

**DESIGN AND INSTALLATION OF 200 WATT SOLAR
POWER SYSTEM**

BY

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**BEING A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENT FOR THE AWARD OF BACHELOR OF
ENGINEERING (B.ENG) DEGREE IN ELECTRICAL/ELECTRONIC
ENGINEERING**

CARITAS UNIVERSITY, AMORJI-NIKE ENUGU

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APPROVAL PAGE

This is to certify that the design and installation of 200watt solar power system embarked upon by the student whose name and registration number appeared have been dully endorsed.

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DEDICATION

I dedicated this project to the Almighty God.

ACKNOWLEDGMENT

My most profound gratitude goes to the almighty God for the gift of life and good health in the actualization of this work.

I am most grateful and highly indebted to my supervisor Engr. C. O Ejimorfor, for his ceaseless, helpful, constructive criticisms and encouragements and comments on this work and also for all his effort in making sure that the department produces quality engineers that can effectively compete in the labour market and give good image of the department in particular and the school in general.

My sincere thanks go to my mother Mrs Martina Ezugwu and brother Leonard for their tireless efforts and support towards the successful completion of my studies. My gratitude also goes to my brothers Felix, Obira, Onyeka, Onyebuchi, Emeka and my sister nkolika for their love, prayers and encouragements. Also to all the members of my family and well-wishers, Worthy of mentioning is all my lectures in the electrical/electronic department of Caritas University for nurturing me up to this extent.

And to my friends ifeanyi ugwu, and Nkeiru.

ABSTRACT

The 200W solar system was determined by load assessment, solar panel number determination, battery requirement and then inverter sizing. A complete solar panel rated at 200w was however purchased, together with 2 no. 150A solar battery, 1500W inverter and also 10A charge controller. These were assembled together with necessary protective gadgets like cut out switches; to give the 200W expected. The solar panel was mounted outside the building to allow for maximum collection of sun energy. It is expected that the system will help the department meet up with its office duties even when central power is not available.

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CHAPTER ONE

INTRODUCTION

1.1 NEED FOR THE PROJECT

The general objective of the system is to provide efficiency, steadiness in the use of power appliances, by ensuring continuous availability of power supply even in the absence of mains. Uninterruptability of the system made it possible to eliminate all suspense from mains outage during the execution of an important and urgent assignment as may be required.

For better production of the system, the system was operated at a fully charged condition of the battery.

The project was rated 200W of 220V and 50Hz. It was expected that at this condition, it was favourable to carry load of the stipulated power. Loads of low power factors are not helpful since they produce spikes. Overloading is not potent to provide zero change over time and the inverter had LEDs which indicates mains failure and battery discharge and system fault.

1.2 SCOPE OF STUDY

This solar power source makes it possible to provide a clean reliable supply of alternative electricity free of sags or surges which could be found in the line voltage frequency.

The solar power system (SPS) system achieved this by direct current from solar panel and by rectifying the standard main supply, using the direct current to charge the batteries and to provide clean alternative power by passing the energy a filter system.

It has zero change over time and LEDs which indicates mains fail and battery discharge level and it provides 100% protection against line noise, spikes surges and audio frequency interference.

1.3 DEFINITION OF TERMS

1. Inverter unit: This unit converts a DC voltage into AC voltage with the help of the inverter unit.
2. Automatic Control Unit: This provides all the required control needed to meet up the objective of the whole system
3. Battery Unit: This is a secondary cell unit, capable of storing enough DC voltage from either sun or AC main, of which is later converted to AC voltage.

CHAPTER TWO

LITERATURE REVIEW

The use of the sun's energy is nothing new and dates back to the beginning of time. In recent years however, the focus on energy consumption worldwide rapidly spurred growth in the research and development of "green" alternative fuel source including the sun, wind, hydro, wave, geothermal, hydrogen and other forms of energy. And today, because of that focus, the use of solar energy is expanding by leaps and bounds especially since sunlight is free, unlimited, readily available, clean and reliable.

A solar power system is one which is capable of converting the absorbed sun energy; store it in a lead acid cell to be used on the load.

