

Design and Implementation of a Solar Power System

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ABSTRACT

Energy is a very important variable that its conservation is of paramount interest to engineers of our time. As we know, the law of conservation of energy states that energy can neither be created nor destroyed, but it can be transformed from one form to another. This helps in sustainable use and protection of natural resources. This research work the Design and Implementation of a Solar Power System focuses on a technique of power generation from solar source. It provides simple basic theoretical studies of solar cell and its modelling techniques using equivalent electric circuits. Solar Photovoltaic (PV) power generation system is comprising several elements like solar cells, inverter, Battery charge controller and single phase inverter for AC loads are implemented in hardware in simple manner.

KEYWORDS: Solar panel, power generation, inverter, charge controller

1. INTRODUCTION

Nigeria is among the tropical countries that fall between 4 degrees and 13 degrees and enjoys sunshine of 6.25 hours daily. Presently, public electricity covers only 40% of Nigerian homes and this is not still on a consistent basis. Due to lack of constant power supply in Nigeria, people have started embracing the culture of generating their own power supply. The use of fossil fuels as a means of generating electricity has become expensive making cost of living very high, especially in the rural part of the country. Also the use of fossil fuel has brought about pollution to the environment which in turn is not safe for our health. It releases carbon dioxide which causes the greenhouse effect. This brings about the deforestation of land and also the pollution of air and water. Further, it also causes the ozone layer to be depleted. These mentioned phenomena can cause several events to occur such as; acid rain, air pollution, land pollution because of excavating operations, etc. Solar energy also known as green energy is gotten solely from the sun and as a result does not emit carbon dioxide which prevents the green-house effect. Nowadays solar energy is

becoming one of the most reliable sources of energy as a result of its surplus and environmentally friendly [1]. Many people use solar inverters these days which proves that its necessity has increased in the current years.

The development of technology has been affecting solar generator system designs, dating back to early stage in which magnifying glass were used to concentrate sun's rays to make fire and to burn ants to the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop PV system [2]. Commercial concentrated solar power plants were first developed in the 1980s. As the cost of solar electricity has fallen, the number of grid-connected solar PV systems has grown into the millions and utility-scale photovoltaic power stations with hundreds of megawatts are being built [3].

The work of David I. and Thomas B. R [4] shows specific information for a solar powered battery charger making use of the SEPIC DC-DC converting technology. The converter uses a MOSFET which operates as an electronic switch completely in an ON

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or OFF state. SEPIC converter was chosen because it can convert the input voltage to either a higher or lower output voltage.

[5] Explained the make-up of a solar battery charger, a dc-dc converter connected between a solar panel and battery was used. The main components of the solar battery charger are standard photovoltaic cells, a single ended primary inductance converter (SEPIC) and a controller. The SEPIC converter is a type of DC-DC converter that is able to convert unregulated input voltage into either a higher or lower output voltage. This allows the solar panel to charge the battery with a wider range of output voltage, thus flexibility is increased. Experimental results of the solar battery charger are evaluated while I used an inverter and generally the SEPIC converter increases the efficiency of conversion.

Trishan Eeram and Patrick L. Chapman in [6] presented the "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques. The Proposed system contains the two LDRs as sensors, a new Design of controller parts and the geared DC motor as Actuator. This system can successfully track the current Positions of the sun and can be used for non-critical and Low power applications. The existing tracking systems have complicated sensor strategies so has high cost and maintenance issues. Many researchers from all over the world have developed So many solar radiations sensing devices and tracking Strategies but they contain large number of LDRs which makes them complicated and very expensive. So, cost effectiveness and portability are the objective of this work.

A portable solar power inverter was designed and constructed by Md. Rabiul Islam et.al [7] making use of solar plates, an 8051 microcontroller, a solar tracker, transformer, lead acid battery and an inverter. The system proved to be a very good one as it is portable and can be easily carried about, the battery chosen for this project is a lead acid battery with 6 cells and 35Ah, which is manufactured by mart. The battery has a battery life of approximately

Over 100,000 operating hours and 450A max discharge surge current and minimum charge current of about 1 amp. While lithium-ion battery is used in carrying out this project which has comparative advantages over deep cycle batteries. Part of which includes more operating life and lighter in weight when compared to lead acid battery.

