



Design and Installation of a 3.5KVA Solar Photovoltaic Power System

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ABSTRACT

Exploitation of solar energy to power electric appliances starts by converting the energy coming from the sun to electricity. Photovoltaic is the direct conversion of the solar energy into electricity. Photovoltaic systems can be used to exploit the solar energy in almost all kinds of applications. Exploiting of solar energy for domestic use is one avenue where the energy emitted from the sun is converted into electricity to power most, if not all the appliances available at our offices, homes and residences. In Aerospace Engineering Department (AED) in Air Force Institute of Technology (AFIT), there are other reasons why the use of solar energy is so necessary; firstly, appropriate climatic conditions, secondly, inadequate electricity supply during working hours in the Department. Installing a photovoltaic system is the process of designing, selecting and calculating the ratings of the equipment's employed in the system. This process depends on a variety of factors such as geographical location, solar irradiation, and load requirements. In this Research, the components required for the design of a stand-alone photovoltaic system that will power most of the electric appliances at a medium-energy-consumption for the offices in AED in AFIT is being studied as presented herein. The result shows that for a daily energy consumption of 6,640kwh and a load of 1,790W, as required from the energy audit in the Department. The suitable rating is a 3.5kva inverter, 4 pieces of 200Ah, 12 V batteries, 1 charge controller and 5 modules 250W panels are required for sufficient supply of power.

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INTRODUCTION

The world is degrading gradually and the change in innovation is giving a positive and negative effect on the globe. Our world is secured by the ozone layer that protect all living being to survive from the intense radiation of the sun. Development as we probably are aware is the antagonistic change that happens in a creature, association or the world, as we probably are aware of, Man has assumed a major part in these happenings and science and technology has being the purpose behind these progressions. Researchers and architects have created component to help man to the detriment of decimating him and the earth with the constant outflow of risky gases that causes ecological contamination and health hazard.

The expanding populace accompanies appeal for an alternative source of energy that will be favorable to human wellbeing and nature. Along these lines, a birth of Renewable Energy as an alternative source of power [1]. Renewable energy is energy gotten from regular events that can be bridled to do work. It can be ordered differently; sunlight (solar energy), wind Turbine, water (hydroelectricity), geothermal and so on. [2]

Conventional Energy otherwise called fossil fuel (Hydrocarbons) has assumed a noteworthy part in the rebirth of the world, changing the system from the Stone Age into an advanced existence where less energy is required to accomplish more work. The unfriendly effect of non-renewable source of



energy in particular; Premium Motor Spirit (Petrol), Dual Purpose (Kerosene), Automotive Gas Oil (Diesel) has achieved increment in emanation of Green House Gases (CO₂, CO, SO₄) which annihilate the earth. Renewable energy has been given more consideration in view of the positive commitment towards the sustainability of the planet [3]. The International Energy Agency (IEA) 2014 world energy Outlook anticipated that an expansion in demand for energy would be evaluated at 37% by 2040 [4]. Renewable energy has contributed throughout the years and record for an estimate of 62% of net increases to global power with the nonstop development in this pattern. Renewable energy will acquire prevalence as elective wellspring of energy over different sources [4].

Solar energy that is our major concern in this project, works on the principle of the sun radiation warming the Photovoltaic (PV) material where the energy is harnessed by technological method into electricity. This type of energy is one of the cleanest, climate-friendly, rich and endless type of energy which can be harnessed all around without causing environmental change [5]. It is portrayed into Passive system and Active system. The Passive system doesn't have mechanical gadgets while the active system utilizes mechanical gadgets. Solar electricity could either be direct with the utilization of PV or indirect with the utilization of concentrated solar power (CSP). The CSP system utilizes lenses, mirror and tracking system to center at area where high sunlight falls on a sectional region which changes sunlight into electricity with the aid of some electrical gadgets like semiconductor that display the photoelectric effects. The name Photovoltaic is gotten from the process of converting light (photo) into electricity (voltaic) and this procedure utilizes the photoelectric effect. The process of power generation includes the utilization of solar panel that has photovoltaic cells made of semi-conductors, for example, silicon, cadmium and so forth. These intersection gadgets are the essential unit of the solar panel that are the principal components of the system and can be connected either in series or in parallel depending on the nature of output needed [6].

