An economical solar PV system for home use: explained

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Abstract: With increasing power tariffs, power cuts and decreasing solar panel prices, there is a lot of interest in people to adopt solar technologies. Solar electricity is one possible way to electrify houses when the power supply is erratic. To convert, store and use the energy in the sunrays as electricity a solar electric system is utilised. Here solar energy is converted to electrical energy by solar panel made up of transducers called solar cell. These panels are placed on the top of houses for the purpose of obtaining maximum solar energy. This received energy is temporarily stored in a battery via a charge controller and is finally made available for use through the inverter. This paper describes briefly the components that make up a solar system, how to calculate the required power output and the cost implications.
Keywords: Solar photovoltaic, charge controller, battery, inverter

1 Introduction

Two urgent energy issues in Nigeria today are rural electrification and development of renewable energy sources. Solar electricity is an appealing solution since there is no need for fuel and little need for maintenance. Electricity is produced in the daytime while it is consumed mainly after dark with the use of battery storage.

The sun is the source of virtually all energy on earth. It provides energy for the photosynthesis, is the engine for all wind and rain, and warms up the atmosphere. Indirectly we harvest the energy from the sun when we use fossil fuels, firewood, hydroelectricity, wind energy, and even when we eat our food. By using solar cells we can convert the solar energy directly to electric energy, so-called solar electricity.

Solar energy is generated by harnessing power from the sun. It is a renewable source of energy. Recurring cost is low since the facility for harnessing power from the sun has little or no moveable parts that may require periodical servicing [1].

There is an increased dependency on electricity for various domestic and commercial purposes and the seemingly declining capacity of power utilities, in Nigeria, makes it necessary for an additional backup power source. So, there is a global need to increase energy conservation and the use of renewable energy resources [2].

A survey was carried for a period of five months from February to July 2015 to determine the number of hours of power supply per day to a particular region, University of Nigeria, in Nsukka, Nigeria as shown in Figure 1. A similar graph illustrated in figure 2 shows the amount of power received between 8:00 - 17:00 hours, (sunshine period for the region). From the graph it could be clearly seen that there is indeed a dire need to support the grid supply with an alternative source of energy.

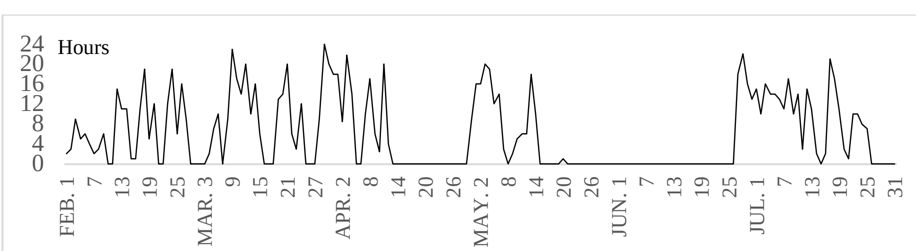

Figure 1 Power supply from February to July 2015

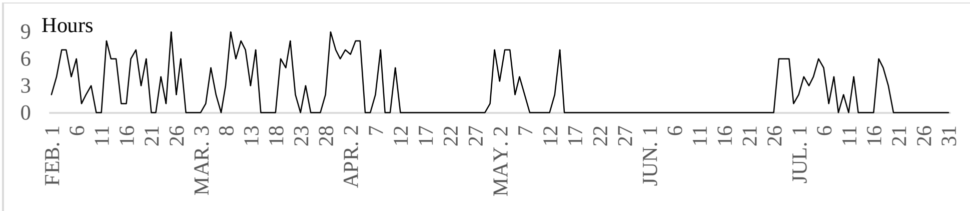

Figure 2: Power Supply between 8:00 – 17:00hrs, from February to July 2015

With the evident erratic power supply, the necessity for an alternative power supply arises. When the electricity supply is running properly via the 'grid', your home/office would use this power. However, in the event of blackout or load shedding on the grid, the system would switch to "off-grid mode" drawing power stored in your battery bank to power your home AND using your solar panels to recharge your battery bank.

To be able to harvest, store and use the energy in the sunrays, there is need for a set of electrical devices combined into a solar electric system or a Solar Photovoltaic (PV) system. This system has 4 basic entities as illustrated in figure 3:

PV Solar Panel Size (which will depend on total electricity that is needed)

2.1 CHARGE CONTROLLER

Battery size (will depend on the total electricity that needs to be stored)

Inverter Size (total electricity load or wattage that needs to be handled).

