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Design of 2kVA Solar Inverter

Olajuyin Elijah Adebayo
Elect./Elect. Engineering
Crown Polytechnic, Odo, Ado Ekiti

Olubakinde Eniola
Elect/Elect Engineering
Federal Polytechnic Ile –Oluji, Ondo State

Abstract - Solar and Wind energy generators are quite common presently due to advances in the technology. This will lead to further increase in the use of photovoltaic (or PV) and Wind generators and more so that Nigeria's electricity production continues to fluctuate without appreciable increase in total output. This study was design and implementation of 2.0 kVA solar power system to solve the problem of power failure in our environment. It is a means of providing an alternative power supply in our homes and offices in case the mains fails and it environmental friendly since produces not smoke and sound. It was carefully designed with 2 solar panels that were wired in parallel and with 2 batteries rated 200AH/12V and were also connected in parallel to produce current. The inverter was 2kVA to produce 12V DC to 220V AC voltage. It can be used in any establishment and this can also be generating in large capacity and it can be into grid if it generated in large quantity.

Keywords: Inverter, Development, Design, Generating, Alternative, Connected and Implementation

I. INTRODUCTION

Solar and Wind energy generators are quite common presently due to advances in the technology. This will lead to further increase in the use of photovoltaic (or PV) and Wind generators and more so that Nigeria's electricity production continues to fluctuate without appreciable increase in total output. The installed capacity for electricity generation, which is 98% owned by the Federal Government, increased by a factor of 6 over the period 1968 to1991 and by 1991, stood at 5881.6 MW. No further addition to generating capacity was experienced over the subsequent decade (National Energy Policy, 2003).
Electricity can be produced from sunlight through a process called photovoltaic."Photo" means light and "voltaic" means voltage .Since, the source is usually from the sun, it is called solar cells / photovoltaic. It is a semiconductor device that converts energy from the sun to electrical energy.
The outlined in energy policy of Nigeria in 2003 by the federal executive council, provisions were made for coordinated development, illumination and management of all energy resources. The policy document clearly admit that the grid extension through conventional petroleum product, gas, coal, electricity) alone will not meet the rural electrification coverage cost- effectiveness within a reasonable time frame and thus make adequate allowance particularly for rural energy supply with non conventional and renewable energy such as solar, wind, small scale hydro, biomass, fuel wood etc. (Jesuleye et *al*,2008).
The role of inverter system in the national energy mix cannot be over emphasized .The global search and the rise in the cost of conventional fossil fuel is making supply-demand of electricity product almost impossible especially in some remote areas. Generators which are often used as an alternative to conventional power supply systems are known to be run only during certain hours of the day, and the cost of fueling them is increasingly becoming difficult (Adejumobi *et al*, 2011). The increasing use of renewable energy sources (especially Solar and Wind) has led to a drive in the research and development of appropriate technologies for energy efficient converters. The use of solar photovoltaic generator sometimes requires one such converter – the inverter. An inverter converts DC power to AC at the required voltage, current and frequency.

Photovoltaic Applications **categorization**:
i. Stand –alone applications (off-grid application): This operates independently off the grid network; it may comprise a control, storage, cable, inverter and loads (lights radio, televisions).
ii. Grid-connected application: Systems are tied into the grid network. Grid connected applications need inverter to convert the d.c generated by PV-module into a.c .Energy surplus will be fed into the grid, while in times of shortages (night) energy will be consumed from the grid. All d.c output of the PV field, which may be of megawatt range is converted to a.c and then fed into the central utility grid after which it is distributed to the consumers. The grid acts like a battery in a grid – connected power system with unlimited storage ability.

Aim and Objectives

The aim is to design and implement a 2.0 kVA solar power system.
The following are the specific objectives:

i. Design of an alternative power supply system which is eco friendly;
ii. Development of alternative power supply.

Statement of problems

The epileptic and incessant power supply in Nigeria by Ibadan Distribution Company and The problem of high and irregular billing of the distribution company has necessitated this and also the environmental pollution contributing to the environment by stand alone generator or individual owns generator.

Solar Panels: An eco-friendly electric generator.

Solar panels generate free power from the sun by converting sunlight to electricity with no moving parts, zero emissions, and no maintenance. The solar panel, the first component of an electric solar energy system, is a collection of individual silicon cells that generate electricity from sunlight. The photons (light particles) produce an electrical current as they strike the surface of the thin silicon wafers. A single solar cell produces only about 1/2 (.5) of a volt. Multiple solar panels can be wired in parallel to increase current capacity (more power) and wired in series to increase voltage for 24, 48, or even higher voltage systems. The advantage of using a higher voltage output at the solar panels is that smaller wire sizes can be used to transfer the electric power from the solar panel array to the charge controller & batteries Embark electronics (2013) .