The cost of setting-up the system is very expensive and could be extremely demoralizing in district of low radiation (sunlight). The merit of

PV systems include; There is no discharge of gases or natural contamination during operation, There is no commotion contamination during operation, There is no danger of flame flare-up, Maintenance culture is exceptionally irrelevant because of no movement system. Solar cells are dependable energy source which can be utilized anyplace, particularly in remote areas where there is no national grid. and The demerit of solar system include; Setting-up cost is very expensive because of segmented portion of the system, and No radiation during the evening and less radiation in cloudy condition creates low yield and an essential storage system is required for productivity in conveyance even at more terrible conditions.

A study of assessment was done on the conventional energy that are coal, natural gas and hydrocarbons, they have been our major source of energy for a longtime and it has recorded part of colossal accomplishment in maintaining human existence. Despite the fact that these energies accompany her real difficulties that is emission, that obliterates all living organism and the planet at large. In like manner the epileptic power supply from the network has been of genuine worry as it neglects to proffer solution in the offices. Our venture is fixated on giving elective answer for clean energy and steady supply of power to the Aircraft Engineering Department (AED) in Air Force Institute of Technology, AFIT, Kaduna State.

The aim of this research is to reduce downtime due to power interruption, by providing an alternative source of power supply for office utilization, effective lecture delivery, and it will support research in the laboratories and workshop, diminish noise pollution from generators, eradicate absolutely the emission from generators by utilizing the Solar system as option for power generation, diminish the over-reliance on the conventional source of energy in the office with the introduction of solar system, diminish epileptic power disappointment in the department, wipe out maintenance cost like conventional energy, on like solar system which is zero cost for maintenance, and also other activities within the Department that requires power supply.

Off-Grid Solar Electrical System

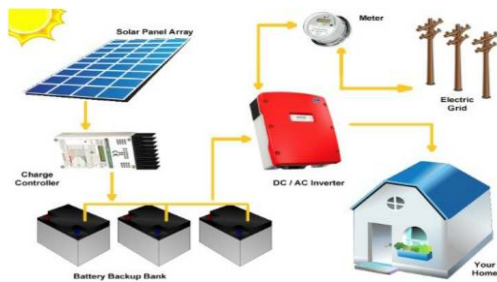


Figure 1: Off-Grid (stand-alone) PV System with battery backup and generator backup.

The off-grid PV system as in figure 1 above, also known as the stand-alone PV system is designed to operate independent of the electric utility grid, and is generally designed and sized to supply certain DC as well as AC electrical loads. These kinds of systems might be powered by a PV array only, or may utilize wind, a motor generator or utility power as an assistant power source in what is known as a PV-Hybrid system. The most well-known sort of stand-alone PV system is the one in which batteries are utilized to store energy created by the PV array.

LITERATURE REVIEW

Several researches have been done on solar energy and its application. The study by Arun et al clearly reveals that the increase in demand for conventional energy sources has driven the society towards the research and development of renewable energy sources; hence solar energy [7]. The solar energy offers lots of advantages over the conventional sources of energy; the application of this energy is useful and provides power to remote areas of the world, it is environmental friendly and inexhaustible. However, the limitations of day and night cycles coupled with high costs in comparison to other sources of energy hinders its ready acceptance which calls for more research to be done in the area of solar photovoltaic, and solar energy as a whole with a view of discovering alternative materials with higher efficiency of conversion, reduced panel areas per kilo-watt, more effective, economic and durable storage system for sustained production of power [8].

According to Michael Geyer *et al* [9], the major setback in the acceptance and application

of solar energy in the environment is the issue of cost. Geyer and other contributors in their research outcome believed that if the cost of installing the solar power system is reduced, it will completely replace other conventional sources of energy. They proposed three methods of reducing the cost of a solar parabolic collector, they include: Cost reduction by simplification of design, Cost reduction by improvement of the optical performance of the collectors, and Cost reduction achieved in additional steps: possible tilt of the collector and extension of collector length per drive unit. After the application of these methods, they were able to achieve an overall cost reduction for the solar field of 14%, an increase in the annual performance of the parabolic trough collector and an additional reduction of solar electricity costs.

