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PERFORMANCE ANALYSIS OF A 1.5 KW PHOTOVOLTAIC POWER SYSTEM

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ABSTRACT

Due to the rising fuel costs resulting from the deregulation of the downstream oil sector in Nigeria, increasing concerns for global climatic change, and a growing worldwide demand for electricity, utilizing renewable energy sources such as solar power becomes a necessity rather than a luxury. Despite the large quantity of energy absorbed by the earth from the sun yearly, only a fraction of that is captured for electrical power production. Solar powered systems can generate electricity using photovoltaic (PV) panels. PV systems can range from utility scale systems (about 14MW) solar arrays 4KW roof-top home systems to small wattage solar backpack for charging portable electronics. This project explores solar PV systems for residential buildings, using three offices as a case study. The design and implementation was based on 1.5KW inverter with two 200Ah deep cycle batteries, 20Amp charge regulator and four 80Watts solar panels.

KEYWORDS: Photovoltaic Cell, Charge Controller, Inverter, Battery, Load and Energy Demand.

INTRODUCTION

Sunlight is made up of tiny packets called photons.[1] Every hour enough of this energy reaches the world to meet the world's energy demand for the whole world. Photovoltaic panels consists of many solar cells, these are made of materials like silicon, one of the most common elements on earth. The individual cell is designed with a positive and a negative layer to create an electric field, just like in a battery. As photons are absorbed in the cell, their energy causes electrons to become free, the electrons move toward the bottom of the cell, and exit through the connecting wire. The flow of photons is what we call electricity. By combining solar cells and photovoltaic panels, we can produce just the right amount of electricity to perform a specific job, no matter how large or small.[2]

Solar energy is the energy derived from the sun through the form of solar radiation.[3] Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Photovoltaic is a combination of two words “Photo” from Greek root meaning, light and “Voltaic” from volt which is the unit used to measure Electric potentials at a given point.[2] Solar technologies tap directly into the power of the sun to produce solar energy which is converted into solar electricity using Photovoltaic (PV) Cell technology.[1] Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air. Photovoltaic (PV) cells convert sunlight directly to electricity. They work any time the sun is shining, but more electricity is produced when the sunlight is very strong and strikes the PV cells directly. The basic building block of PV technology is the solar cell. Solar power in rural areas is a viable alternative for providing electricity for telecommunications, telemetry, water pumping, lighting, television, DC refrigeration and other low power non- heating applications. Heating appliances such as kettles, toasters, stoves, geysers and heaters are consuming too much energy and therefore cannot be used on a solar system.[4] The basic components for this solar energy system are; solar cell, solar panel, inverter, battery, charge controller, wiring, and connected loads. The photovoltaic modules normally have a manufacturer’s power output warrantee of 20 to 25 years. The only maintenance on a solar module is to clean the glass on a regular base. The regulator has a 1 year warrantee, but can be damaged if the instructions are not properly followed. The 12V solar batteries also come with a 1-year warrantee and the expected lifetime is between 3-4 years. Most of the solar batteries available are semi sealed batteries and are low maintenance or maintenance Structural features.