The Three Basic Types of Solar Panels

a. **Monocrystalline solar panels:** The most efficient and expensive solar panels are made with Monocrystalline cells. These solar cells use very pure silicon and involve a complicated crystal growth process. Long silicon rods are produced which are cut into slices of .2 to .4 mm thick discs or wafers which are then processed into individual cells that are wired together in the solar panel.

b. **Polycrystalline solar panels**: Often called Multi-crystalline, solar panels made with Polycrystalline cells are a little less expensive & slightly less efficient than Monocrystalline cells because the cells are not grown in single crystals but in a large block of many crystals. This is what gives them that striking shattered glass appearance. Like Monocrystalline cells, they are also then sliced into wafers to produce the individual cells that make up the solar panel.

c. **Amorphous solar panels**: These are not really crystals, but a thin layer of silicon deposited on a base material such as metal or glass to create the solar panel. These Amorphous solar panels are much cheaper, but their energy efficiency is also much less so more square footage is required to produce the same amount of power as the Monocrystalline or Polycrystalline type of solar panel.

Types of Solar Panel Array Mountings

a. Fixed: If you use the most simple and least expensive type of solar panel mounting system, it will be completely stationary. The solar panels should always face the sun direction.

b. Adjustable: The solar panel can be adjusted manually to the direction of the sun.

c. Tracking: Solar panel mounts follow the path of the sun during the day to maximize the solar radiation that the solar panels receive. A single axis tracker tracks the sun east to west and a two-axis tracker tracks the daily east to west movement of the sun and the seasonal declination movement of the sun.

Factors affecting the Performance of a Solar power System

i. Rating for PV Modules: PV modules are rated at ideal factory conditions, such as specified illumination (1000 W/m2), spectrum of the light and temperature (25 °C / 77 °F). This is called the STC (Standard Test Condition) rating and is the figure that appears on the spec label of PV module. Generally speaking, only around 60% to 70% of its peak STC-rated output will be produced from your PV modules due to unpredicted environmental factors.

ii. Temperature and Power Reduction Environment temperature affects the power output of PV modules. The higher the temperature, the lower the power output of PV module. Comparing with pole-mounted PV module array, roof-mounted PV module array generates less power due to less air circulation and excess heat from roof top.

iii. The angle of the Sun: The angle of the sun in relation to the PV array surface—the array orientation can dramatically affect the PV array output. The array energy output will vary depending on the time of day and time of year as the sun's angle in relation to the array changes. Sunlight output decreases as the sun approaches the horizons (such as in winter in Europe) due to the greater atmospheric air mass it must penetrate, reducing both the light intensity that strikes the array's surface and spectrum of the light. In general, you can expect only six to eight hours of direct sunlight per day.

iv. Partial Shade: Shading on a single PV module of the array will reduce the output power of the entire system. Such shading can be caused by something as simple as the shadow of a utility wire or tree branch on part of the array's surface. This condition, in effect, acts like a weak battery in a flashlight, reducing the total output, even though the other batteries are good. However, the output loss is not proportionate to shading even a tiny bit of shading will reduce the PV power to the inverter. The inverter is designed to maximize its power production in all of the above situations using its proprietary MPPT algorithm.

v. Other factors that reduce power generation of a solar system are: Dust or dirt on the modules, Fog or smog, Mismatched PV array modules, with slight inconsistencies in performance from one module to Inverter efficiency, wires losses, utility grid voltage.

II. METHODOLOGY

This gives the materials and the method used in the design and implementation of the solar power system.

System Design

The block diagram of the solar powered system is showed below. It consists of 2 (160W,12V) Solar panels that are wired in parallel, it is wired in such a way that the positive terminal is connected to positive terminal and negative terminal being connected to negative terminal. The charge controller is rated 30A, this means we can connect up to 30A of solar panel output current to this controller. The two batteries rated 200AH /12V each are connected in parallel as well to produce current of 4800A per hour. The inverter constructed for this project is 2KVA inverter converting the 12V dc from the battery into 220AC