Future research for ways of reducing the cost of installing the solar power system will prove very efficient in the acceptance of solar energy in the world. Another research carried out by Dr. Okoro [10] reveals that solar energy should be a necessary investment in a developing country. In his research, Dr. Okoro analyzed and compared the advantages and disadvantages of using conventional energy sources and solar energy. According to him, solar energy is very important in a developing country because the over-dependence of fossil fuels and other energy sources has caused energy crisis in developing countries. After his work, he was able to conclude that, though the initial cost of installing the solar power system is high as compared to the conventional sources, the cost of maintaining the solar power system is very low when also compared to the conventional source. It is evident from his paper that the solar energy is the most attractive and efficient way of electrical generation in a developing country. A study done by Harry [11] showed that solar energy has vast application. In his research "Solar to Fuels Conversion Technologies", Harry pointed out that for solar energy to completely replace the conventional source of energy, two important challenges must be addressed. According to him, the first challenge is to provide adequate energy storage capabilities for solar-generated electricity, given the intermittent character of the solar resource. The second and perhaps the most important challenge, is utilizing solar energy to aid in the production of clean alternative fuels for the

transportation, industrial and housing sector. In his attempt to address the second challenge, hary studied the conversion of solar energy to fuel for use in the transportation sector. Solar energy collected and concentrated within a solar utility can be harnessed in different ways to generate an environmentally friendly solar fuel, this processes includes;

1. Photovoltaic system to convert sunlight into electricity which, in turn, could be used to drive electrochemical (electrolysis) cells that decompose inert chemical species such as H₂O or CO₂ into useful fuels.
2. Photo electrochemical or photocatalytic system could be designed wherein electrochemical decomposition reactions are driven directly by light, without the need to separately generate electricity.
3. Photo thermal systems could be used either to heat working fluids or help drive desired chemical reactions such as those connected with thermolysis, thermochemical cycles, etc.

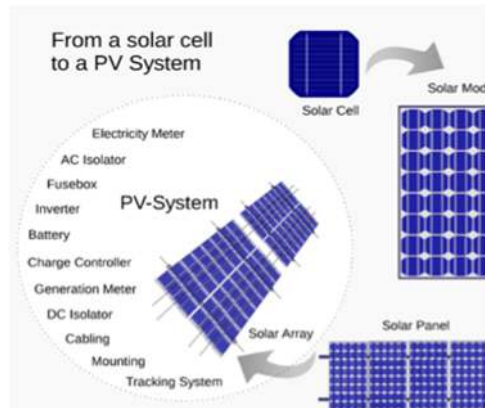


Figure 2. From Solar Cell to a Photovoltaic System [13]

Source: Photovoltaiccell@www.wiki/photovoltaiccell.com

The solar fuel so produced offer efficient production, sufficient energy density, and flexible conversion into heat, electrical, or mechanical energy. Solar energy has numerous applications when it is converted to heat, electricity or biomass. The technologies for conversion of solar energy into heat and electricity can be classified into solar thermal systems and PV systems [11]. A work carried out by Ilenikhena [12] helps define the solar thermal system and the PV system. In his

research, “solar energy application in Nigeria”, he described the solar thermal systems as solar energy technologies for conversion of solar radiation into heat which can be used directly or converted into mechanical energy and in turn electricity. The solar radiation and conversion are done using the solar energy collector. The efficiencies of these collectors can be improved by using spectrally selective surface. The conversion of solar heat into mechanical energy and then to electricity is termed concentrated solar power (CSP). Also the PV system is a solar energy technology for direct conversion of sunlight into electricity using panels made of semiconductor cells. After defining the solar thermal system and the PV system, he gave different applications of solar energy which includes; solar water heaters, solar crop, fish and manure dryers, solar cookers, solar chicken brooders, solar photovoltaic and solar concentrated power. In this research, much emphasis will be made on the solar PV system and it applications that make it more viable than conventional power supply. The conversion of the solar cell to the solar photovoltaic system is shown in figure 2 above.

The birth of PV technology dates back to 1839 when Edmund Becquerel, a French experimental physicist, discovered the photovoltaic effect while experimenting with an electrolytic cell made up of two metal electrodes [4].

RESEARCH METHOD

In the design and establishment of a solar photovoltaic system, there is an arrangement for general improvement to guarantee that the research is accomplished successfully. A comprehensive literature review is carried out to ascertain extent at which similar research has been conducted and identify knowledge gap. This comprises of survey of the solar PV system outline and development throughout the years and furthermore a definite clarification of the essentials of the fundamental parts of the PV system. Furthermore, an energy audit was carried out at the Department to ascertain the required power rating for electricity consumption. This comprises taking the power rating for every required electrical appliance at the Department and sum up to give an approximate power rating of 3.5kva considering safety factor of 25%. Afterwards, a thorough market survey was made to meet the market

worth of all the necessary components required for successful installation of solar PV power supply.

