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DESIGN AND CONSTRUCTION OF SOLAR POWER PLANT

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ABSTRACT

Nigeria has been plagued in recent times with epileptic power supply. There is need to develop an alternative power supply to ameliorate the situation. The solar power plant is a device that can adequately serve as an alternative to the power supply by the Power Holding Company of Nigeria. The major components of the Solar Power Plants are the frame two solar panels, solar charge controller, inverter, battery, and the cable. The frame was constructed from angle bars welded into two rectangular shapes to house the panel. Design and stress calculation were done to ensure the safety of the project. Tests were carried out to ascertain the functionality of the project by connecting a laptop computer to the power plant for 6 hours. The difference in voltage was about 0.5 volts, which was negligible. The Watt per square meter of Ogwashi-Uku was determined to 125.4 Watts/Square Meter.

INTRODUCTION

Background of Study

Africa being located in the tropics is exposed to enormous amount of energy radiated from the sun. According to Agbo and Oparaku (2006, energy from the sun is not only infinite in a practical sense but also abundant; enough to take care of mankind's energy requirements. The sun radiates a hundred billion megawatts, out of this, the earth receives two hundred megawatts, therefore, there is need to find ways to tap this energy and utilize it for the benefit of man.

The solar power plant is a device designed to absorb the radiant energy from the sun, convert it to electrical energy and make it available for both domestic and industrial use.

History of Solar Power Plant

According to Groneman and Feirer (1986), generating electricity directly from the sun depends on the photovoltaic effect. This is the process that occurs when light hits certain sensitive materials and creates flow of electrons (an electrical current). The devices that accomplish this change are solar cells. The first practical solar cells were manufactured in the mid 1950s and were used to supply small amounts of power for remote weather station.

According to Perlin (2005), a solar cell or photovoltaic cell (PVC) is a device that converts electric current using the photoelectric effect. The first solar cell was constructed by Charles Frits in the 1880s.In 1931, a German engineer Dr. Bruno Lange, developed a photocell using silver selenide in place of copper oxide. Although the prototype selenium cells converted less than 1% of incident light into electricity, both Ernst Werner Von Siemens and James Clerk Maxwell recognized the importance of this discovery. Following the work of Rusell Ohl in the 1940s, researchers Gerald Pearson, Calvin Fuller and Daryl Chapin created the crystalline silicon solar cell in 1954.

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According to Pulfrey (1978), research into solar power began in 1939 when Antonio Cesar Becquerel observed the photoelectric effect. This occurs when materials absorb photons with certain energies. This energy can excite charged electrons out of the material. These charges can then be separated to develop a photo-voltage. Becqueral detected this effect between AgCl (Silver Chloride) and Pt (Platinum) electrodes immersed in electrolyte. The 1930s showed a further advancement in solar cell technology when the first solid-state system was constructed. These advancements were made with Cu – Cu_2O (Copper and Copper (1) Oxide structures), but were originally engineered for film development exposure meters, and little credence was given to the idea of producing more than minuscule amounts of power. In 1954, it was demonstrated that for spacecraft, silicon solar cells could feasibly power systems and their applications could also be used on earth.

Now, solar cells have been extensively exposed, and the new boundary to using only renewable energy is the cost. However, cheap alternatives to the classic silicon based cell are possible and are the current cutting edge of solar cell research. The idea being, materials other than silicon can be manufactured, and at one hundredth of the thickness of silicon, while still outputting at efficiencies similar to that of silicon. Poortmans and Arkhipov (2006).

Stephenson (1986) stated that photovoltaic cell commonly called the solar cell or battery (and made semiconductor materials) is now a reality and has found important uses in providing electricity for more than 80 communication satellites that can relay telephone conversions , radio and television around the world. Space communication of all types rely heavily on the solar cell. For the consumer , the solar cell is seen in the millions of economical solar-powered calculators sold almost everywhere.

Uses of Solar Energy

Solar energy is currently in use in a number of applications. These include the following:

(i) **Solar Power:** This entails the conversion of sunlight into electricity by directly using concentrated solar power.

(ii) **Solar Heating:** It is used for water heating, space heating, space cooling and process heat generation.

(iii) **Agriculture and Horticulture:** It helps to optimize the productivity of plants and in the preservation of products.

(iv) **Water Treatment:** Solar hot water systems use sunlight to heat water and make saline and brackish water potable.

(v) **Architecture and Urban Planning:** It has influenced building design since the beginning of architectural history.

(vi) **Solar Vehicles:** Development of solar powered cars and boat has been an engineering goal for some time.

(vii) **Solar Lighting:** Day lighting systems collect and distribute sunlight to provide interior illumination.

(viii) **Solar Cooking:** Solar cookers use sunlight for cooking, drying and pasteurization.