2. Basic Theory of Solar Cell

Solar cells are made by two types of semiconductor materials one is N-type semiconductor and other is P-

type semiconductor material for generation of electricity [8]. When light strikes on semiconductor, it generates electrons (-) and holes (+) pairs. when electron and hole pair reaches between two different type of semiconductor's joint surface then electron and hole are separated, electron is attached by N-type semiconductor and hole is attached by P-type semiconductor after that they are not rejoin due to joint surface do not allow both way traffic.

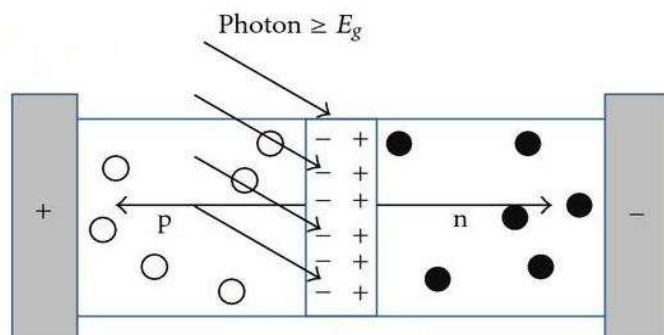


Fig 1 P-N junction illustration of PV cell

Now electrons are contained by N-type semiconductor and holes are contained by P-type semiconductor, an electro motive force (emf) is generated in electrodes. When these electrodes are connected together by a conductor electrons run toward P-type semiconductor and holes run toward N-type semiconductor.

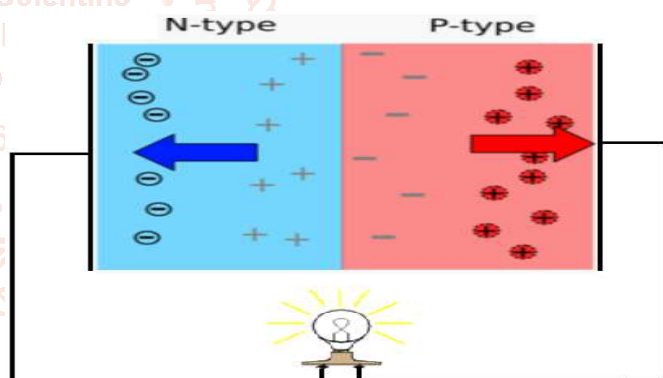


Fig. 2 Flow of current

2.1. Solar Cell Connections

Solar cell connection is just like battery connection. When positive terminal of one solar cell is connected to negative terminal of another solar cell then they form series connection. In series connection current is same for all cells and voltage is added by each cell shown in figure 3.

And when all positive terminals of solar cells connected to one terminal and all negative positive terminals of solar cells connected to another one terminal then forms parallel connection. As shown in figure 4 here current is added and voltage is same for all cells.

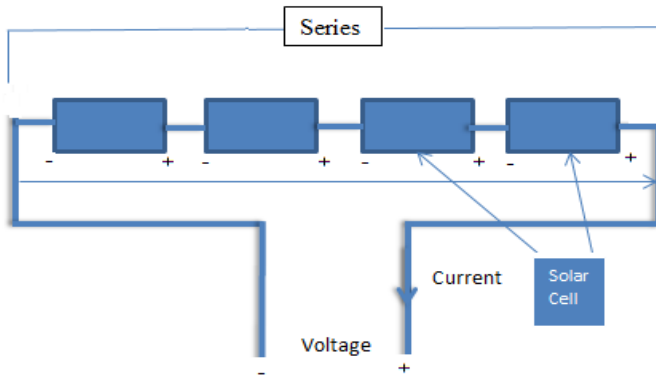


Fig 3 Series connection of solar cell

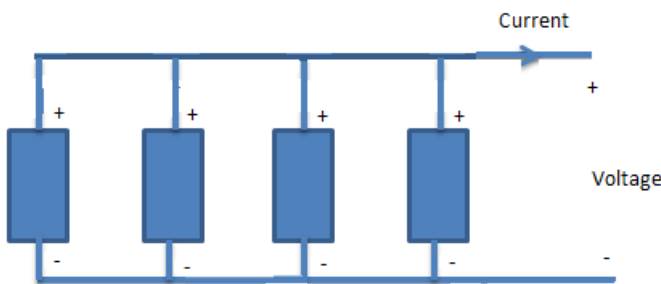


Fig. 4 Parallel connection of solar cell

2.2 Solar Cell, Solar Module or Panel and Solar PV Array

In solar power generation system a number of solar cells is required to produce high power so they are connected in form of Solar Module or Solar panel and for a higher capability form[9]. An Array as shown in figure 5 is needed.