Proper design of the rack, angle of inclination of the rack on which the panels are to be mounted are scaled to standard dimension to enable maximum productivity of the solar radiation. The stipulated battery, inverter, charge controller and all required components are put in place to achieve research aim. A study is further conducted on the installation site. Here, the latitude, longitude, elevation, climate conditions per annum, the measure of solar radiation and period of solar radiation every day is gotten and recorded. After the site review, an energy review is done on the site.

The outcome from the energy review is then recorded on a tabular form and it includes calculating the aggregate energy consumption of every gadget to be controlled daily. Subsequent to social event all important data about the PV system from the literature review, and a detailed description of the site has been gotten including completing an appropriate energy review on the site, at that point the best PV system compose is selected, and the different components are identified.

Subsequently, a legitimate measuring of the components is done by numerical computational methods. At the point when the estimation has been done, the system is then installed and tested. The testing procedure is to accumulate data about the working state of the PV system and the power delivered by the system. This is to test if the system is working legitimately, if yes, at that point the venture moves to the following procedure that is composing a definite result of the project. In the event where the PV system and its parts are not working appropriately or according to expectation, at that point the procedure falls back to the measuring and installation process where important adjustment is made to guarantee the system operates or works as expected. At the point when this is done, the project moves to the last stage that is composing of the outcome from the different exercises carried out over the span of the project. The research has so far shown a promising outcome at this preliminary stage. An outline demonstrating the project flowchart is as shown in fig 3 below.

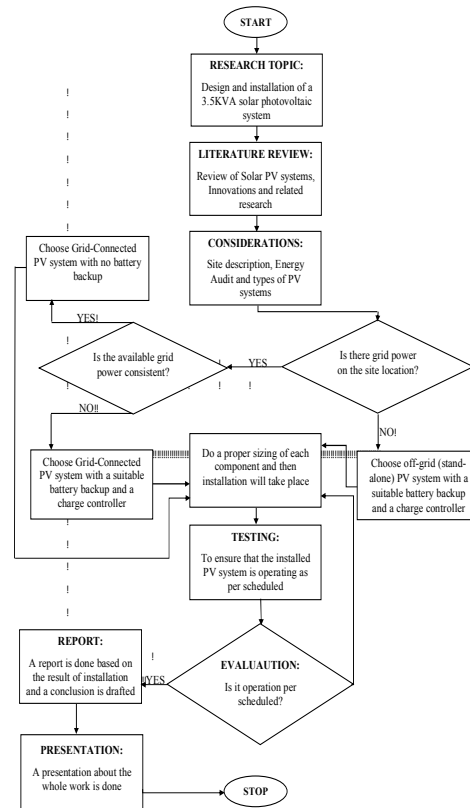


Figure 3: Flow Chat

Location Description

This site is the Faculty of Engineering building in AFIT, Kaduna State. The Institution is a fast growing institution in Nigeria. It is located in Kaduna, Kaduna State. The school lies within latitude $10^{\circ} 36' 33''$ N and longitude $7^{\circ} 25' 46''$ E (36), thus it enjoys two climate seasons in a year: The wet season from April to October and the dry season from November to March. As a result of the effect of climate change, the city of Kaduna has more sunlight than rainfall in a year.

Energy Audit

The energy audit involves itemizing the various electrical device that will be powered by the PV system with their power ratings and time of operation during the day to obtain the average energy demand in Watt-hour per day (Wh/day). The total average energy consumption is used to determine the equipment sizes and ratings starting with the



solar array and ending with system wiring and cost estimation. This part of the project is very vital as it will determine the sizes of all other components and the cost of the project. It involves checking the power rating of each device to be powered and summing them up, the result is then represented on a tabular form.

Selection of the Best Grid

Essentially, there are three kinds of PV system; the grid-connected without battery backup, the grid-connected with battery backup and the off-grid or stand-alone PV system. The selection of any of the three kinds of PV system will be based on the following; Amount of solar radiation and span of sunlight per month on site, Energy audit accomplished on the site, Availability of a grid power nearby, and Reliability of the grid power nearby.

The amount of solar radiation and duration of solar radiation per day will determine how well and how long the radiation from the sun will hit the solar array, a very large amount of solar radiation will mean that the amount of sunlight available to be converted into electricity will be significantly high, and the duration will determine how long the solar array will convert light into electricity. Basically, large solar radiation and long hours of sunlight will need fewer solar modules to charge the storage battery and vice versa. The energy audit will help determine how much power is needed and the size of the PV system. A large power will need a grid-connected PV system with battery backup while small power can use a stand-alone PV system.