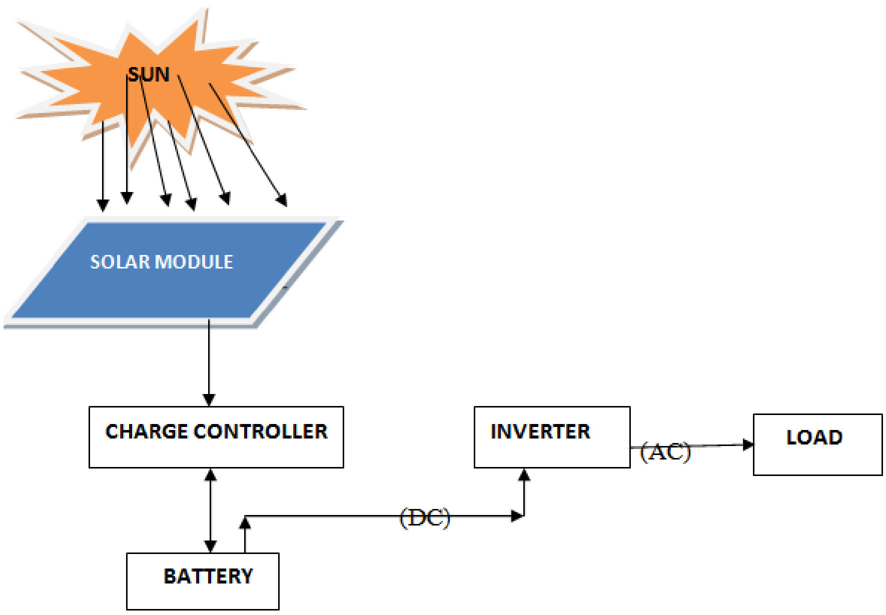

Fig. 1.0: Block diagram of the system.

2.0 REVIEW OF RENEWABLE ENERGY

Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished).[5] Renewable energy is derived from natural processes that are replenished constantly.[4] In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.[5] Renewable energy is a form of energy that can be produced without depleting natural resources such has fossil fuels and wood. It does not rely on the burning of a fossil fuel to create electricity. This type of energy is sustainable as it is derived from sources that do not run out. Renewable energy is that form energy obtained from sources that are essentially inexhaustible, unlimited and rapidly replenished or naturally renewable such as wind, water, sun, wave, refuse, biofuels etc.[6] It has brought about the need for technology innovation as a means to addressing climate change challenges that is, by reducing the rate and volume of green house gases (GHGs) emissions/concentration in the atmosphere and saves the ozone layer from on-going depletion, which eventual collapse would spell catastrophe to the world. This has however brought about the need for technology innovation which indeed, requires skilled manpower, especially in the developing nations where technology advancement is a desideratum.[5] Renewable energy has the following advantages.[5]

It is highly sustainable as it is derived from sources that are inexhaustible. It does not emit any greenhouse gases or toxic waste making the world a cleaner and safer place. It is highly cost effective as fuel does not need to be brought to sustain the electricity plant. It is also cost effective as less labor is needed to operate a renewable energy station and they require less maintenance. They may bring economical benefits to remote communities, as many renewable energy plants are situated away from large cities.

Renewable energy generators such as solar power can be applied to existing buildings making them more environmentally friendly and energy efficient. Some forms of renewable energy such as geothermal steam plants take up less area than larger conventional power plants and can be run day and night.

Hydroelectric power stations can be controlled to produce more power at peak times and be inactive during lulls in power usage. Biomass energy helps cut down on the amount of rubbish that is transported to landfills. In most cases if an individual has a renewable energy source, such as solar power, attached to their home or business they can sell any excess power back to the grid reduce the overall amount of homes or businesses being powered by fossil fuel plants. Renewable energy replaces conventional fuels in four distinct areas: power generation, hot water/ space heating, transport fuels, and rural (off-grid) energy services.[5]

Procedure for Result presentation

To effectively design the photovoltaic system, certain factors were considered. These factors include.

(a) Total load and energy demand.

The total load and energy demand enable us to determine the capacity or sizes of the following equipments:

ii Size of the inverter.

ii Size of battery bank.

iii Size of the solar panel.

iv Size of the charge controller.

(b) Space for solar panels.

(c) Clients financial status.

3.0 Determination of total load and energy demand

There are four issues that arose in the design of the system.

That the load on the system is not constant over the period of the day.

The daily load varies over the year.

The energy available from the sun source may vary from time to time during the day.

The available energy radiant from the sun source varies from day to day during the year.

If the system is based on photovoltaic module, that a comparison should be made between. The actual energy demand and the available energy from the sun.

In all cases, the first step in system sizing is to estimate the load placed on the system and to examine the actual requirements from the system.

This is done by establishing an AC and DC load assessment sheets. But since the project is aimed at the use of AC, the AC load assessment shall be considered.

Load Assessment Procedure

It is imperative that the assessment process captures the following,

PRPA * N = TPRPA (Watts)…………………………………………………..1

Where PRPA is Power Rating per Appliance.

N is Number of each appliance to be powered.

NOTE: N is not constant.

TPRPA * T = E (Whr)………………………………………………………….2

Where E is Energy in Watt-hour (Whr).

