Design and Construction of 3.5KVA Inverter

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Abstract- This project gives a deep insight of an inverter system. This includes the theories and literatures that govern the implementation of an inverter, components of an inverter system, methodology adopted to physically achieve the inverter system. The 3.5KVA inverter is designed to have an input voltage specification of 24V, output voltage of 220V and a frequency of 50Hz, these specifications were designed such that it synchronizes with the standard parameters of Nigerian electrical distribution companies, such as the Enugu Electrical Distribution Company (EEDC). The core purpose of this design is to combat epileptic nature of power supply in Nigeria by serving as a backup supply when the primary source of power fails and also charge the batteries when the utility is active. A pulse width modulation technique using a H-bridge circuit was utilized to achieve a frequency of 50Hz and with aid of MOSFETs, a sinusoidal signal equivalent to the battery voltage is gotten at the output of the H-bridge, this is sent to a transformer which transforms the 24V AC to 220V AC.

Indexed Terms- Inverter, Solar, Battery, MOSFET, Transformer.

I. INTRODUCTION

In Nigeria, the problem of power supply is not a new one, and this has hurt the economic growth of the country and had made it hard for businesses to thrive. Various reforms have been put in place to curtail this issue of lack of continuous power supply in the country but they have not yielded much results. As aforementioned, industries have found it hard to thrive in the country due to the power crisis and have been forced to relocate to more environmentally friendly locations for their businesses, which does not do much good to the country and its economy.

It is also noteworthy that no nation in the world can satisfy its electric power demand by generating power from only one source. To then meet up with the high demand for electric power supply and to achieve any set goals or growth to the economy, there is a need for multiple sources of power supply with a well-articulated electric power policy framework. This energy mix would mean a supplement of our easily available sources of energy (e.g. hydro energy, coal) with new ones that are proven to be efficient. The low power generation experienced in Nigeria since independence is mainly due to the fact that the nation concentrated all her efforts in generating electric power from only two sources namely hydro and natural gas. To make matters worse, the two energy sources have not been properly harnessed and managed. For Nigeria to overcome the challenge of low power generation, there is a need to supplement the hydro and gas sources of energy with other sources such as solar, biomass and wind, and based on Nigeria's technological level of development and the availability of the mineral, coal should contribute at least 20 percent of energy needed for electricity generation. Also, proper management of this energy mix can guarantee stable electric power supply in Nigeria. When considering energy sources that can be mixed to improve the nations power issue we have to take a look at solar energy. It has the potential to bring to an end Nigeria's recurring problem of energy generation. In fact, estimates suggest it could increase the availability of electricity to almost 80 million people who currently have none. It would also diversify the country's energy portfolio. Most of these assumptions are based on the fact that solar-based generation capacity can be built up far quicker than traditional power plants. It can also be built in chunks, starting small and adding on the capacity as time goes on. Solar can also be connected to a country's electricity grid or it can be run off the grid. This makes it the most practical option for improving access to electricity across Nigeria. It can also be used on its own, or as part of a hybrid mix with other technologies.

A solar energy system consists of the solar inverters, solar panels, batteries, charge controllers, protection components like circuit breakers and other necessary electrical components. Assembling of these components done properly can help harness energy from the sun and make it available for both industrial and domestic use.

Beginning in the late 1800s, attempts have been made to convert DC power to AC power. During this time, rotary converters or motor generator sets were used to achieve this goal until the mid-1900s. Vacuum tubes were first employed as switches in inverter circuits at the beginning of the 20th century (Bedford and Hoft, 2014).

In modern inverter circuits, the dc power is connected to a transformer primary through the center tap of the primary winding. A switch is rapidly switched back and forth to allow current to flow following two alternate paths through one end of the primary winding and then the other. The alternation of the direction of flow of current in the primary winding of the transformer produces an alternating current in the secondary winding. The electromechanical version of switching devices includes; two stationary contacts and spring support moving contact. The current in the electromagnet is interrupted by the action of the switch so that the switch continually switched rapidly back and forth, this electromagnetic inverter switch called vibrator or buzzer was used in vacuum automobile radios (Bedford and Hoft, 2014).

The newest inverter circuit have transistors, FETs, SCRs and other electronic switches incorporated in them because of their advantages over electromagnetic switches.

Olusegun , (2014) developed and designed a 50Hz-frequency, 1000 Watt (1 KVA), 220 Volt inverter. It should be noted that this project's efficiency is dependent on both the total power of the load connected to its output terminals and the power rating of the battery connected to the input. For a predetermined number of hours, the inverter could therefore provide continuous power. Given the inconsistent and unstable public power supply, the high cost of electric power generators in addition to their high maintenance costs, and other factors, it is determined that an inverter provides a more reliable and constant supplementary power source over an extended period of time. It is inexpensive, safe, and makes no noise. It is also a preferred power backup to a computer and other appliances because it switches automatically to the battery when the AC mains is not available. Consequently, there will be fewer system failures, hard drive damage, and data loss. Furthermore, the longevity of computers and other devices that are connected to a continuous or standby inverter is increased. Despite the fact that the project's goals have been met, the inverter cannot power any device with a higher power rating. Additionally, any variations in the AC input reach the inverter output when it is running off the mains supply (Olusegun, 2014)