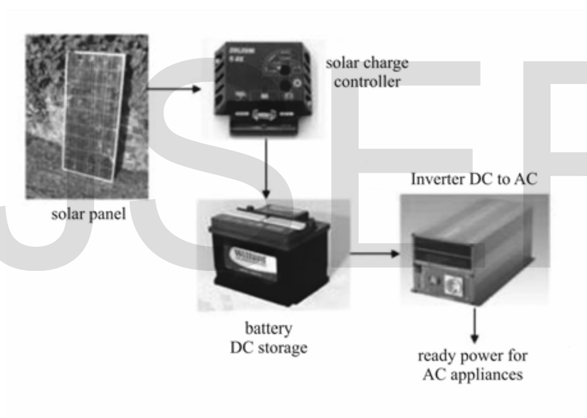

Figure 3: 4 basic components that make up a Solar PV system

2.0 PHOTOVOLTAIC SOLAR PANELS

There are number of different types of solar panels, from an ever increasing range of manufacturers. Each manufacturer claims that they are best for one reason or another; with different sales people all giving different information.

There are differences between the various types of panels that are worth mentioning. However in the end, it is the total overall power that makes the biggest difference. A 2.4KW system would generate a very similar amount of electricity whether the panels being used are poly, mono, a thin film or hybrid. The 'panel efficiency' quoted by manufacturers has very little bearing on the annual generation, it just affects how much roof space is needed for the same powered system [3].

Solar panels are classified according to their rated power output in Watts. This rating is the amount of power the solar panel would be expected to produce at standard testing conditions (STC) of sunlight intensity 1000W/metre2 at 25°Centigrade [4]

Photovoltaic solar panels can be wired in series or in parallel to increase voltage or current respectively. The rated terminal voltage of a solar panel is usually between 17-22 volts (for 12V) and between 34V-44V (For 24V) but through the use of a solar regulator, this voltage is reduced to around 13 or 14 volts as required for safe battery charging.

Higher wattage panels are presented as 24V or even 36V Solar panels, i.e. 250W, 300W etc.

Solar panels output is affected by the cell operating temperature. The output of a solar panel can be expected to vary by 0.3% for every 1 degrees

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variation in temperature. As the temperature increases, the output decreases.

The cost of solar panels has greatly reduced in recent years. The cost of a solar panel is determined in part by the size (in Watts), the physical size, the brand, quality of materials, the durability / longevity (or warranty period) and any certifications the solar panel might have.

2.2 Charge Controller

The Charge Controller or Voltage Regulator is basically the same thing just a different name. This essential piece of your solar system controls the Charge put into your battery, stops overcharging and prevents the solar panel pulling power from the battery at night. There are two main types of charge controllers.

Pulse Width Modulation (PWM) is the most effective means to achieve constant voltage battery charging by switching the solar system controller's power devices. When in PWM regulation, the current from the solar array tapers according to the battery's condition and recharging needs [5].

The PWM controller is in essence a switch that connects a solar array to a battery. The result is that the voltage of the array will be pulled down to near that of the battery.

The Maximum Power Point Tracking (MPPT) controller is more sophisticated (and more expensive): it will adjust its input voltage to harvest the maximum power from the solar array and then transform this power to supply the varying voltage requirement, of the battery plus load. Thus, it essentially decouples the array and battery voltages so that there can be, for example, a 12 volt battery on one side of the MPPT charge controller and a large number of cells wired in series to produce 36 volts on the other [6].

2.3 Battery

A battery bank stores electricity produced by a solar electric system. There are many types of batteries available, and each type is designed for specific applications. Lead-acid batteries have been used for residential solar electric systems for many years and are still the best choice for this application because of their low maintenance requirements and cost. These batteries are specially designed for stationary solar electric systems. The size of battery storage required is also dependent on the number of cloudy days the system must operate using energy stored in the battery.