In our part of the world, where power supply is not effective and efficient, the use of solar power supply is of immense value and advantage considering the fact that we are blessed or rich in sun light i.e. high degrees of temperatures which is the main thing that feeds a solar power supply unit for uses.

It is low cost compared to other alternative sources of power supply in this society e.g. the use of generators which consume fuel or diesel and are really expensive, and its life span is better and reliable when used under or within or above the stipulated rating of the solar power device.

2.1 THE BASICS OF SOLAR POWER SYSTEM

A typical solar power supply device is comprised of solar panel (a.k.a. photovoltaic or PV panels), a charge controller, a power inverter having a meter or monitoring system which is capable of monitoring voltages and system condition and the electrical distribution system.

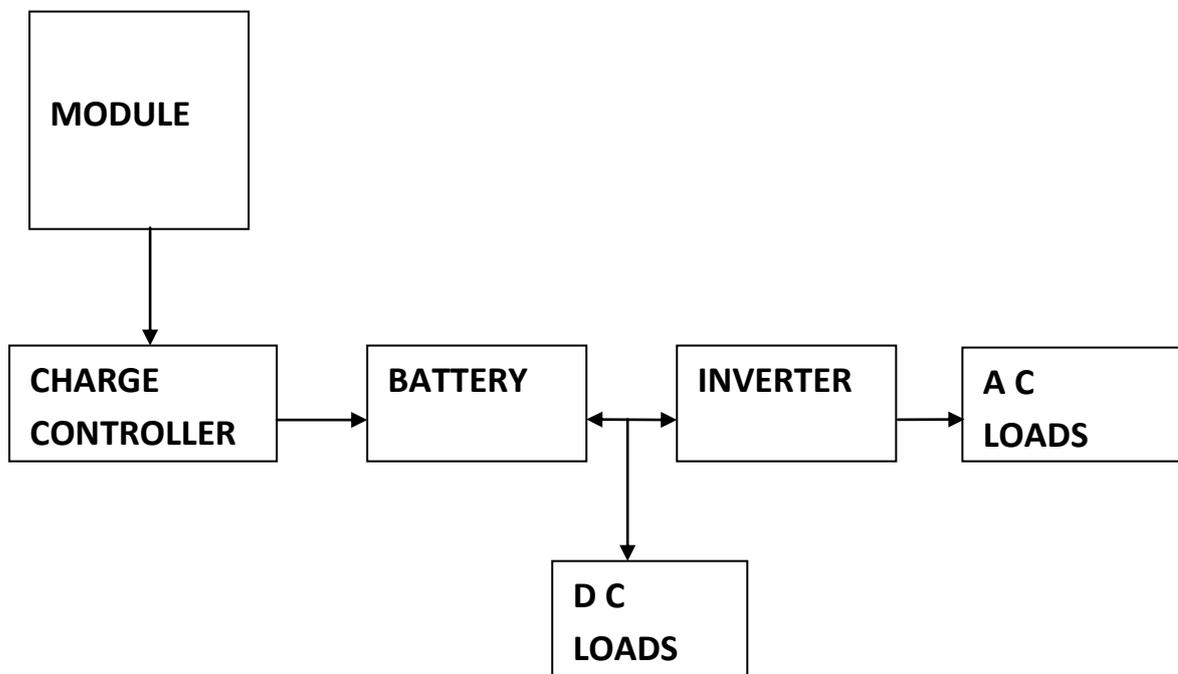


FIG 2.1 BLOCK DIAGRAM OF SYSTEM COMPONENT

2.2 PRINCIPLE OF SOLAR PANEL

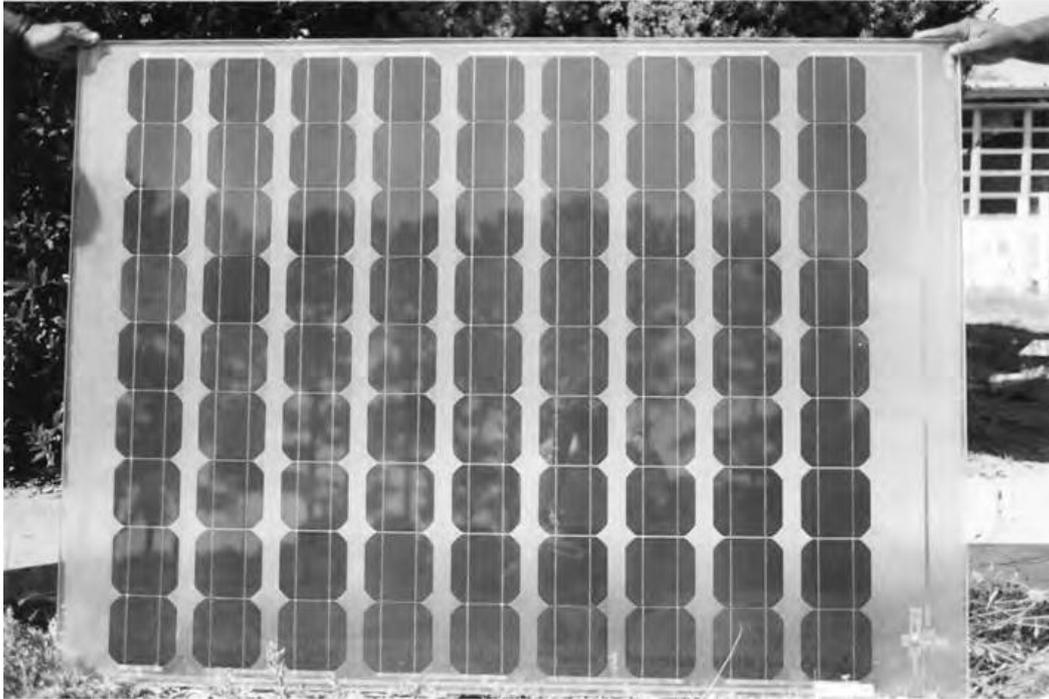


FIG 2.2 SOLAR PANEL

A solar panel is a device that is able to absorb sun rays and convert it into electrical energy precisely DC. The photovoltaic panel comprised of silicon crystals, which reacts with sun ray and under this process, converts the sun rays into electricity. They supply the electricity for charging the batteries and for use by the appliances either directly or through an inverter.

Multiple modules where used to produce more electricity and then any excess energy that was produced was stored in the batteries for use during the cloudy/ rainy weather.

The panels are available in different sizes, voltages and amperage. They can be wired in series or in parallel depending on how the system is designed.

2.2.1 Estimating solar panel output

This PV system produced power in proportion to the intensity of sunlight striking the solar array surface and this varied throughout the day, so the actual power of the solar power system varied substantially. There were other factors that affected the output of the solar panel. These factors needed to be understood so that there will be realistic expectation of overall system output and its economic benefits under variable weather conditions over time.