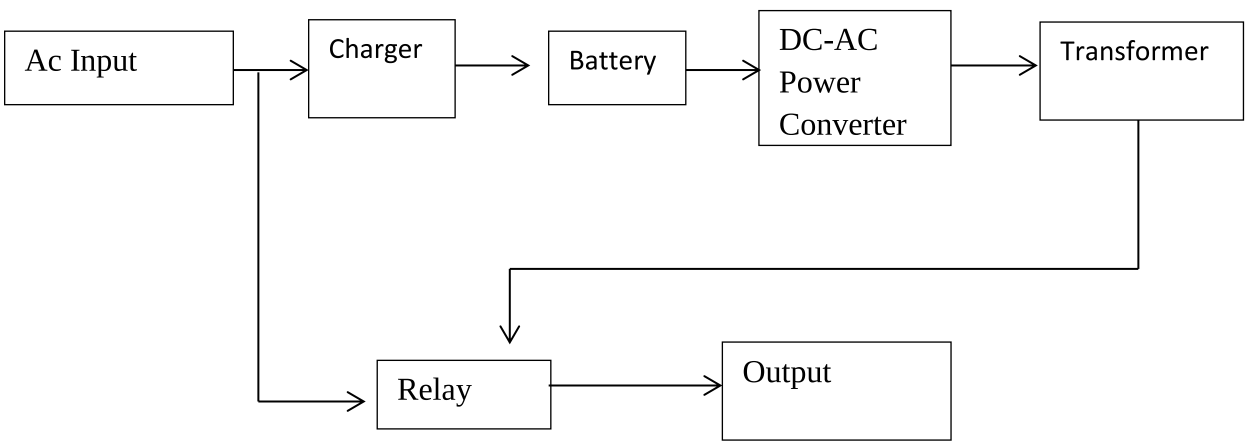

Figure 1: Block Diagram of an Inverter

Oscillator stage

The oscillator stage is meant to produce 50Hz AC current in line with what most equipment operates on. The inverter has oscillator that creates a 50Hz at the same voltage as electricity in home with the wave being square wave.

Switching stage

This study employed the use of metal oxide semi-conductor field effect transistor (MOSFET) for switching of 12V battery back and forth the primary terminals of centre-tap transformer The low voltage current is now induced to the secondary coil which will now supply the output voltage of 240V by the help of step-up transformer.

Design of the transformer

A centre-tapped step-up transformer was used. The voltage at the primary side is 12V while the voltage at the secondary is 240V. The number of turns at the primary and secondary is calculated henceforth. The rms emf induced in primary of a transformer is

$$E_p = 4.44 f \emptyset_m N_p \quad (3.1)$$

E_p is the rms emf induced in the primary, f is the frequency, $\emptyset_m$ is the magnetic flux in the core of the transformer and N_p is the number of turns at the primary.

$\emptyset_m$ = magnetic flux density $(B_m) \times$ Area of the core

E_p=12V,f=50Hz, magnetic flux density is assumed to be 1 and area of the core is taken to be 28×10^{-4}, the number of turns is obtained from equation 3.1 as

$$N_p = \frac{E_p}{4.44 f \emptyset_m} = \frac{12}{4.44\times 50\times 28\times 10^{-4}} = 19.31 \text{ turns}$$

The number of turns at the secondary is obtained using equation 2.1

$$\frac{V_1}{V_2} = \frac{N_p}{N_s}$$

$$N_s = \frac{V_2\times N_p}{V_1} = \frac{240\times 19.31}{12} = 386 \text{ turns}$$

The number of turns at the primary is 19 and the number of turns at the secondary is 386 turns

Design of the charger

When there is input from the mains, the relay is excited and the secondary windings of the transformer are connected to the mains. In order to achieve charging, charging windings are wound on the main transformer. Since the number of secondary windings is 354 turns, the number of charging windings can be calculated. Assuming a voltage of 220 from the mains and charging voltage of 15V for effective charging

$$\frac{N_c}{N_s} = \frac{V_p}{V_s} = N_c = \frac{354 \times 30}{240} = 44.2turns$$

Using

$$V_{dc} = \frac{2V_m}{\pi} \qquad 3.2$$

where V_m is the peak value of the voltage, $V_{rms} = 30V$

$$V_{dc} = \frac{2 \times \sqrt{2} \times V_{rms}}{\pi} = \frac{2 \times \sqrt{2} \times 15}{\pi} = 13.5V$$