Purpose of the Project

The main purpose of this work is to generate electricity from solar radiation using solar cells or the photovoltaic cell. It will provide continual free energy supply after installation, as the sunlight is free and readily available. Since it is almost maintenance free, it is cheap to operate. The energy produced serve as an alternative to that supplied by Power Holding Company of Nigeria that is always epileptic in nature, as well as that produced by burning coal or other fossil fuels that can produce pollutants such as carbon monoxide, fluorocarbon and other dangerous gases that are responsible for global warming.

Scope of Study

In general, this project work largely covers the installation or assembling of a photovoltaic cells and connecting it to an inverter that converts direct current to alternating current (A.C.) before use. Most components for this project were bought since the raw materials needed for their construction are not available in the country. This project also involves construction of a solar panel using silicon chips from broken down computers. An effort is made to read the voltage generated using voltmeter. To ensure constant supply of electricity, energy generated in the day is stored in a 12V battery.

Principles of Operation

The photovoltaic cell (PVC) is made up of silicon chips that are connected in series and in parallel in an insulating board. This photovoltaic (PV) cells which is the solar cell consist of two layers of semi-conductors, which are the ultra-thin layers of phosphorus doped (N-Type) and a top thicker layer of boron doped (P-Type) An electric field is created at the top surface of the solar cell where the two materials are in contact. This electric field created can also be referred to as the built-in electric fie1d. The insulating board is then screwed to a black plate which assists in retaining heat in the system. The black plate is joined to the bottom of a frame made of angle bars. On the surface of the frame, is a glass plate which helps in concentrating the sunrays that fall on the silicon chips (collector)

When sunrays fall on the silicon chips, particles of light (protons) are absorbed by the semi conductors, they transfer their energy to some of the semi-conductors' electrons, which are then able to move about through the material (free electrons). For each such negatively charged electron, a corresponding mobile charge called a 'hole' is created. Definitely, the absorption of light in the absorber material of the solar cell results in energetic free electrons that move in the direction forced on them by the built in electric field. The flow of electrons to external loads is what we call electricity. Each photocell can generate approximately one (1) volt of electrical energy.

Limitation

The major limitation to this project work is that, the solar heat is not available at night, and may be unavailable some days due to weather conditions; therefore, a storage device is required for most applications. Also an environmental hazard such as rain, wind, dust and particles in the atmosphere sometimes hinder the sunrays from getting to the panel.

Insolation

Insolation or sunlight intensity is measured in equivalent full sun hours. One hour of maximum or 100% sunshine received by solar panel equals one equivalent full sun hour, even though in a day, there may be six hours of equivalent full sun The most productive hour of sunlight is from 9:00am to 3:00pm around solar noon (solar south). This is different from 12.00 noon. Before and after these times power is produced, but at much lower levels. When we size solar panels for a solar power system, we take these equivalent full sun hour figures per day and arrange them over a given period

Design/Material Requirement

Design

According to Ugural (2004), the ultimate goal in mechanical design process is to size and shape the elements and choose appropriate materials and manufacturing processes so that the resulting system can be expected to perform its intended functions without failure. Generally, it is assumed that a good design meets performance, aesthetics and cost goals. Definitely, these three stated goals were met during the design of the project. The stress generated is very minimal since the frame and the solar panel are light in weight.

Material Considerations

A proper and adequate consideration of the material for construction is considered before commencing on the construction of the project work. Some of the areas considered are listed below

Availability of the Material

The availability of the material was put into consideration so that if for any reason, any part of the work has a problem, it can be readily replaced. No matter how good the qualities of the materials are, unless it is available, it cannot be used for the project work.

Durability

The work was designed in order to withstand the test of time. According to Ugural (2004), durability denotes the ability of material to resist destruction over a long period of time. The destructive conditions may be chemical, electrical, thermal, or mechanical in nature or a combination of these conditions.

Cost

One of the most important factors that must be considered in the choice of materials is the cost of the materials. Designs must be cost effective, therefore materials were carefully chosen, depending on cost after considering their ability to meet the design requirement.

Material Selection

Most of the materials and equipments used for the accomplishment of this project work were bought. Examples of such are the solar panel, inverter, solar charge controller etc. However, in the construction of the framework (also known as the support structure), the under listed materials were carefully selected.

1. Galvanized pipe
2. Flat steel sheet
3. Angle bar
4. Bolts, nuts and washers.

Choice of Components

The choices of components were made after considering their efficiencies and the achievement of our goal, which is the generation of electricity using array of photovoltaic cells. The components of the solar power plant are as follows:

The Solar Panel (Photovoltaic Cell)

The solar panel is designed so as to absorb the radiant energy. For the purpose of this project work, a 40 Watts rated solar panel made from silicon chips was bought. Also another solar cell was constructed using used computer chips connected both in series and in parallel.