Factors affecting output:

2.2.2 Standard test conditions

The Solar modules produced DC electricity. The DC output of the solar modules was rated by the manufacturers under standard test conditions (STC). These conditions were easily recreated in the factory, and allowed for constant comparisons of products, under common outdoor operating conditions. Solar cell temperature = 25°C, solar irradiance (intensity) = 1000W/m² often referred to as peak sunlight intensity, comparable to clear summer noon time intensity.

2.2.3 Temperature

Module output power reduces as module temperature increases. When operated on the roof, a solar module will be heated up substantially, reaching temperatures of 50-75°C. For crystalline modules, the typical temperature reduction factor, recommended by the STC was 89% or 0.89. so the 200 watt module would be operated at about 85 watts ($200 \text{ watts} \times 0.89 = 178 \text{ Watts}$) in the middle of a spring or fall day, under full sunlight conditions.

2.2.4 Dirt and Dust

Dirt and dust would accumulate on the solar module surface, blocking some of the sunlight and reducing output. Although typical dirt and dust would be cleaned off during every rainy season. The typical annual dust reduction factor was 93% or 0.93, so the 200 watt module, operated with some accumulated dust may operate on average of 166 watts ($178 \text{ watts} \times 0.93 = 166 \text{ watts}$)

2.2.5 Mismatch and Wiring losses

The maximum power output of the total PV array was less than the sum of the maximum output of the individual modules. This difference was the result of slight inconsistency in the performance of one module to the next and was called module mismatch and amounts to at least 2% loss in system power. Power was also lost to resistance in system wiring. These losses were kept to

minimum but it was difficult to keep these losses below 3% for the system. A reasonable reduction factor for these losses was 95% or 0.95.