2.3.1 Battery Tips

1. The largest cost, over the life of the system, is the batteries. The lifetime cost, including maintenance, of your batteries is dependent on your initial purchase price, how well you adhere to a maintenance schedule, and the replacement interval for the batteries you select.
2. The energy storage capacity of a battery is measured in watt-hours, which is the amp-hour rating times the voltage. For example, a 12-volt, 100-amp-hour battery has a storage capacity of 1,200 watt-hours, which is the same as a 600-amp-hour, 2-volt battery.
3. Follow manufacturer recommendations for voltage set points. Make sure that your charger or charge controller will supply the correct voltage.
4. Place batteries in a well-ventilated, temperature-moderated area because batteries give off gases that could accumulate to form an explosive mixture. Batteries should be kept in an uncluttered, dry area of a shed or garage or placed in a vented box with a strong lock for easy but safe access.
5. Always refer to the battery manufacturer's recommendations for use and maintenance.

Battery Charging Current and Battery Charging Time formula

Here is the formula of Charging Time of a Lead acid battery.

Charging Time of battery = Battery Ah / Charging Current

$T = Ah / A$

Example, Suppose for 100 Ah battery,

First of all, we will calculate charging current for 100 Ah batteries. As we know that charging current should be 10% of the Ah rating of battery.

So charging current for 100Ah Battery = 100 x (10/100) = 10A. But due to losses, we can take 11-12A for charging purpose. Suppose we take 12A for charging purpose, then charging time for 100Ah battery = 100 / 12 = 8 Hrs. (this is an ideal case scenario) [7].

2.4 Inverter (Power Inverter)

A power inverter is an electronic device that converts Direct Current (DC) from sources (like batteries or solar panels) to Alternating Current (AC) [8].

The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source.

3.0 How Inverters Work

DC power is steady and continuous, with an electrical charge that flows in only one direction. A power inverter uses electronic circuits to cause the

DC power flow to change directions, making it alternate like AC power. These oscillations are rough and tend to create a square waveform rather than a rounded one, so filters are required to smooth out the wave, allowing it to be used by more electronic devices [9].

AC is thus the form of electricity that powers appliances in homes or offices. The inverter makes use of electronic components like transistors, battery bank and all other necessary connections, particularly on the utility side. Inverters also provide over voltage protection to connected load.

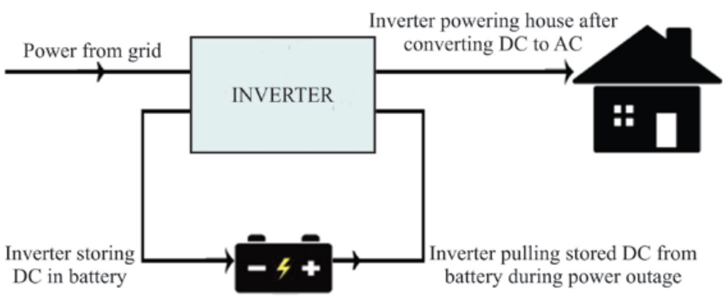

Figure 4: An inverter system

Both the inverter and the charger work together to provide you with backup power when the regular utility power goes off by doing the following:
It charges the batteries by converting AC into DC when power supply is available.
It converts the energy stored (DC) in the battery to AC energy that powers your appliances when there is power outage as illustrated in figure 4.
Inverters can be seen as a form of UPS that can provide backup power to run your appliances when there is a power outage. However, the duration of the backup supply is dependent on the rating of the inverter and capacity of battery storage connected. In other words the higher the capacity of both the inverter and the battery storage the longer the duration of the backup supply. Compared to generators, inverters are noiseless and do not pollute the environment.