Solar Charge Controller

The function of solar charge controller is to regulate the power flowing from a photovoltaic panel into a rechargeable battery. It ensures that the battery is not over-charged and for the purpose of this work, a 10Amps 12/24 volts rated solar charge controller was purchased.

Battery (Rechargeable)

Solar batteries are rechargeable batteries used for the purpose of storing currents generated by the PV module. This is because the PV module can only absorb radiant energy in the day and the energy needs to be stored, so that at night when there is no sun, the stored energy can be made available for use. For this purpose, a 12V 100AH rated cell lead acid battery was purchased.

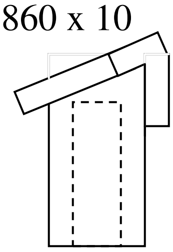
Inverter.

The inverter is employed in the solar system to convert voltages from direct current (DC) to alternating current (AC) before it can be used to power our domestic electrical appliances. For this purpose, a 1000Watts power inverter was purchased corresponding to the capacity of the battery.

Stress Calculation

The mechanical components of this project are the frame and the pipe. The major stress is developed by the frame on the pipe.

Weight of frame = (B X H + b x h) xL x p x g + LBHpg
= (0.035 x 0.005 + 0.005 x 0.030) x 0.284x
X 7860 x 10 + 0.58 x 0.15 x 0.01 x 7860 x 10
= 72.55 + 68.38
= 140.93N



Since the frame is inclined at 15^0 to the horizontal

The effective force = $140.93 \sin 15^0 = 91.65N$

Area of pipe = $\frac{\Pi (D^2 - d^2)}{4}$

= $\frac{\Pi}{4}(0.0036 - 0.0016)$

= $1.57 \times 10^{-3} m^2$

Direct stress on the pipe = effective weight

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Area

$= \frac{91.65}{1.57 \times 10^3}$

$= 58.4 \times 10^3\ N/m^2$

Mass moment of inertia Ix = $\underline{m} \quad (d_0^2 - d_1^2)$

But mass m $= \frac{\Pi LP}{4} (D_0^2 - D_1^2)$

$= \frac{\Pi X 6 X 7860 (0.06^2 - 0.04^2)}{4}$

$= 74.07kg$

I x $= \frac{74.07}{8} (0.06^2 + 0.04^2)$

$= 0.096\ m^4$

l y $= \frac{m}{48} (3d_0^2 + 3d_1^2 + 4L^2)$

$= \frac{74.07}{8} \quad (3 (0.06)^2 + 3 (0.04)^2 \times 4 \times 6^2$

$= \frac{74.07}{8} \times 144$

$= 1333.4\ m^4$

Polar moment of inertia $= \frac{\Pi t d^3}{4}$

$= \frac{\Pi \times 0.01 \times 0.06^3}{4}$

$= 1.70 \times 10^{-6}\ m^4$

Section modulus Z = $\frac{\Pi\ t\ d^2}{4}$

$= 2.83 \times 10-5\ m^3$

Torque T $= 91.65 \times 290$

$= 26578.5\ N - mm$

Shear stress τ $= \frac{2.83T}{\Pi\ S\ d^2}$

$= \frac{2.83 \times 26578.5}{\Pi \times S \times 60^2}$

$= \frac{6.65}{S} \quad N/mm^2$

Bending moment M $= 91.65 (6000 - 5)$

$= 91.65 \times 5995$

$= 549441.75$

$= 549442 \text{ N} - \text{mm}$

Bending stress, $\alpha_b = \dfrac{5.66m}{\Pi \; S \; d^2} = \dfrac{5.66 \times 549441.75}{\Pi \; s \; (60)^2}$

$= \dfrac{274.97}{S}$

From table maximum shear for steady load

$\tau s = 70 \text{ MPa}$

$\tau s = \frac{1}{2} \quad (\alpha b)^2 + 4\tau^2$

$70 = \frac{1}{2} = \frac{1}{2} \quad \left(\dfrac{274.97}{S}\right)^2 + 4\left(\dfrac{6.65}{S}\right)^2$

$70 \times 2 = \dfrac{75608.5}{S^2} + 4\left(\dfrac{44.2225}{S^2}\right)$

$= \dfrac{75608.5 + 176.89}{S^2}$

$140 = \dfrac{75785.39}{S^2}$

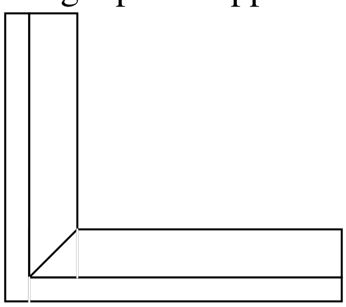
$140 = \dfrac{275.29}{S}$

$S = \dfrac{275.29}{140}$

$= 1.966$

$= 2\text{mm}$

For the angle plate support



Tensile strength of the joint for single fillet weld.