2.3 SOLAR CHARGE CONTROLLER



FIG 2.3 SOLAR CHARGE CONTROLLER

The charge controller is an electronic voltage regulator that was used to limit the rate at which electric current was being drawn in or out of the batteries. This charge controller turns off the charge when the battery reaches the optimum charging point and turns on when it goes below certain level. It fully charges the battery without permitting overcharge while preventing reverse current flow. Over voltage may reduce the battery performance or lifespan, and may pose a safety risk. This charge controller shows system operation parameters, battery status and protection from over discharge. The charge controller is the brain behind the system. It monitors the electricity produced by

the solar panel and then regulates the electricity that was used to charge the batteries and prevent them from becoming over charged.

Proper charging was considered to prevent any damage to the batteries and thereby increasing the battery life and performance.

Different technologies were available for selecting pulse width modulation and other charge controllers.

2.4 INVERTER



FIG 2.4 An Inverter

The inverter convert the DC voltage produced by the solar panels (and from the energy stored in the batteries) into A C voltage. The inverter could also charge the batteries by using an alternative source such as the mains or generator connected to the inverter when they are available.

Choosing the right inverter for the load demand and power requirements of the system was critical for the components to function properly.

2.4.1 Inverter Sizing

An inverter uses the (DC) direct current power supply and creates an alternating current (AC) supply usually at the voltage similar to that of a normal mains power supply. In other words, it enabled the running household appliances from a low voltage DC supply such as a solar battery as the heart of the system.

Inverter sizing was considered before purchasing the inverter, while sizing the inverter, two figures were looked at

1. The continuous wattage output
2. The surge capacity.

The inverter was selected observing the largest load to be operated at one time.

2.4.2 DC to AC Conversion Losses

The DC power generated by the solar module was converted into common household AC power using an inverter. Some power was lost in the conversion process, and there were additional losses in the wires from the rooftop, from the panel down to the inverter and out to the house cut-out. The inverter used with the PV power systems have peak efficiencies of 92-94% indicated by the manufacturer, but these again were measured under well- controlled conditions.

Actual field conditions that usually resulted in the overall dc-to ac conversion efficiencies was about 88-92% as a reasonable compromise.

2.5 SOLAR BATTERY



FIG 2.5 SOLAR BATTERY

The battery that was used in this project is a solar battery. Without the battery, the system could only power when the sun is shining. The power would interrupt each time the cloud passes, the system would become very frustrating. The solar battery provided constant electricity and the load discharges 80% of its charge.

The batteries are the heart of the system and were available in different voltages and various amp-hour ratings depending on the requirement of the system.

2.5.1 Temperature effect

The speed of the chemical reaction occurring in the lead-acid battery was determined by its temperature, the colder the temperature the slower the reaction and the warmer the temperature the faster the reaction and the more quickly the charge could be drawn from the battery. The optimum operating temperature of a lead acid battery is around 77° Fahrenheit. An example of temperature effect on a battery could be seen when starting a car on a cold morning; the engine just does not turn over quickly.

2.5.2 Battery voltage

Voltage meters are used to indicate battery state of charge, they are relatively inexpensive and easy to use. In this PV system it was usually charging or discharging or doing the both at the same time.

As the battery was charged the indicator lit up and while it discharges, another lit to show the level of its discharge. A good, accurate digital meter with a tenth of a voltage calibration was used with success.

2.5.3 Battery power conversion efficiency

Energy can never be created or destroyed, but it merely changes form. The efficiency of conversion was never 100% and in the case of new batteries they ranged from 80% to 90%. That means that to discharge 100 watts power battery, it would be charged with 100 to 120 watts of power.