TPRPA is the total power rating per appliance

T is back-up hour.

NOTE: T = 8 hours.

Size of the Inverter

Inverters are rated in Kilo Volt Amps (KVA). The total estimated load above, when converted to its KVA equivalent was calculated as 1.1438KVA. From this value, a 1.2KVA inverter would be required to satisfy the load requirement.

I decided to design a 1.5KVA inverter to enable the system cope with the surge start-up of some equipment such as the television sets and computer monitor, to compensate for power losses and to allow additional loads to be energized as may be required, without posing danger to the life span and proper functioning of the system.

Due to the complex circuitry involved in the design, and the possibility of voltage drops across each circuit component, inverters above 915Watts must be supplied with DC voltages at 24 Volts and above.[7] The more power required, the more the DC Voltage demand Furthermore, inverters have DC input voltages such as; 6volts, 12volts, 24volts, and 48volts. My decision to use a 24volts inverter is to enable more power to be transferred from the low voltage to the high voltage side of the transformer in the inverter and to ensure a stable and pure sinusoidal waveform of the AC output voltage.

Size of the Battery Bank

Batteries are normally 12 volts, rated in Ampere Hours. Since the inverter requires a 24 volts dc input, our battery bank would therefore be a combination of two 12 volts batteries connected in series. To determine the amp hour capacity of the battery bank, the total energy demand and the total back-up hours need to be considered.

$$\left(\frac{\text{total Energy demand} \times \text{days of back-up}}{\text{battery voltage}}\right) \div (0.707 \times \mathbf{1.1}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where; 1.1 is the battery bank constant.

$$= \left(\frac{7320 \times 1}{24}\right) \div (0.707 \times 1.1) = 305 \div 0.78$$

$$= 391.0.2 \text{ Ah at 24Volts.}$$

An approximately 400Ah at 24Volts battery would therefore be required for the system. My decision to use a 400Ah battery at the same voltage is to increase back-up time. I would therefore require two 12 Volts, 200Ah batteries connected in series.

Size of the Solar Panel

Since the system is designed to work independently i.e. as standalone, the energy required from the panels would just be that sufficient to charge the battery.

Since the combined battery voltage is 24 volts. The solar panel would also have to supply approximately the same voltage. Solar panels are designed to give an output voltage of 12 volts per panel, therefore four panels, wired in series and parallel was used to produce 24 volts sufficient to charge the battery. This configuration was used to increase the current. Another consideration for selecting the solar panel is the battery charging current. The solar panel(s) must also provide the necessary charging current for the battery bank. Deep cycle batteries require a charging current of approximately 10Amps. Therefore each of the panels would have to be rated at 10Amps or even higher to compensate for losses that may arise due to uneven distribution of the radiant energy on the panels.

Size of the Charge Controller

Charge controllers regulate the charge entering the battery from the solar panels. They also ensure that the batteries are not over charged and that they are not over drained during use. Solar regulators often short circuit the solar panel input when regulating. This however does not damage the panels but implies that the solar regulator must be sized to handle about 125% of the rated short circuit current of the solar panel.

Since the system voltage for the DC section is 24 Volts, a 24 volt charge controller would be required. The current rating of the regulator is determined below;

$I_{reg} = (I_{sc} * 2) * 1.25$ ………………….....……………………………………………..4

Where, I_{reg} = current rating of the regulator; I_{sc} = short circuit current of the solar panel.

Given that the short circuit rating of the panels used in this project is 7.4 Amps. We must recall that the panels are wired in series/parallel, so the output current remains the same

Therefore; $I_{reg} = (7.4 * 2) * 1.25$

$= 14.8 * 1.25$

$= 18.5$ Amps.

A 20Amp charge controller would therefore be required.

4.0 RESULTS AND DISCUSSION

4.1. Testing/PV characteristics During a Rainy Day.

To know the characteristic of a PV, hourly readings was taken for 10hours, values for Voltage and Current using Voltmeter and Ammeter connected in parallel with the solar array was gotten. The values of Power were gotten from calculation using the formula:

P = IV………………………………………………………………………………1

Where, P = Power,

I = Current and

V = Voltage.