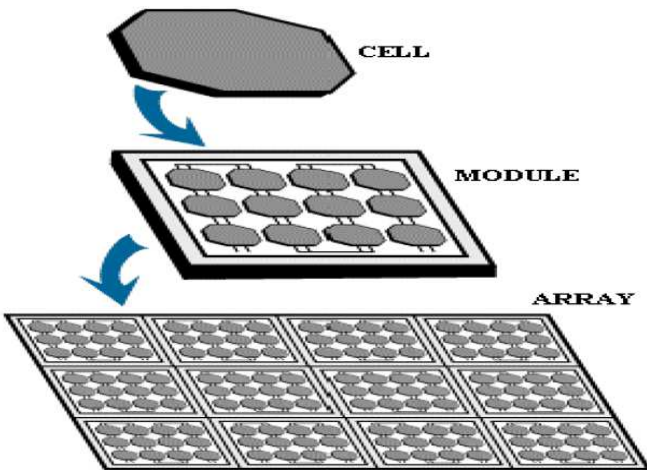


Fig.5 Formation of solar Module and solar PV Array

3. METHODOLOGY

Out of all the methods which include waterfall, prototype, iterative enhancement, evolutionary development, spiral and RAD (Rapid Application Development), the waterfall method was chosen as it met most of our necessary requirements.

As per the model implemented, it was the waterfall model that have five phases, namely;

1. Requirement analysis and specifications
2. System Design
3. Implementation and subsystem testing

4. Integration and system testing
5. Operational and maintenance phase

4. SYSTEM DESIGN ANALYSIS

The design of the project is in two subsystems namely:

- Portable solar generator subsystem
 - Smart Solar panel subsystem
- The block diagram in fig.6 shows the various subsystems that make up the system design, fig.7 shows their interconnections

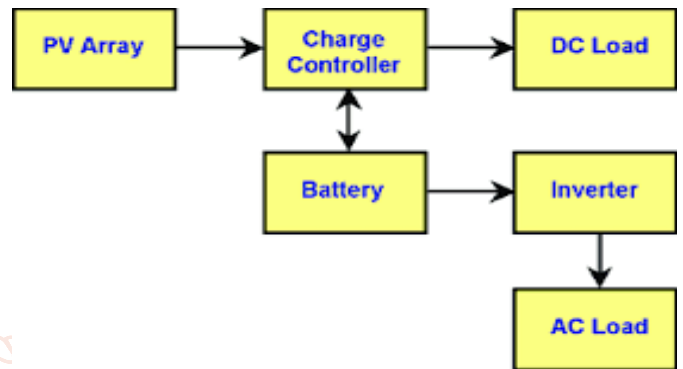


Fig.6 Block diagram of the components of the system.

System connection diagram

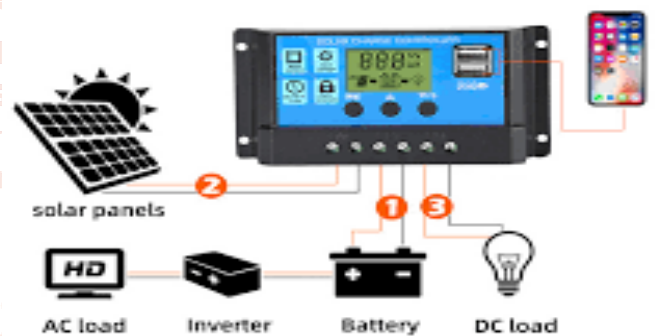


Fig 7 Schematic diagram our Solar Power System

Portable Solar Generator subsystem has the following sections

Battery bank. Two lead-acid cells were used, each has a rating of 12V/9Ah. The lead-acid batteries were connected in parallel to produce an output of 12V, 18A

Battery calculations;

$$\text{Battery runtime / Duration} = \frac{\text{Battery Power in watt}}{\text{Connected Load in watts}} \quad (1)$$

But,

$$\text{Battery Power in watt / Hour} = \text{Battery Voltage} \times \text{Number of batteries}$$

Let battery runtime/duration = T C = Battery capacity in AH V = Battery voltage in volts N = Number of batteries in series/parallel as the case may be.

$$PI = \text{Connected load in watts} \therefore T = \frac{C \times V \times N}{PI} \quad (2)$$

For $V = 12V$, $P = 200$ watts, $N = 2$, $C = 18Ah$

$$\therefore T = \frac{18 \times 12 \times 2}{200} = 2.16 \text{ hrs}$$

Solar Charge Controller Unit

The following calculations were made in selecting solar charge controller. The energy of the battery bank is calculated. Here we made use of two lead acid batteries of parameters 12V, 18A

Energy of the Battery

$$= 2(\text{voltage} \times \text{current}) Ah = 2(12 \times 9) = 216 Ah \\ \Rightarrow 2(12 \times 9) = 216 Ah$$

Since the charging current should be 10% of the Ah rating of battery.