2.5.4 Battery Monitoring and Maintenance

Monitoring battery state of charge was the single largest responsibility of the system charge controller. The battery voltage was kept at above 50% state of charge for maximum battery life. Should the battery is contain wet cells then it would be good to keep the battery's electrolyte level to the indicated level and never let the plates be exposed above the electrolyte. Only distilled water could be used to refill the batteries, over watering dilutes the acid excessively and electrolytes would be expelled when charging.

CHAPTER THREE
SYSTEM OPERATION

3.1 BLOCK DIAGRAM OF THE SYSTEM

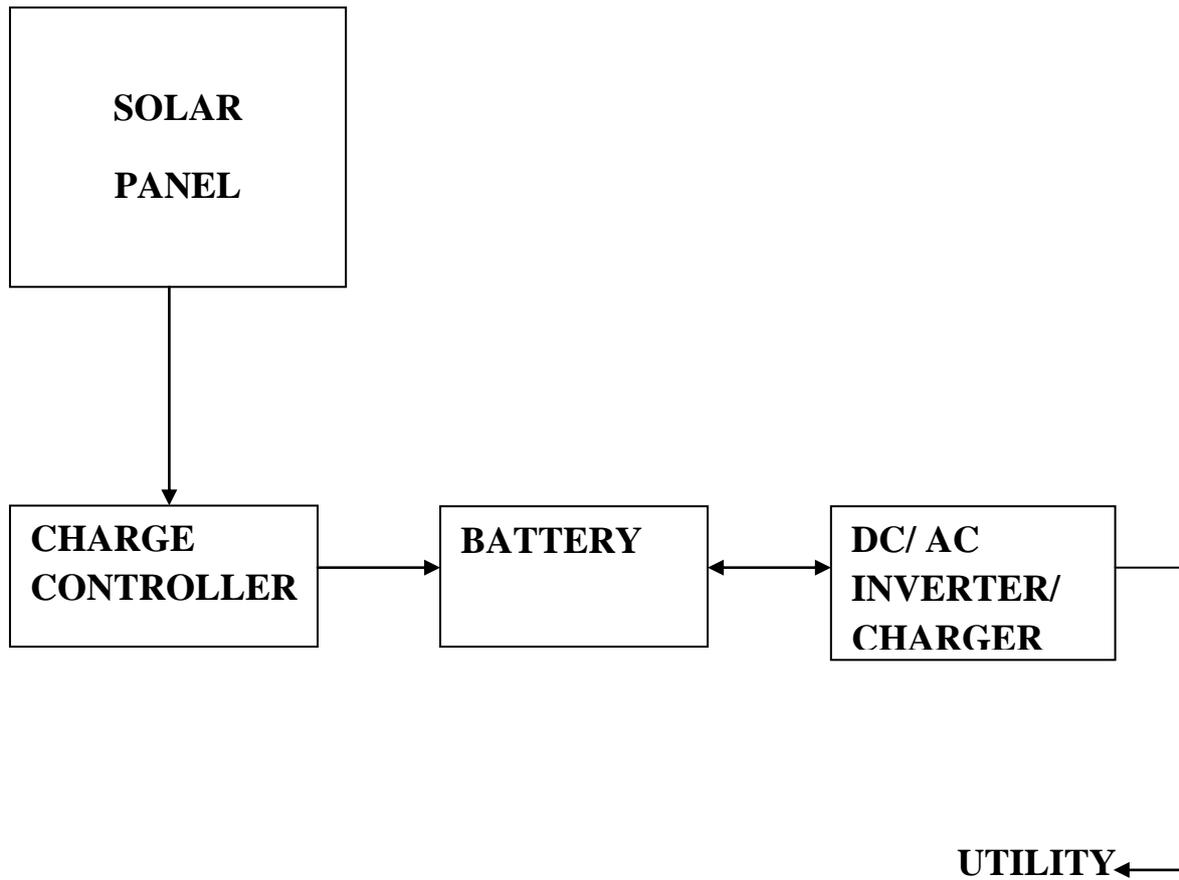


FIG 3.1 SOLAR SYSTEM BLOCK DIAGRAM

3.2 SYSTEM OPERATION WITH BLOCK DIAGRAM

The solar panel absorbs energy produced by the sun and converts it into electrical energy. It does this by absorbing the sun rays into the modules of the solar panel hence produced free electrical charge carriers in the conduction and valence bands. The electricity produced by the solar panel was then transferred to the charge controller as shown in fig 3.1 above. The charge controller regulates the rate at which electric current were drawn in and out of the battery. It turns off charge when the battery reaches the optimum charging point and turns it on when it goes below a certain level. It fully charges the battery without permitting overcharge.