The availability and reliability of the grid-power on site is the most important factor to be considered. Is there a reliable grid-power on site, then a grid-connected PV system without battery bank can be used to supply power to devices when there is a grid power outage. If the grid-power on site is not reliable, then, there will be need for a storage battery; hence, a grid-connected PV system with battery backup will be used. On the other hand, if there is no grid-power available, then the Stand-Alone (off-grid) PV system with battery bank and/or generator backup can be utilized.

System Sizing

The system sizing involves sizing of the significant components of the PV

system. After a legitimate PV System has been chosen, the next thing is to pick the parts of the system. A grid-connected PV system with battery will require a battery backup and a charge controller which isn't required for the grid-connected PV system without battery reinforcement. Likewise, the kind of inverter required for the stand alone inverter will be quite different from the Grid-connected PV system. In general, the system sizing incorporates; sizing of the solar array, sizing the battery capacity, sizing the charge controller, sizing of the inverter and measuring of the wiring cables. The strategy utilized here is depicted by Ali et al [15].

Sizing of the Solar Array

Before sizing the array, the total daily energy in Watt-hours (E), the average sun hour per day T_{min} and the DC-voltage of the system (VDC) must be determined. Once these factors are made available then, the sizing process can commence. To avoid under sizing, losses must be considered by dividing the total power demand in Wh/day by the product of efficiencies of all components in the system to get the required energy E_r . To avoid under sizing, we begin by dividing the total average energy demand per day by the efficiencies of the system components to obtain the daily requirement from the solar array:

$$\begin{aligned}
 & \text{Daily energy required} \\
 &= \frac{\text{daily average energy consumption}}{\text{product of component efficiency}} \\
 &= \frac{E}{\eta_{overall}} \dots \dots \dots (1)
 \end{aligned}$$

To obtain the peak power, the previous result is divided by the average sun hours per day for the geographical location T_{min} .

$$\begin{aligned}
 & \text{Peak power} \\
 &= \frac{\text{daily energy required}}{\text{minimum peak sum - hour/day}} \\
 &= \frac{E}{T_{min}} \dots \dots \dots (2)
 \end{aligned}$$



The total current needed can be calculated by dividing the peak power by DC- voltage of the system.

$$\begin{aligned} & \frac{\text{Total current } I_{DC}}{\text{Peak power}} \\ &= \frac{\text{system DC voltage}}{E_r} \\ &= \frac{E_r}{T_{min}} \dots \dots \dots (3) \end{aligned}$$

Modules must be connected in series and parallel according to the need to meet the desired voltage and current in accordance with: First, the number of parallel module which equals the whole module current divided by the rated current of one module I_r .

$$\begin{aligned} & \frac{\text{Number of parallel module } N_p}{\text{Total module current}} \\ &= \frac{\text{rated current of one module}}{I_{DC}} \dots \dots (4) \end{aligned}$$

Second, the number of series module which equals the DC voltage of the system divided by the rated voltage of each module V_r .

$$\begin{aligned} & \frac{\text{Number of series module } N_s}{\text{system DC voltage}} \\ &= \frac{\text{module rated voltage}}{V_{DC}} \dots \dots \dots (5) \end{aligned}$$

Finally, the total number of modules N_m equals the series module multiplied by the parallel ones.

$$N_m = N_s \times N_p \dots \dots \dots (6)$$

Sizing of the Battery Bank

The amount of rough energy storage required is equal to the product of the total power demand and the number of autonomy days.

$$\begin{aligned} & \text{Energy storage required } (E_{rough}) \\ &= \text{Total power demand } \times \text{ autonomy days} \\ &= E \times D \dots \dots \dots (7) \end{aligned}$$

For safety, the result obtained is divided by the maximum allowable level of discharge:

$$\begin{aligned} & E_{safe} \\ &= \frac{\text{energy storage required}}{\text{maximum depth of discharge}} \dots \dots (8) \end{aligned}$$

At this moment, we need to make a decision regarding the rated voltage of each battery V_b to be used in the battery bank. The capacity of the battery bank needed in ampere-hours (Ah) can be evaluated by dividing the safe energy storage required by the DC voltage of one of the batteries selected.

$$C = \frac{E_{safe}}{V_b} \dots \dots \dots (9)$$

According to the number obtained for the capacity of the battery bank, another decision has to be made regarding to the capacity C_b of each of the batteries of that bank. The battery bank is composed of batteries. The total number of batteries is obtained by dividing the capacity C of the battery bank in ampere-hours by the capacity of one of the battery C_b selected in ampere-hours.

