel by a safety factor $F_{safe}$, the voltage regulator's size can be determined. The voltage regulator's rated current is provided by the outcome:

$$I = I_{Sc} * N_P * F_{safe} \qquad (12)$$

In order to ensure that the regulator can manage the maximum current generated by the array, which may exceed the tabulated value, the safety factor is utilised. Additionally, in the event that equipment is added and the load current exceeds the planned amount. Stated differently, this safety factor permits a small system expansion.

The array short current amps divided by the amps for each controller determines the number of controllers.
:

$$N_{controller} = \frac{I}{Amps\ of\ each\ controller} \qquad (13)$$

**3.6. Sizing of the inverter**
The exact power drawn from the appliances that will run simultaneously must be ascertained before sizing the inverter.

**3.6. Sizing of the system wiring**
Optimising the size and kind of wire will improve a solar system's efficiency and dependability. NEC stands for National Electrical Code.

**4.0 Result of the sizing and design**

**4.1. Sizing of the Solar Array**
The select panel is Luminous (240W, 24V, 8.85 A). The following procedure can be used to calculate the solar array's daily energy requirement. First, the entire Watt-peak rating required for photovoltaic modules is computed. The PV modules' total daily Watt-hour need is split by the panel generation factor. The panel generation factor for the locations is calculated to be 3.625.

***Total Watt-peak rating needed for PV modules*** $W_p$ = *82.3875/3.625 = 22.7276k*$W_p$
$V_{dc}$ = *24V*

*Total Current Needed* $I_{dc} = W_p / V_{dc}$ = 22727.6/24 =946.33 A

In order to get the desired current and voltage, panels are connected in series and parallel.

Rated Current of the Module $I_r$ = 8.31 A

*Number of Parallel Panels* $N_p = I_{dc} / I_r$ = 946.33/8.31= 113.88

*Number of Series Panels* $N_s = V_{dc} / V_r$ = 24/24 =1

*Therefore, total number of panels required* = $N_p \times N_s$ = 127.024 or 128 panels

**Table 4.** Specifications of solar panel Poly Luminous (250Watts, 24V, 8.31 A) (GZ-SUPPLIES, 2024)

| Property | Specification |
|---|---|
| Brand | Luminous |
| Model Name | Solar Panel 250W |
| Capacity | 24V |
| Output Power | 250 Watts |
| Operating Voltage | 24 Volt |
| PV Panel Type | Poly Crystalline |
| Manufacturer warranty | 1 year on Manufacturing defects |
| Performance Warranty | 25 Years |
| Key Features | A+ Grade, anti PID Poly Crystalline cells, Cell Conversion efficiency > 16%, Compliance to IEC standards |
| Voltage at Max Power ($V_{max}$) | 30.20 V |
| Open Circuit Voltage ($V_{oc}$) | 37.42 V |
| Current at max power ($I_{max}$) | 8.31 A |
| Short Circuit Current ($I_{sc}$) | 8.85 A |
| Dimensions (in cm) | 167 * 5 * 101 |
| Weight(kg) | 25 |

## 4.2 Sizing of the battery bank

The maximum discharge depth of $LiFePO_4$ battery cells ranges from 98% to 100%. This outlasts the majority of other battery technologies that are available right now. This implies that you can fully drain these batteries without risk. Table 5 displays the specifications of the Polinovel $LiFePO_4$ battery, which is a 48V 400ah high capacity 20kWh energy storage battery for solar systems.

## 4.3. Sizing of the Battery Bank

Rough energy storage needs are determined by multiplying the total power demand by the number of autonomous days.