Therefore,

Charging Current for Ah battery

$$= 216 Ah \times \left(\frac{10}{100} \right) = 21.6 Ah$$

Considering tolerance of 20%, we may take (3.0 – 5.0) Amperes for effective battery charging purpose as the current determines the charging duration (i.e. the amount of time it takes to fully charge). Suppose we took 4.4 Amp for charging purpose, then,

$$\text{Charging time for Ah battery} \\ = \frac{21.6}{4.4} = 4.9 \text{ hours}$$

But this was an ideal case...

Practically, it has been noted that 40% of losses occurs in case of battery charging.

$$\text{Then} = 21.6 \times \left(\frac{40}{100} \right) = 8.64$$

$$\therefore = 21.6 + 8.64 = 30.2 Ah$$

Since Charging Time of battery = Ah / Charging Current

Putting the values;

$$\therefore \frac{30.2}{4.4} = 6.9 \text{ hrs}$$

Therefore, our 216Ah battery would take 6.9 hrs to fully charge in case of the required 4.4A charging current.

To choose a suitable charge controller we need the following information.

- The power (watts) of the solar panel
- The battery bank voltage

Using ohms law to find the current $P = I \times V$ (3)

Where, $P =$ Power (watts) $I =$ Current (amps)
 $V =$ Voltage (volts)

Now using a 120 watts panel and 12 volts battery to get the current needed

$$I = \frac{P}{V} \quad (4)$$

So we need a charge controller of output charging voltage greater than 10 Amps.

Adjusting the value by 25% to take into account any special condition that might cause the panel to produce more or less power than it is normally rated for

So we have 10 amps increased by 25%
 $10 + \left(10 \times \frac{25}{100} \right) = 12.5 A$

Having this in mind, we need a solar charge controller of charging current greater than 12.5 amp. For this work, we chose a PWM solar charge controller of charging current, 50A.

The charging subsystem consists of the solar panel and a PWM solar charge controller which comes with LCD display that can clearly indicate the status and data of the battery and PV array. This controller can only use photovoltaic panel as the charging source. It has a maximum charging and discharge current of 50 Amps. 12V panels have a varying output of 16V to 20V, so if there is no regulation the battery will damage from overcharging.[18] PWM controllers work by slowly reducing the amount of power going into your battery as it approaches capacity. When your battery is full, PWM controllers maintain a state of “trickle”, which means they supply a tiny amount of power constantly to keep the battery topped up. The solar charge controller works as an automatic disconnect of non-critical loads from the battery when the voltage falls below a defined threshold. The charge controller stops the charging of the batteries once these are sufficiently charged. This will prevent over-charging. It also facilitates a unidirectional flow of current from the solar panel to the battery, and blocks the reverse voltage flow. This helps to prevent batteries from unnecessary discharging and it increases the battery uptime and blocks the reverse flow during the night. Also an added features - two external USB ports which accommodate the direct charging of other small and medium devices and a dc jack as an alternative for charging the system when there is not enough sunlight.

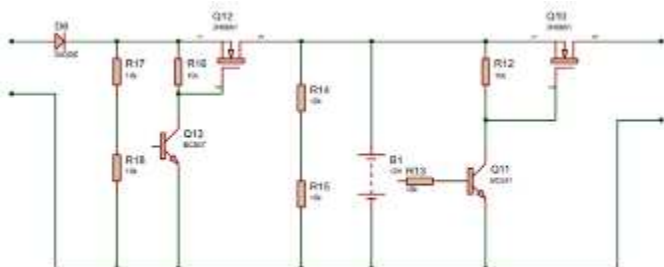


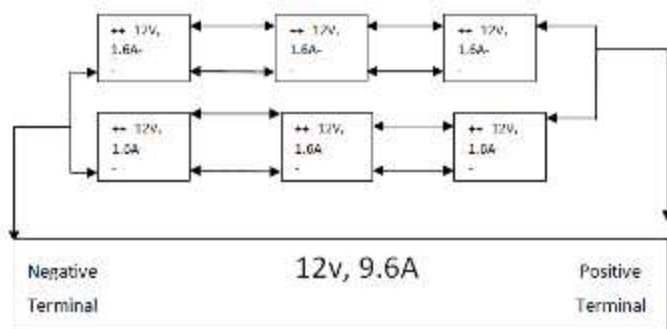
Fig 8 Circuit diagram for charge controller