$$N_{batteries} = \frac{C}{C_b} \dots \dots \dots (10)$$

The connection of the battery bank can then be easily figured out. The number of batteries in series equals the DC voltage of the system divided by the voltage rating of one of the batteries selected.

$$N_s = \frac{V_{DC}}{V_b} \dots \dots \dots (11)$$

Then number of parallel paths N_p is obtained by dividing the total number of batteries by the number of batteries connected in series:

$$N_p = \frac{N_{batteries}}{N_s} \dots \dots \dots (12)$$

Once the sizing of the battery bank is made available, we proceed to the next system component.

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Sizing the Charge Controller

The major function of the charge controller is to prevent over charging of the batteries, so the capacity of the charge control will be the total voltage of the batteries connected in series.

Cap. of charge controller

= Volt. cap. of the batteries in series. (13)

Sizing the Inverter

Since the work of the inverter is to control the AC devices in the connected PV system, in this way, when estimating the inverter, the genuine power drawn from the apparatuses that will keep running in the meantime should be resolved. This power is the limit of the inverter required.

Inverter size

= product of total load and 25% $\frac{pf}{0.65}$... (14)

Determining Angle of Inclination

To maximize solar energy, there is need to have to point them toward the path that attracts the most sunlight. Be that as it may, there are various factors in making the best location. Solar panels ought to regularly confront genuine south in the event that you are in the northern hemisphere or genuine north if you are in the southern hemisphere.

The next step is to determine at what angle from horizontal should the panels be tilted? The tilt ought to be equivalent to your scope, in addition to 15 degrees in hot climate, or minus 15 degrees in cold climate. This can be improved by about 4%. To get the best tilt angle resultant, one of the equation is utilized to locate the best point from the horizontal at which the panels ought to be tilted; If your latitude is beneath 25°, utilize the latitude times 3.05 and If your latitude is in the vicinity of 25° and 50°, utilize the latitude times 0.76 in addition to 3.1 degrees. Utilizing one of the above will ensure the best measure of sunlight promptly accessible for conversion [16].

Method of Mounting

Different solar technologies work with different mounting types, but in general there are three common solar mounting types, namely the roof, ground and pole [17, 18]. The roof mounting solar array of a PV system can be

mounted on rooftops, generally with a few inches gap and parallel to the surface of the roof. If the rooftop is horizontal, the array is mounted with each panel aligned at an angle. If the roof is already constructed, it is relatively easy to retrofits panels directly on top of existing roofing structures. In all cases of retrofits particular considerations to weather sealing is necessary. This is why this method is applied in this particular research. An example of the similar view is as could be seen in figure 4 below.



Figure 4: Roof mounted PV Solar Array

RESULTS AND DISCUSSIONS

The result for the various factors that are considered by utilizing standard formulas expressed in the last session and the geographical region as well as power requirement analysis of the site area to get the result for the design considerations. The major considerations are the location, sizing of the major components, mounting angle etc, of which energy auditing was carried out to investigate the required power rating.

Energy Audit

In the design of a solar PV system, it is first vital to do an energy review on the devices accessible in the site area. The energy audit utilizes values such as voltage, current of every device to be powered to acquire the total energy in watts and Watt hour. The energy audit helps in the computation of; Size of the solar array, Size of the battery bank, Size of the charge controller, and Size of the inverter.

From Table 1 below, the total power input in Watt is obtained by first determining the quantity of devices to be powered and then obtaining the power input for every device, at that point, the total of all power input is



resolved which sum-up to the total power input in Watt (W). Also, to obtain the total power input in Watt hour (Whr), the power input for every device is multiplied by the number of hours it is utilized every day and the quantity of days it is utilized every week then it is divided by the number of days in a week. This will give the individual power unit in an hour for every device, the aggregate of these values will give the total power input in an hour. The table 1 beneath gives the results for the energy audit.

Selection of Best grid

As earlier stated, there are three kinds of PV system; the grid-connected with battery backup, the grid-connected without battery backup and the off-grid or stand-alone PV system. Selection of the best grid system will rely upon the following factors; Amount of solar energy radiation and duration of sunlight per month of the site, Energy audit carried out on the site, Availability of a grid-power on the site, Reliability of the grid-power on the site.