*Total Average Energy Use* = 82.3875

*Days of autonomy or no-sun days,* $D_{ns}$ = 3 days

According to the selected Battery, *(UB-8D AGM 250 AH, 12V-DC)*, the amount of energy storage required is

$E_{rough} = \boldsymbol{W_p} \times D_{ns}$ = 82.3875 x 3 = 247.1625

Maximum Depth of Discharge MDOD =0.98

For Energy Safety, $E_{safe} = E_{rough}$ /MDOD = 247.1625/0.98 = 252.21 kWh

The capacity of the battery bank $C = E_{safe} / V_b$ = 252,210/48 = 5,254.375Amps h=

The Number of batteries
$N_{batteries} = C/C_b$ = 5,254.375/250= 21.89 or 22 batteries

Number of batteries in series = $\frac{V_{DC}}{V_b} = 24/48 = 0.5 = 1$
Number in parallel = 22/1 = 22

**Table 5.** Specification of Polinovel $LiFePO_4$ battery (POLINOVELBATTERY, 2024)

| Property | Specification |
|---|---|
| Model | ES48400 |
| Nominal Voltage | 51.2V |
| Nominal Capacity | 400Ah |
| Energy | 20480Wh |
| Self-Discharge | <3%/month |
| maximum discharge depth | 98% - 100% |
| Dimensions (L x W x H) | 927 x 460 x 475 mm (36.5 x 18.1 x 18.7 in) |
| Weight | 198kg (437 lbs) |
| Terminal Type | Customizable |
| Case Material | SPCC Steel With 250℃ High Temperature Baking Paint |
| Enclosure Protection | IP54 |
| Cell Type | Cylindrical |
| Chemistry | LiFePO4 |
| Recommended Charge Current | 80A |
| Maximum Charge Current | 200A |
| Charge Current (0 to -10 ºC) | ≤0.1C |
| Charge Current (-20 to -10 ºC) | ≤0.05C |
| Recommended Charge Voltage | 56.8V-58.4V |
| BMS Charge Voltage Cut-Off: | 62.4V (3.9 ±0.025 vpc, 1~1.5s) |
| Reconnect Voltage | 60.8V (3.8 ±0.05vpc) |
| Maximum Continuous Discharge Current | 200A |
| Peak Discharge Current | 400A (<5s) |
| BMS Discharge Current Cut-Off | 550A (±20A, 9±2ms) |
| Recommended Low Voltage Disconnect | 40V |
| BMS Discharge Voltage Cut-Off | 32.0V (2.0±0.05vpc, 120~180ms) |
| Reconnect Voltage | 36.8V (2.3±0.1vpc) |
| Discharge Temperature | -20 to 60 ºC (-4 to 140 ºF) |
| Charge Temperature | 0 to 45 ºC (32 to 113 ºF) |
| Storage Temperature (1 month) | -20 to 60 ºC (-4 to 140 ºF) |
| Storage Temperature (3 months) | -20 to 45 ºC (-4 to 113 ºF) |
| Storage Temperature (6 months) | -20 to 25 ºC (-4 to 77 ºF) |

### 4.4. Sizing of the Voltage Controller:

Usually, the solar charge controller is rated based on its voltage and amperage capacity. After determining which solar charge controller type is best for your application, choose one that matches the voltage of the PV array and batteries. Verify the solar charge controller's capabilities to manage the PV array's current. The total PV input current that is supplied to the series charge controller type controller determines its size, as does the arrangement of the PV panels (series or parallel). It is normal procedure to multiply the PV array's short circuit current (Isc) by 1.3 in order to determine the size of the solar charge controller.

Solar charge controller rating = Total short circuit current of PV array x 1.3

Conext™ MPPT 60 150 solar charge controller is selected as the controller. The specifications are presented on Table 6.