The regulated voltage from the charge controller was then transferred to the solar battery. The batteries were the key component in this solar power system. It provided energy storage for the system.

The energy stored in the batteries was then used to power the load but it was first converted to AC voltage by the use of an inverter due to they were AC loads. The photovoltaic ally produced direct current was commuted periodically by controlled oscillatory system and feed to power electronic semiconductor switches such as transistors which were connected the power transformer. Here the voltage was stepped up to the desired ac voltage. The inverter could also charge the battery when there is public power supply.

CHAPTER FOUR

SYSTEM DESIGN

4.1 LOAD EVALUATION AND POWER CONSUMPTION

Based on the table below

1. The electrical appliances to power were listed.
2. The AC and Dc systems were separated and entered in their appropriate table.
3. The operating watt of each load was recorded
4. The number of hours per day for each item was specified.
5. The operating wattage and the number of hour per day were multiplied out to determine the watt hour per day.
6. The total watt hour per week was determined by entering the number pf days per week the load should be operated.

4.1.1 Calculating Power Consumption

There was need to determine the size of the load that were powered.

The unit of measurement used was watt-Hour because it was applicable to both AC and DC circuits. The table below shows the average daily watt hours, the highest AC load in watts, the total AC connected wattage at a time, the total

watt-hour per day, load correction multiplying factor from page 15 and the corrected watt hour per day.

These had allowed for easy determination of how many modules that were needed to produce the power required and how many batteries that were also needed to store the power.

The table below was an analysis of energy usage for a representative of an office, the HOD's office. The loads were itemized for its individual run time per day and per week then summed the watt hour of all the units for a total daily watt hour figure.

The chart below helps for clear understanding of where the power had gone to and it also gave an idea of how to reduce the loads in the most effective manner when required.

Appliance	AC	DC	Qty	×	Wattage (volt x Amps) mult. By 1.15 for AC	×	Hrs per day	×	Day per week	/7	=	Avg. Watt hrs per day
Bulb	60		1	×	69	×	5	×	1		=	49.3
Fan	25		1	×	29	×	5	×	1		=	20.7
Refrigerator	60		1	×	69	×	5	×	1		=	49.3
Computer	40		1	×	46	×	5	×	1		=	32.8

Highest AC loads in Watts
60W

Total AC connected in wattage at one time
185 W

Total watt-hour per day
160W

Total Watt-Hour per Day ÷ Load Correction Factor
160 ÷ 70%

Corrected Watt-Hour per Day
229 Watt Hr / Day

Table 4.1 LOAD EVALUATION AND POWER CONSUMPTION TABLE

4.2 BATTERY SIZING

This solar electric system was made up of a number of components and of these; none needs as much attention as the batteries. If batteries are neglected, degradation will occur at a very fast pace.

Battery Sizing Worksheet

S/N	Description	Calculation description	Calculation	Result
1	To determine the watt-hour per day	It is taken from power consumption table		200 watts
2	The number of days of the storage required	Got from the approximation of number of cloudy days	3 chosen	3
3	Multiply line 1 by line 2	200×3 (load wattage)	200×3	600

		multiplied by 3)		
4	Determine planned depth of discharge. 80% is the max. for lead deep cycle battery, 50% is a common amount for optimum longevity	Divide line 3 by 0.50	$600 \div 0.50$	1200
5	Derate your battery for low temperatures by multiplying line 4 by the factors below using lowest expected weekly average temperature	Multiply line 4 by the factor of 60°f which is equal 1.11 as the multiplier	1200×1.11	1332
6	Find the watt-hour capacity of your selected battery that is voltage times ampere hour capacity	$12V \times 150Amps$ Voltage \times Amperage hour	12×150	1800
7	Divide line 5 by line 6. The result is the number of batteries required	Divide line 5 by line 6	$1200 \div 1332$	0.900

8	Round number of batteries to find system voltage. Where a 24 volts system require sets of 2 batteries	We are using a 12 volts system	0.900 is approximate to 1	1
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TABLE 4.2 Battery Sizing Worksheet

4.3 SOLAR PANEL SIZING

Accurately sizing the components of the solar electric system was important. This sizing helps ensure that the system produced the right amount of power that was required.