In the site location i.e. Faculty of Engineering, the average solar radiation and span of sunlight hours is 13.64 and 4.20 respectively. The energy audit carried out on the site revealed that the total AC load connected is 1790W and the average daily AC load consumption is 6640 Watt hour. Likewise, from the electrical examination did on the site area, it was found that there is grid power available on the site and the grid power is reliable, generating 8 hours of power daily on average.

System Sizing

The system sizing involves sizing of the major component of the Stand-alone PV system. The major components include; the solar Panel, The battery bank, the charge controller, and the inverter. The daily energy requirement from the solar array can be determined by using equation (1)

$$E_r = \frac{E}{n_{overall}}$$

To obtain the peak power of the PV, we use equation (2);

$$P_p = \frac{E_r}{T_{min}}$$

The total current needed can be calculated using equation (iii);

$$IDC = \frac{P_p}{V_{DC}}$$

Modulus must be connected in series and in parallel according to the need to obtain the desired voltage and current in accordance with; first, number of parallel modules:

$$N_p = \frac{I_{DC}}{I_r}$$

That is, four solar modules are needed with all four connected in parallel. Battery sizing: The total energy use = 6640Watt.hour. Days of No-sun days = 1 day. According to the selected battery (UB – 8D

Size of Charge Controller

According to the selected charge controller (Xantrex C-60, 24V, 30-A), the rated current of the charge controller is;

$$\begin{aligned} I &= I_{sc} \times N_p \times F_{safe} \\ &= 6.06 \times 4 \times 1.25 \\ &= 30.3 \text{Amps} \end{aligned}$$

The number of controllers equals;

$$N_{controller} = \frac{I}{\text{Amps each controller}} = \frac{30.3}{30} = 1.01 = 1 \text{charge controller}$$

Therefore, 1 charge controller is required for this research.

Size of Inverter

The power of the devices that may run at the same time is Ptotal = 1790Watts. The inverter needed must be able to handle about 1790Watts at 220Vac. Therefore,

$$\begin{aligned} \text{inverter size} &= \text{Total load} \times 25\% \text{ pf} \\ &= 1790 \times 1.25 \\ &= 2,237.5 \end{aligned}$$

$$\begin{aligned} \text{Power factor} = 0.65 &= \left(\frac{2,237.5}{0.65} \right) \\ &= 3.442.3 \text{kw} \\ &= 3.4 \text{kva}. \end{aligned}$$

Hence, the minimum size of inverter required for this job is 3.5kva, 48V.

Panel Sizing

Note: PSH=8hrs and Total Watt hour=6,640 x 1.25=8,300

$$\begin{aligned} \text{Panel Capacity} &= \left(\frac{8,912.5}{8} \right) \\ &= 1,114 \text{kw} \end{aligned}$$

Approximately 1.2kw. This will require 4 pieces of 300W panel.

Battery Sizing

Battery Capacity (Ah) = (Total Wh per day used by appliances x DOA) / (0.85 x 0.5 x

normal voltage)= $(6640 \times 3)/(0.85 \times 0.5 \times 24)=19,920/10.2=1,952.9\text{Ah}$. Assuming DOA-1, Battery Capacity=650.9. This is equivalent to 4 x 200Ah, 12 V battery.

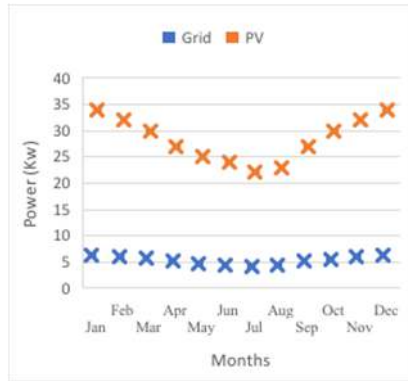


Fig 5: Average Monthly Electricity Production for the PV and Grid.

The figure 5 shows above the comparison between the PV and grid. It can be observed that the highest and lowest point is the month of February and August respectively. This is due to the temperature of 34°C and 22°C for the two months respectively. This goes further to explain the effect of sunrise in power generation for the PV array.

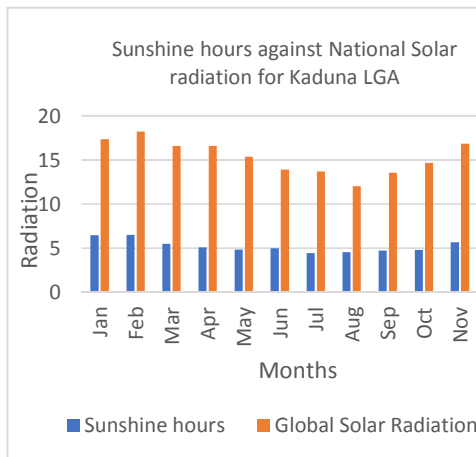


Fig 6: Sunshine hours against Global Solar Radiation for Kaduna LGA.