**Table 6.** Specifications of Conext™ MPPT 60 150 solar charge controller (Conext™ MPPT 60 150 solar charge controller (SOLAR.SE, 2024)

| Property | Specification |
|---|---|
| Device short name | Conext™ MPPT 60 150 |
| *Electrical specifications* | |
| Nominal battery voltage | 12, 24, 36, 48, 60 V |
| Battery voltage operating range | 0 Vdc to 80 Vdc |
| Min. PV operating voltage | Battery voltage +5 V |
| Max PV operating voltage | 140 V |
| Max. PV array open circuit voltage | 150 V including temperature correction factor |
| Max. array short-circuit current | 60 A (48 A @ STC) |
| Max PV array rating | 5250 W |
| Max. charge current | 60 A (for all battery voltages except 60 V) |
| Max. and min. wire size in conduit | #6 AWG to #14 AWG (10 to 2.5 mm²) |
| Max. output power | 3500 W |
| Charger regulation method | Three-stage (bulk, absorption, float) plus manual equalization Two-stage (bulk, absorption) plus manual equalization |

From Specification of the solar panel, the short circuit current ($I_{sc}$) is 8.85 A.

Therefore
$I = I_{sc} * N_p * F_{Safe}$ = 8.85 A x 22 x 1.30 = 253.11.8 Amps

Number of Controllers
$N_{Controllers}$ = I/Amps of each controller = 253.11.8/60 = 4.22 or 5 controllers

### 4.5. Sizing of the Inverter:

In systems that require AC power output, an inverter is employed. The overall wattage of the appliances should always exceed the input rating of the inverter. Your battery's nominal voltage and the inverter's voltage must match. The inverter for standalone systems needs to be big enough to manage all the Watts you'll be utilising at once. The inverter's size should be 25–30% larger than the appliances' combined wattage. If the type of appliance is a motor or compressor, the inverter size needs to be at least three times the capacity of those appliances. Additionally, the inverter capacity needs to be increased in order to withstand surge current at startup. To ensure safe and effective operation, the input rating of the inverter for grid tie or grid connected systems must match the rating of the PV array.

The power of devices that may run at the same time is:

$P_{total}$ = 9.81 kW.

The required inverter needs to have a capacity of roughly 9.8 kW at 220-Vac. Mercury 11KVA Solar Hybrid Inverter MPPT is so chosen. The details are displayed in Table 7.

**Table 7.** Specifications of Mercury 11KVA Solar Hybrid Inverter (MERCURYDIRECT, 2024)

| Specifications | Details |
|---|---|
| Rated Power | 11000VA / 11000W |
| Parallel Capability | 120-450VDC; 230VAC (170-280VAC range)<br>230VAC +/- 5% |
| Surge Power | 22000VA |
| Peak Efficiency | 93% |
| Transfer Time | 10ms (PC); 20ms (Home Appliances) |
| Solar Input Power | 11000W (4000WX2); 150A; 48VDC |
| Operating Temperature | -10°C to 50°C |

## 5.0 Conclusion

Nigeria is one of the biggest countries in West Africa, home to about 213 million people. With a GDP of about $477 billion, it is ranked 31st globally and first in Africa. In addition to enhancing the country's current infrastructure, Nigeria has to develop solar and renewable energy sources in order to maintain economic growth, meet SDG7 targets, and raise the standard of living for its people. The methods used to choose the various components of a standalone photovoltaic system have been examined in this study. The technique will be implemented in a typical Nigerian household located in a posh neighbourhood. In order to attain the design's goals, the sizes of the solar PV array, battery bank, voltage controller, and inverter have been determined in this paper, along with the suggested brands. for the home under consideration. According to the design, in order to supply solar electricity to the household, 128 Poly Luminous solar panels (250 Watts, 24 V, 8.31 A), 22 LiFePO4 batteries (48 V, 400 Ah, High Capacity, 20 KWH Energy Storage Battery), 5 ConextTM MPPT 60 150 solar charge controllers, and 1 Mercury 11 KVA Solar Hybrid Inverter are required.

Additionally, all of the elements that influence the size and design of each piece of equipment in the system have been listed. When sizing every piece of equipment In order to guarantee an adequate, dependable, and cost-effective system design, oversizing and undersizing have also been avoided. The same techniques might be used, modified for applications with different energy consumption levels, and applied to different regions. Nonetheless, the design ought to take into account the relevant design constraints of these sites.

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