4.3.1 Typical PV electrical system types

There are two general types of electrical design for PV power systems for homes; systems that interact with the utility power grid and had no battery back-up capability and systems that interact and include battery back-up as well.

1. Grid Interactive only (NO battery backup)

This type of system only operated when the utility was available. Since utility outages were rare, this system would normally provide the greatest amount of bill savings to the customers per charge cost of the investment.

However, during the event of an outage, the system was required to shut down until utility power was restored.

2. Stand-alone power system

For this project, a stand-alone power system was chosen for design and installation. First there was need to consider the electricity needs which the PV system had to power, the unit measurement was in kilo watts for consideration.

Solar panels are classified according to their rated power output in watts. This rating was the amount of power the solar panel was be expected to produce in one peak sun hour. Different geographical locations received different quantities of average peak sun hour per day.

Solar panels could be wired in series or in parallel to increase voltage or current respectively. The rated terminal voltage of a 12 volts solar panel were usually around 17.0 volts, but through the use of a regulator, this voltage was reduced to around 13 to 15 volts as required for battery charging.

To size the solar panel, how much power each items consumed while operating was determined. Most appliances had a label on the back, which listed the wattage and specification sheets, local appliance dealers and the product manufacturers were the sources of the information.

4.3.2 Solar Array Sizing worksheet

SOLAR ARRAY SIZING WORKSHEET		YEARLY AVERAGE
1	The site for mounting was located and the isolation sun penetration value was chosen as 5.	6
2	The daily corrected loads in watt hour from the load calculation sheet was taken as	200W
3	The corrected load value divided by the sun isolation penetration value was the number of watt needed to be generated per hour.	33.3W/h
4	The actual power produced by the selected module GP 64's had each module produce 3.66amps. 26 volts which was a common charging voltage for a 24 volt system, hence actual power = amperage × charging voltage.	95W
5	The value of the generated power per hour divided by the actual power produced by the selected module, the result was the number of module required for the system. When rounding this number, 6set of module were needed for the 24 volts system.	1

Table 4.3 Solar Array Sizing worksheet

CHAPTER FIVE

PROCUREMENT AND INSTALLATION

5.1 PROCUREMENT

During the process of procuring all the materials used for this project, taking the right decision for the battery, inverter, solar panel and the charge controller was totally based on the result of their individual evaluations.

The materials; solar panel, inverter, batteries and the charge controllers where all order from Lagos with the following price list

S/N	ITEMS	QTY	PRICE	RATING
1	Solar panel	1	₦ 115000	200W, 6module
2	Inverter	1	₦ 75000	1.5KV, 24V
3	Batteries	2	₦ 77000	150A, 12V
4	Charge controller	1	₦ 15000	150A, 24V
5	4mm wire	16 yards	₦ 5600	4mm
6	16mm wire	3 yards	₦ 1500	6mm
	TOTAL		₦289100	

The above listed materials were all tested before delivery and were confirmed to be in good condition. With the addition of all cost of transportation it amounted to ₦293100.

This amount was got through the collective financing process

5.2 DETERMINATION OF INSTALLATION SITE

5.2.1 Mounting options

The PV was mounted on a roof. The PV system produced 5 to 10 watts per square foot area. This was based on a variety of different technologies and the varying efficiencies of different PV products.

Roof mount

Often the most convenient and appropriate place to put up the PV array is on the roof of the building. The PV array was mounted above and parallel to the roof surface with a stand-off, several inches for cooling purposes.

The 200 watts PV system needed about 40 square feet of unobstructed area to site the system. Consideration had to be given for access to the system. This access to mounting had added space up to 2% of needed area to the mounting area used.