Figure 9 Image of PWM charge Controller

5. IMPLEMENTATION AND HARDWARE TESTING

The solar panel designed has six solar cells connected in parallel as shown in fig. The Maximum power of 1 smart solar cell = 20Watts given a total 120watts.



The solar panel has the following ratings, $P_{max} = 20$ Watts, $V_{max} = 12V$, $I_p \text{ max} = 1.66A$, $V_{OC} = 14V$, $I_{sc} = 1.96A$. Maximum power of smart solar panel (six solar cells) = 120 Watts.

Photo of hardware solar panel is shown in fig. This solar panel consists of six solar cell. A continuity test was done across each path of the system. A multi-meter in buzzer mode was connected to the terminals across the path that needed to be checked. There was no inhibition to the flow of current hence continuity is achieved, and a beep sound was heard.

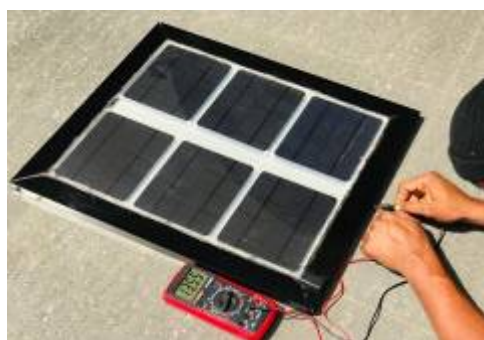


Figure 4.2: Quality test of our smart solar panel

A 200watt converter modifies DC12V into AC 220V 50Hz, and USB output is DC 5V was used. Rated output power of the product is 200W, which can be widely used to power all kinds of electrical equipment such as mobile phone, TV sets, Laptops, digital cameras, DVD player, PSP, iPad, and other digital equipment. This 200 watts converter used has the following features; Input voltage: DC12V (10.5-14.5V)/DC24V (19-32V), Output voltage: AC220V/AC110V $\pm 8\%$, Peak power: 400W, Continuous power: 200W, Output frequency: 50HZ or 60HZ USB output: 5V, 2.1A+1A+2.1A+1A

6. RESULT ANALYSIS

➤ Load Analysis

The designed project was tested with the following load:

Table 2: Load test

S/No	Load	Wattage
1	Mobile phone	5
2	Laptop	30
3	Electric fan	50
4	Electric bulb	20
5	LED television (42 inches)	120

Inverter system behavior at maximum load (i.e., 200 watt) each of the battery cell is rated 9Ah, 12 volts. With 2 batteries in parallel

System Voltage = 12 volts.

$$\text{System capacity} = 9 \text{ Ah} + 9 \text{ Ah} = 18 \text{ Ah}$$

$$\text{Total Energy} = IV \tag{5}$$

$$= 12 \times 18 = 216 \text{ Wh}$$

Working Energy = (80% of total power)

Inverter Efficiency = 80%

$$\text{Total Energy} \times \eta = 216 \times 0.8 = 172.8 \text{ Wh}$$

$$\text{Actual Energy} = \eta \times \text{working Energy}$$

$$= 0.8 \times 172.8 = 38.24 \text{ Wh}$$

Since inverter rating = 200 watts.

At max load = 80% of 200watts

$$0.8 \times 200 = 160 \text{ watts}$$

Time of operation on max load

= ratio of actual energy to max load

$$\text{Time of operation on max load} = \frac{138.24}{160} = 0.864 \text{ hrs}$$

Inverter system behavior at other loads; 150, 100, and 50 were also calculated. Table 3 shows the results.

Table 3: Load-Time relationship of the battery duration

Load (W)	Time (Hr)
200	0.86
150	1.2
100	1.8
50	3.7

7. CONCLUSION

The implemented system was tested and the result was excellent. No-Load test was carried on the inverter and as well as Load Test. Both results were very okay. The packaging of the inverter was done so that the Portable Solar PV Generator would look presentable. These achievements serve as the criteria to regard this project work a success.

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