P = Throat Area x Allowable tensile stress

$= 0.70\,7 \; S \times 1 \times \alpha_t$

From recommend list

Allowable tensile stress for fillet welds on steady load

$\alpha_t = 98 \text{ mPa}$

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leg or size of weld for 3 – 5 mm thickness plate

$S = 3$

.. $P = 0707 \times 3 \times 35 \times 98$

$= 7275.03$

$= 7275 \text{ N/mm}^2$

Polar moment of inertia $= \frac{t \times 1^3}{12}$

But $t = 0.707 S$

$= \frac{0.707 S \times 1^3}{12}$

$= \frac{0.707 \times 3 \times 35^3}{12}$

$= 7578.16 \text{ mm}^4$

Maximum sheer stress

$\tau_{max} = \frac{4.242 T}{S \times 1^2}$

from recommended list

$\tau_{max} = 70 \text{ MPa}$

$70 = \frac{4.242 \times T}{3 \times 35^2}$

Torque $T = \frac{70 \times 3 \times 35^2}{4.242}$

$= 60643.6$

$= 60644 \text{ N – mm}$

$= 60.6 \text{ N – m}$

Testing the PV System

Proper testing of the photovoltaic system was done to determine the performance or efficiency of the whole system.

However the battery was first connected to the charge controller. Thereafter, the inverter was connected to the battery, but was switched off. Finally the PV module was then connected to the charge controller. After some hours of charging, the system was ready for assessment. It was then connected to a laptop computer and used in charging it.

4.1.1 **Results**

When the battery was connected to the charge controller, a red light indicator came up showing that the battery was down but after some hours the red light went off and the green light came up showing that energy has been stored. The yellow light indicator that came up when the PV module was connected indicated that there was energy flowing from the module to the charge controller which means that the PV modules are converting sun rays to electrical energy. When the switch on the charge controller was switched on; it clearly indicated that electricity was generated. In general, the charge controller has three indicators, which are as follows:

1) The PV indicator (Yellow)
2) The battery indicator (red), and
3) The load indicator (green)

The PV indicator shows that solar module is connected to the charge controller; this is only when the solar module is doing conversion of energy from the sun to electrical energy. Also if the sun indicator starts blinking, it means that battery is fully charge and if blinking fast, it means that energy received from the PV module is being converted to heat and radiated away to the atmosphere. Battery indicator, which is usually red, comes on when the battery is completely drained. The load indicator always come on when the load is switched on, and when load is put off, it goes off too. The indicators in the charger controller tell us if the whole system is working at a normal rate.

To further ascertain the working condition of the system, the digital multi-meter or voltmeter was employed to measure the working of the system and charge rate of the battery. The 40 watts PV module recorded 19 Volts while the constructed PV module recorded a negligible voltage about 0.01 volts.

However, when the battery was fully charged, it measured 13 volts and voltage measured at the inverter (the A.C. source) was 220 volts.

Finally, when a laptop computer was connected to the system, the system was able to power it throughout the hours of the sunlight (6 hours). The system was also able to power a radio player. Conclusively, the system recorded a negligible discharge of about 0.5 volts when the loads were unplugged from the system.

Calculation of Power generated

According to measurement, the PV module recorded 19Volts, 2.11 ampere power (watts) = voltage (V) x current (1)

Power = 19 x 2.11

= 40watts

Watt per square meter according to the sun in Ogwashi-Uku

Area of panel = 0.58mx 0.55m

= $0.319m^2$

Therefore watt per square meter = $\frac{40}{0.319}$

= 125.4 watts/ m^2

Discussion of Result

From the installation and testing of this work, it was evident that sunlight can efficiently generate electricity when all necessary factors are put into place.

The solar energy can be converted to electricity using the photovoltaic cells which could be used directly and indirectly employing suitable solar technology.

From the result of the load calculated, it observed that with appropriate design proper installation of components and precautions, the power produced will work throughout the day and as well as provide power for some time at night.

Conclusion and Recommendation

Conclusion

From all indications, the photovoltaic cells can convert free energy of the sun which is the most abundant energy source on the planet directly into electricity. The PV system has no moving parts, no pollutants, and no noise and yet supplies regular power.

Recommendations

Based on the research findings, the following recommendations are made:

i. Industries that build photovoltaic components should be cited by government to allow easy development of the solar electricity generation

ii. The PV system is made up of no moving parts. Therefore it is cheap to maintain and non-pollutant therefore it is recommended for homes and towns

iii. The government should provide these solar components at a more subsidized rate so as to encourage Nigerians to buy them for their use.

iv. Since power supply is a major problem in Nigerian, it is recommended that students in engineering should be exposed to its construction and working principles.

v. Since solar power is a purer and more efficient way of generating electricity, government should endeavour to make use of it and eliminate other sources that emit dangerous gases to the Ozone layer. In fact, the energy is renewable and readily avai1able

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