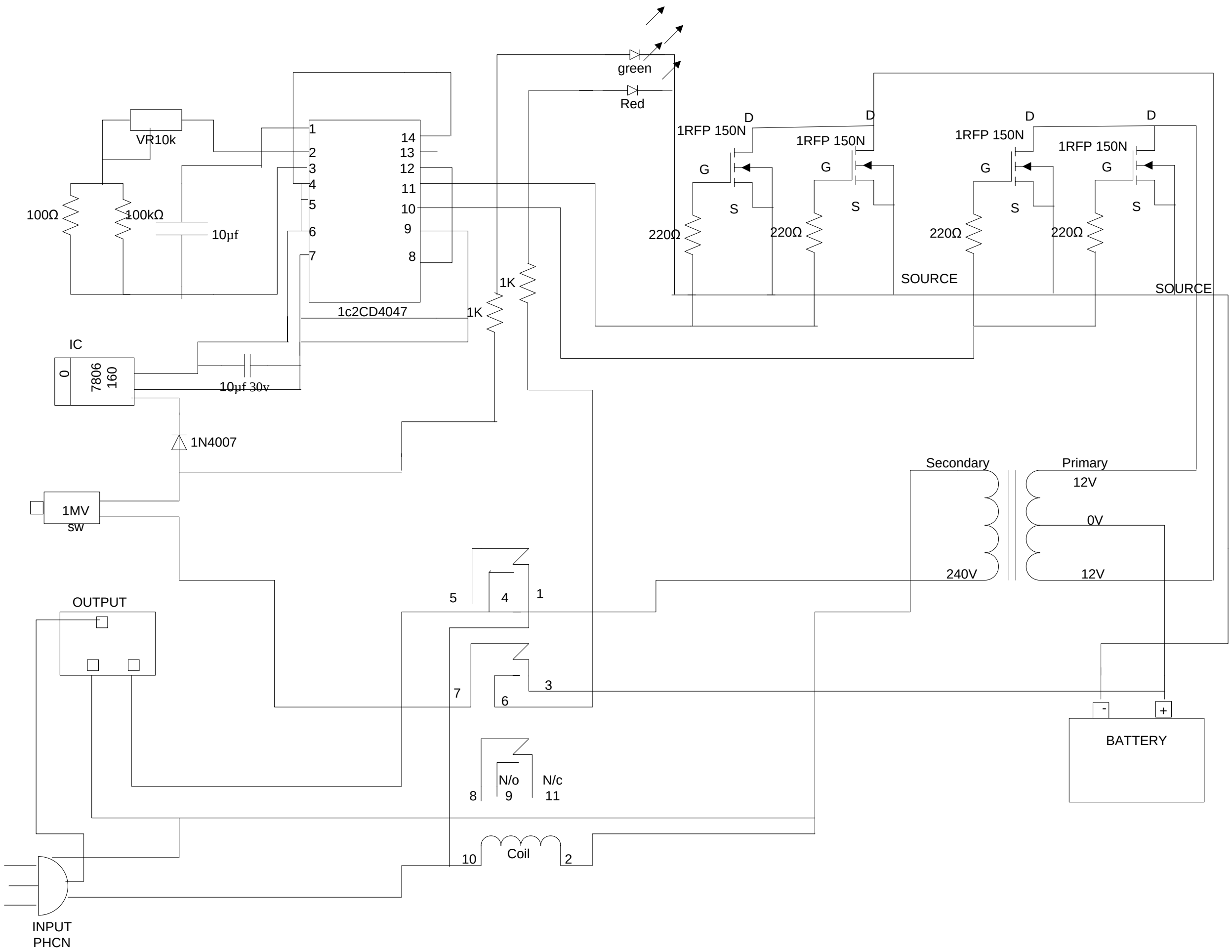

Figure 2: Circuit diagram of an inverter

Charging time of the battery using Solar Energy

It is important to determine how long to charge the battery when there is full sun on the solar panel.

Total Power obtained from solar panel =320W

Maximum Current from Solar panel = $\frac{320}{12}$

= 26.67A

This means 26.67A will be pumped into the battery.

The two batteries are rated 200AH/12V and they are connected in parallel. The amount of charge per hour from the two batteries is 400C

Using Q=It

Where Q is the amount of charge the battery can supply per hour

T= time in hours

I is the current being pumped into the batteries

Time to charge the battery = $\frac{400}{26.67}$

=15hrs

This means, it will take 15hrs to charge the battery fully.