The table below shows the values of Voltage, Current and Power at different time of the day. These values were taking for three days and the average was used to plot the graphs to show the characteristics of a PV during a rainy day.

Table 4.0: Average values for PV characteristics. 19th November, 2016.

Time (Hour)	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Voltage (Volts)	28.07	39.03	38.83	37.80	37.80	38.60	38.70	32.7	33.80	30.60
Current (A)	1.64	5.30	7.24	4.73	6.46	8.31	6.78	1.86	2.88	1.82
Power (Watts)	45.05	206.75	208.25	182.31	249.14	321.98	262.69	62.56	100.27	61.43

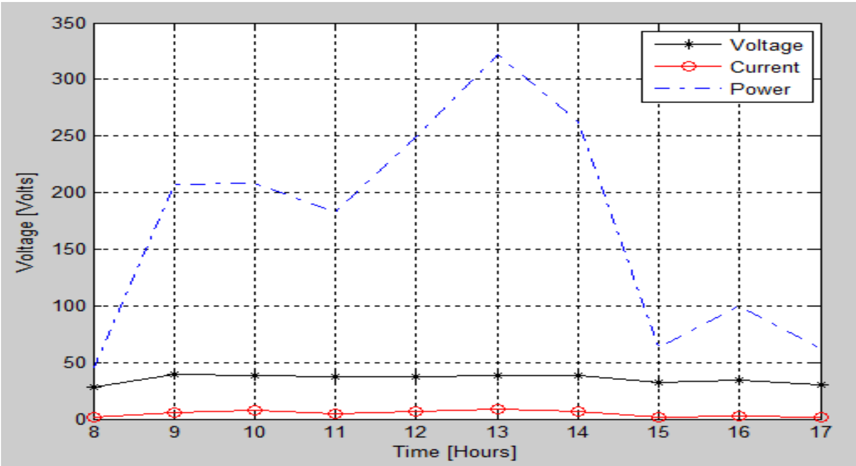

Fig. 4.0: Graph of Current, Voltage and Power against Time.

Therefore, the essence of the PV test, result and graph is to show the sensitivity, performance and reliability of the PV system and how it can work effectively using the test of every hour of the day.

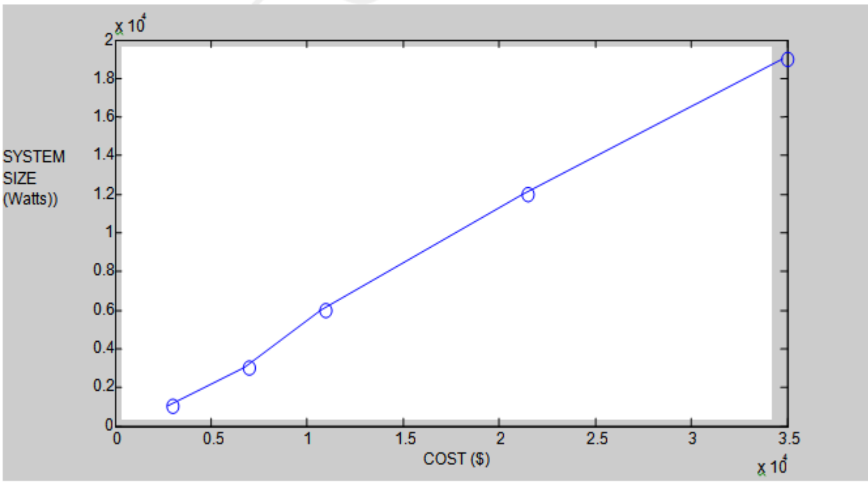

Fig. 4.1: Graph of System Size against Cost.

The plotted graph (SYSTEM SIZE VS COST) above shows that the size of the solar module is proportional to the cost of the module making it effective for usage and affordable by consumers or clients.

5.0. CONCLUSION

Although initial cost for this kind of design seems high, the long run benefits tremendously outweigh its possible alternatives.

The system has the ability of sustaining itself for a period of 25 to 30 years if operated as recommended. At a certain time, the system begins to save money and in turn generates income if connected to the grid. We have also learnt how the various components of this system function together and can eventually take up any PV contract anywhere without fear of failure. This photovoltaic system is therefore a great investment.

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