3.1 Calculating Your Solar Power Requirements

There are three main things to consider in order to create a Solar system.
How much energy can your battery store? Battery capacity is measured in Amp Hours (e.g. 100Ah). You need to convert this to Watt Hours by multiplying the Ah figure by the battery voltage (e.g. 12V). For a 100Ah, 12V battery the Watt Hours figure is 100Ah x 12V = 1200 WH. This means the battery could supply 1200W for 1 hour, 600W for 2 hours and so on. The more energy you take, the faster the battery discharges. However you are never really able to take all the power from a battery as once the voltage drops below your equipment's requirements it will no longer be able to power it.
How much energy will your appliance(s) use over a period of time? The power consumption of appliances is generally given in Watts (e.g. an LED TV is around 60W this information can be found on the data sticker that most electrical items have). To calculate the energy you will use over time, just multiply the power consumption by the hours of intended use. The 60W TV in this example, on for 2 hours, will take 60 x 2 = 120WH from the battery. Repeat this for all the appliances you wish to use, and then add the results to establish total consumption.
How much energy can a Solar panel generate over a period of time? The final part to sizing your solar system is the solar panels. The power generation rating of a Solar panel is also given in Watts (e.g. our part number STP010, is a 10W solar panel). In Theory, to calculate the energy it can supply to the battery, you multiply Watts (of the solar panel) by the hours exposed to sunshine. Therefore if we consider on average, 6 hours of sunshine daily a 200w panel will provide 1200W worth of energy back into your battery. Using the above calculation takes into consideration any losses in the system from the regulator, cables and battery you may be using.
How much Watts Solar Panel We need for our Home Electrical appliances?
We can find it by very easy and simple example and explanation. Suppose we want to power up 5 lights of 20 Watts and we need to use these 5 lights for 7 hours every day plus a TV of 60 Watts for 4 hours.
Plights = 20 x 5 = 100W. Than we multiply 100Watts with 7 hours. Plights Daily = 100 x 7 = 700Wh.

PTV = 60W. Than we multiply 60Watts with 5 hours.
PTV Daily = 60 x 4 = 240Wh.
PTotal = (700 + 240)W = 940Wh
We are going to use 1100Wh daily. Let us say we are going to have complete sunshine 6 hours each day. Now we divide 1100W with 6 hours, so we will get hourly power charge that we need
So here will be hour power charge that we need i.e. watts of solar panel that we want for our electrical appliances.
PHourly = 940 / 6 = 156W.
So we could use a 200W solar panel.

4.1 Cost of the Simple System

There is no valued reaction to the question how much it would cost to own a power system substitute, unless the capacity of load/appliance the system will carry is ascertained.
From the above we have identified the various components required to set up our simple solar energy system for a home. We have assumed that a 1KVA system would be sufficient for simple home use, bearing in mind the cost of the system. Table 1 is the breakdown of the various cost involved (cost is in Naira, approximately $1=N220).

Table 1: Cost implications for a simple solar PV system.

	component	size	cost (N)
1	solar panel	200W, 5.4A, 40V	35,000
2	charge controller (PWM)	20A	6,000
3	Battery	100AH, 12V	26,000
4	Inverter	IKVA	24,000
5	Accessories		5,000
	TOTAL		96,000

4.0 Installation

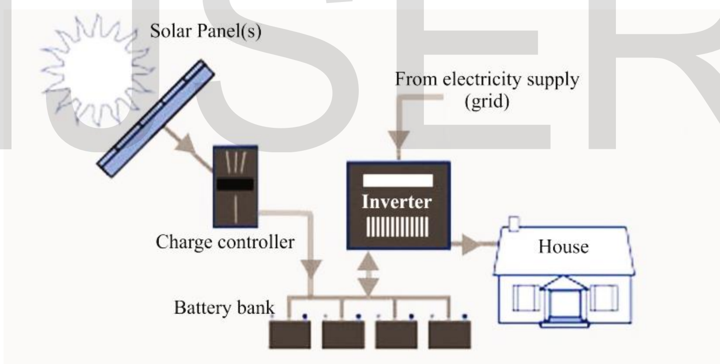

Figure 5: pictorial depiction of the complete solar PV system

Once all the components are available, setting up the system is the final phase as shown in figure 5. The panel is mounted on the roof so as to enable it get maximum sunlight. It is then connected to the charge controller. Since a 200W panel is expected to generate 40V DC, on connecting to the charge controller, this is stepped down to 12V that is connected to the battery terminals. It should be noted however, that the corresponding current depends on the amount of sunlight, which could be about 5A on a hot day, (depending on the panel specifications). Since the charge controller under consideration is rated 20A, we are well within the range. If the number of panels and batteries is increased, this would amount to the batteries charging faster, and a longer period of electricity.

5.0 Conclusion

As have been clearly outlined and enumerated, solar energy could be greatly utilised to generate electricity that would power a house. The system could be used to power the entire house, from your electric fans to lights, as long as the power consumption is monitored. If the system is required for even longer periods of time, the size of the inverter, panels and batteries should be increased. This of course would increase the cost of the overall system, but the benefits are significant.
It is good practice to consider the combination of renewable energy source like solar panels as this will

save you the costs of paying the hefty electricity bills that come from charging the inverter batteries among other things. These solar panels charge the batteries during the day when sunlight is available.

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