If battery is not fully drained and there is 30% charge left over as it is not economical to discharge the battery 100%, the amount of time required to charge the battery assuming 30% left over then,

The amount of charge per hour on the battery = 0.7×400

= 280C

Therefore the time taken to charge the battery = $\frac{280}{26.67}$

= 10hrs

So if the battery is not fully drained, 10hrs will be used to charge the battery full

Discharge Durations of the battery

The batteries are supplying 4800W for 1hr, and assuming total load on the inverter is 1000W,

Power = $\frac{workdone}{time}$

$$\text{Power factor} = \frac{Real\ power}{Apparent\ power}$$

Output voltage=240V

Input voltage=12V

Inverter Power Output=2000VA

Real power= Power factor $\times\ apparent\ power$

Assuming the power factor of 0.8, the real power of the inverter is

Real power (W) = 0.8×2000 = 1600W

If Load applied to the inverter is 1000W, the inverter will work for

Time = $\frac{workdone}{Power} = \frac{4800}{1000} = 4.8hrs$

This means if the batteries are fully charged and a load of 1000W is connected, the inverter can work for 5hrs before switching off. The amount of time the inverter works depends on the amount of load connected to the inverter and charging capacity of the batteries

Relay Switch

A relay is a mechanical switch that uses low electrical power to control high one. It is a switch that is operated by magnetic force. The inverter has facility to alternate between mains and battery such that when there is supply from IBDEC, the two batteries will be charged and the moment the mains supply is off, the inverter will invert the dc supply from the battery to AC.

III. IMPLEMENTATION AND TESTING

Implementation

The circuit of the whole diagram was constructed on the Vero board while the components were arranged and soldered on the Vero board as shown in the complete diagram.

The following materials were used in packaging the inverter:

Fuses are used to protect the circuit (transformer and rectifying circuits) from flow of heavy current and high voltage which could be more than their ratings.

Heat sink is used to remove the heat generated by the transistor to the surrounding air. A common 5Amp or 15Amp three pin power output socket is used in inverter to provide inverter output to the various devices. One can connect an ordinary 5/15Amp plug to the Inverter output.

Testing

After the necessary installation was completed the system was powered with printer, laptop, bulbs, sockets and desktop computer and observed for at least 10mins and were working properly.

Maintenance

The following maintenance procedures are outlined in order to ensure uninterrupted power supply

1. The right polarity of the Inverter battery terminals must be maintained on the battery that is, Red clip to positive terminal and Black clip to negative terminal.
2. Regular check-up of the battery electrolyte must be carried out. The electrolyte should be changed as soon as there is a change in colour.
3. A void bridging the .battery terminals for any reason.

Battery care

It is important to know battery voltage in order not to drain the battery completely and reading has to be taken with meter in order to know the level of battery storage. The chart below shows the voltage that will be displayed on meter for various levels of charging of the battery.

Battery Voltage Chart

The battery voltage chart is shown in the Table 1. It is important to note that this test is taken when the battery has been at rest for an hour and neither charging nor discharging.

Battery Voltage Chart

Table 1: Percentage of Battery Voltage at different Level of Charging

100 % charged	**12.7 volts**
90 % charged	**12.6 volts**
80 % charged	**12.5 volts**
70 % charged	**12.3 volts**
60 % charged	**12.2 volts**
50 % charged	**12.1 volts**
40 % charged	**12.0 volts**
30 % charged	**11.9 volts**
20 % charged	**11.8 volts**
10 % charged	**11.7 volts**
completely discharged	**11.6 volts or less**

It is important to note that this test is taken when the battery has been at rest for an hour and neither charging nor discharging.

IV. Conclusion and Recommendations

CONCLUSIONS

A 2.0 KVA power inverter stand alone was designed to compliment the power supply from IBDEC. Power inverter is a DC to AC inverter device that is capable of turning DC power in batteries or the one collected from solar panels into AC power that can run home appliances and electronics. The power inverter would transfer readily available DC power, from a battery or other stored power source, and turns it into readily usable AC power on available devices normally plug into a home electrical socket/ outlet. It will provide alternative energy for homes and offices. The two solar panels employed were connected in parallel to receive solar energy from the sun and with 2 batteries also connected in parallel to produce current. The inverter will convert the dc energy received from the sun to alternating voltage.

RECOMEMDATION

The power inverter will perform efficiently and can be safe on a plain, dry surface (indoors) and it must be kept away from hot weather and it should be placed within the close range of the battery supply to get a direct and clear signal. It will be good if the system is not overload with high power ratings equipment such as photocopy machine, air conditional should not be used when connect to solar source. Power inverters are not waterproof and should be kept from getting wet. It should be kept dry like any other electronics device. The inverter should not be allowed to get struck by lightning. Ensure that the power inverter is kept away from any kind of generated heat or flammable source that can cause overheating and fires. Higher rating can be developed, this will allow the students to carry out practicals and also solve the problem of incessant power supply from Ibadan electricity Distribution Company and be fed into grid or use in companies and homes provided it is of high capacity.

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