The figure 6 above shows the monthly sunshine hours and global solar radiation all through the year for a typical weather condition in Kaduna State. It can be observed that the highest and lowest sunshine hours is 6.49 and 4.55 for February and August respectively. And that of the monthly solar radiation is 18.22 and 12.02 for same months respectively.

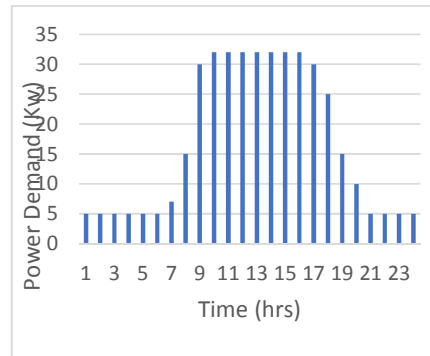


Fig 7: Hourly Energy Consumption in the Institute.

Figure 7 shows the amount of power usage in a typical day at the Department. It can be observed that power usage started rising from about past 8am when workers started clocking into the days' job which starts at 9am and stable till about 5pm when the days' job come to an end, and shorting down keeps some workers using power up till about 7pm for those doing overtime before it returned to normal level at about 8pm.

The table 1 below shows the various appliances, quantity, load, power rating and daily energy usage. It is deduced from this table to calculate the major requirements of the main components in the solar array applied in this research.



Table 1: Cost of Energy Consumption from recommended appliances

S/N	Appliance	Quantity	Power rating (W)	Connected Load (W)	Operating Time (hrs)	Daily Energy (KWh)
1	32' TV	3	70	210	4	840
2	Fan	4	70	280	4	1120
3	Projector	1	60	60	4	240
4	Desktop	2	80	160	5	800
5	Laptop	4	60	240	4	960
6	Printer	2	70	140	2	280
7	Scanner	1	100	100	1	100
8	Bulb	10	10	100	8	800
9	Miscellaneous		500	500	3	1500
	Total			1,790		6,640

CONCLUSION

Solar energy is predicted to play a major important role in the nearest future, thereby reducing reliance on petroleum derivatives (fossil fuels), as well as diminishing the environmental hazards as priority. This research introduces the utilization of solar PV system in producing a sustainable power supply, likewise decreasing the over reliance on conventional energy as PV system meets the general requirement of power production, being that it is renewable, sustainable, cost effective, almost maintenance free, and suitable for off-grid applications. It can be utilized to replace the conventional source of generating power. The solar PV power generation system converts the DC energy by a solar cell array into AC energy that is fed into the utility. The PV system composed of the solar array contains the solar cell that is used for the direct conversion of sunlight into electricity, the battery bank that stores the battery for use in less sun days mainly during the night, the charge controller or charge regulator regulates the voltage entering the battery by creating a short circuit if the voltage supply is too much, and the inverter that converts the DC produced by the solar array into AC that is fed into the utility. Furthermore the proposed 3.5KVA power size was successfully generated, the system was design to feed out 3.0KVA as utility output while 0.5KVA was reserved as factor of safety and for avoidance of power fluctuation and system overloading.

RECOMMENDATIONS

The output of a solar PV system is very reliant on good system design derived from accurate site and demand data. It is important that exact assumptions are made with respect to energy demand/pattern of operation and energy availability. Considering solar PV system and energy availability, the daily variation in solar power generation requires storage capacity of surplus of energy on sunny days for utilization on cloudy days. This research will enable accurate valuation of the solar PV system components to be expanded, additionally, further modification on the system can be completed to effectively capture more sunlight and create more electrical power during the day. Such modification may incorporate, solar tracking mechanisms, increase in the quantity of solar panels, or utilization of a solar concentrated panels to focus sunlight over an enormous region. Improving solar power generation capabilities will help to reduce the global carbon footprint, meet climate change goals, and reduce pollutants and greenhouse gases from traditional energy sources. If any cell in a solar panel is blocked from the sun, it will disrupt the energy output of the panel. Cleaning dust and dirt from the panel can be challenging, time consuming and dangerous considering the location of solar panel mounting being the roof of the Faculty of Engineering, windshield self-wipers can be attached to solar panels in subsequent solar PV design and installation.

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