As the PV system was properly mounted, it was labour intensive. Particular attention was paid to the roof structure and the weather sealing of roof penetrations. It was typical to have two support brackets for the 200 watts of solar panel modules. During the installation, support brackets were mounted for holding the solar panel.

5.3 INSTALLATION PROCEDURE

Basic steps that were followed while installing the PV system

1. It was ensured that the roof area for installation was capable of handling the system area or size.
2. It was ensured that there were no roof penetrations that needed roofing industry approved sealing methods.
3. The PV system was installed according to the manufacturer specifications, using installation requirements such as the right wire gauge, nuts and bolts from the manufacturers' specification.
4. The PV system was properly grounded with the system parts to reduce the threat of shock hazard induced surges.
5. It was ensured that the right wire with the right polarity was observed while connecting the solar panel to the charge controller.

6. It was ensured that the design met local utility interconnection requirement.
7. It was finally inspected for completion by the HOD of electrical electronics department.

CHAPTER SIX

6.1 TEST AND RESULTS

The solar panel was set placed under the sun at 45° south, there the peak sun irradiation was on the panel surface and then at 39.5 volts was observed using a multimeter. While observing the voltage, the panel was slightly adjusted and the voltage varied at an angle away from the sun, the voltage depreciated.

The output from the solar panel was connected to the charge controller with respect to their polarities and when the output voltage was observed, it then read 26 volts which was right for charging 24 volts battery, since the two 12 volts batteries were connected in series. Also there was an indicator on the charge controller that showed when the battery was full by showing green light and the other LED showed red when load was connected to the system.

Each battery read 12.8 volts each and then connected in series to give an output of 24 volts afterwards was connected to the inverter. The voltage was 25.7 volts DC because the solar and the charge controller were also connected but without load, then load was added to the inverter which gave an output of 220 volts and was left for about 30 minutes after then it was observed again and the voltage did not vary. The inverter had three indicators. The first displayed if the system was connected to the mains or not, the second displayed if the inverter system

was switched ON or OFF and the third was to display if the system was experiencing any fault or not.

The inverter also had an additional socket for plugging the inverter to mains to serve as another means to charge the batteries other than the solar system. When tested with the volt meter as it was plugged on the mains out, it read 14.4 volts which was basically because of the state of the charge level of the batteries. The batteries would normally self-discharge over time even when not used. Since the inverter included a triple cycle charger, it could continue to maintain the battery with equalization charge voltage of about 12 volts just to make sure that the battery does not discharge even it was on standby mode.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 CONCLUSION

The project was intended to supply 200 watts of energy to the office of the HOD electrical electronic department. To serve as another source of alternative energy besides the diesel engine this serves the electrical utilities of the faculty.

The installation was a successful one and worked efficiently as intended. However during the design of the system requirement, it was considered to adjust the wattage of the inverter from 200 watts to 1500 watts inverter system due to an expected future expansion of the load capacity. Another change that had occurred during the design was the change from 12 volts solar panel to 24 volts solar panel and from 12 volts battery to an additional one more battery, which then became a 24 volts system to fit the solar panel that was already purchased.

The solar system worked effectively and cost no further operational cost. When compared to a 1.5 KVA petrol generator, it was costly but for the initial expenses. However it was later seen to be cheap since the system needed no petrol to operate but sunlight which was nature's free gift. Therefore there was no need to time or limit the hour of power supply of the up and down experiences from the mains supply.

7.2 RECOMMENDATION

Solar panel with inverter would be recommended since it was a noiseless, it does not use fuel and it is environmental friendly. The solar power system was a convenient way of producing an alternative means of power supply to supplement the mains failure. It was advantageous to user who could afford its initial cost of installation. This project was recommended for expansion if the need arose. There would be need to add up more batteries to meet up with the running time and the system load capacity since the system had an adjusted wattage, more load could be added only with addition of more batteries to meet up with the capacity.

7.3 LIMITATIONS

1. Space: The photovoltaic cells take up a lot space with this we can predict that with proper design can be taken care of.
2. High cost: Currently, the cost of solar system in short term is high for average Nigerian citizen.
3. Low energy efficiency: For now the commercially available have efficiency of 45%.

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