O. Oladimeji, (2018) Developed a modified square wave inverter, the conversion is accomplished with two functional modules called the control stage and the power stage. It also has a topology for a single source and single load converter application that includes a power processor (the power stage) and a controller (the control stage). The converter, handles the power transfer from the input to output, or vice versa, and is constituted of power semiconductor devices acting as switches, plus passive devices (inductor and capacitor). The controller is responsible for operating the switches according to specific algorithms monitoring physical quantities (usually voltages and currents) measured at the system input or output. The inverter system is relatively affordable and reliable. It is easy to operate and provides a high level of power supply when there is power outage. Finally, it reduces the danger and noise associated with a generator when using it as an alternative source of power supply. This inverter cannot be used to power most of the sensitive medical devices etc (O. Oladimeji, 2018)

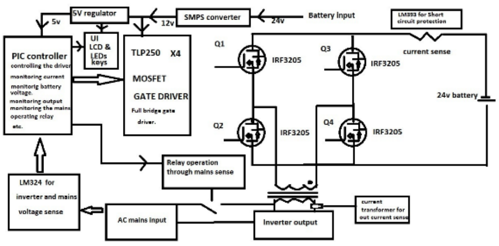
Babarinde, (2014) Designed and constructed a 50HZ, 240V 1kVA inverter which is primarily based on an inverter circuit which inverts the D.C. source voltage from a battery to A.C output voltage for AC powered appliances. The overall operation of this system comprises inter connections of many sub-circuits to give optimum performances. The sub circuit include; the oscillator circuit, PWM circuit, driver circuit, low battery/overload shutdown circuit, charging control/soft charging circuit, surge protection circuit, changeover/power supply circuit, and the output circuit (MOSFET and transformer section). This project incorporates monitoring circuit that employs visual display components such as light-emitting diodes and voltmeter to communicate the state of the system to the user.

The inverter was tested on a section by section basis. The output voltage of the oscillator was obtained to be 4.24volts on each side with frequency set to approximately 50Hz.The other unit could not be tested until the final coupling had been done. The battery overcharging protection unit, low battery cut off unit, low and high voltage surge protection as well as the time delay units, feedback unit and the overload and short circuit protection unit were all tested by varying the potentiometer associated with each of them and observing the response through the displays.

John. and Hassaine (2014) presented solar power generation system with two power conversion stages such as boost dc-dc conversion and buck dc-ac conversion. Transformerless solar power generation scheme is proposed which consists of solar PV array, boost dc-dc converter and full bridge inverter. In this system the output voltage of the PV array is boost by step up chopper and this boost dc voltage is inverted by using full bridge inverter which is buck dc-ac converter. The output voltage of the full bridge inverter is not pure sinusoidal but it is a square wave ac voltage. Therefore, it needs L and C filter for converting the square wave ac voltage into pure sine wave voltage and it consists of more power electronics components due to two power conversion stages, which results in larger size, higher cost and more switching losses.

II. METHODOLOGY

Components Used: Battery, and inverter which comprises of transistor, capacitor, resistor, MOSFET and power diodes.



Block Diagram of 3500VA Pure Sine Wave Inverters

Battery

Without the battery, the system could only power when the sun is shining. The power would interrupt each time the cloud passes, the system would become very frustrating. The solar battery provided constant electricity and the load discharges 80% of its charge. The batteries are the heart of the system and were available in different voltages and various amp-hour ratings depending on the requirement of the system. The battery voltage was kept at above 50% state of charge for maximum battery life. Should the battery is contain wet cells then it would be good to keep the battery's electrolyte level to the indicated level and never let the plates be exposed above the electrolyte. Only distilled water could be used to refill the batteries, over watering dilutes the acid excessively and electrolytes would be expelled when charging. For this study, the required power is 3500W. Therefore, the battery capacity was estimated as follows

$$\text{Battery Capacity Ah} = \frac{\text{Total Watt} - \text{hour required} \times \text{Days of autonomy}}{0.85 \times 0.6 \times \text{nominal battery voltage}}$$

$$= \frac{3500 \times 2}{0.85 \times 0.6 \times 24} = 571.89\text{Ah}$$

Inverter

The inverter design starts with fabricating a step-up transformer. A step-up transformer is a type of transformer use for increasing voltage supply to a circuit. The step up transformer consists of two coils called the primary and secondary coils, wounded round a soft iron core that was made of sheets of soft iron. The secondary coil of this type of transformer is however greater than the number of turns in the primary coil. The primary winding of this step-up transformer is 24V-DV-24V and the secondary winding is a bifilar winding of 240V. The alternating current which entered into each end of the primary winding induced an alternating current at 50Hz in the secondary winding of the transformer and the alternating current voltage is stepped up by the transformer causing it to become 240V. The output voltage of the secondary winding is transferred to the socket outlet of the output of the inverter system (Yahaya, Zhimwang , Ibrahim, Shaka,and Frank (2022).

Output power of the Transformer:

Output power = $V_S I_S \text{Cos}\theta$ Watt

(1)

Where Vs = Secondary voltage of the transformer,

Is = Secondary current of the transformer and Cosθ = Power factor

But Ps = IsVs

(2)

Ps = 2000VA and Vs = 220V using (2) Is = 9.1A.

Using (1) Cosθ =0.9

From (1) power factor = 1802 watts.

From (2) the output power rating (VA) in terms of the power factor is

$$\text{Output power VA} = \frac{\text{Output power (Watt)}}{\text{Cos}\theta}$$

$$= 2002\text{VA} = 2.002 \times 10^{-3}\text{MVA}$$

Inverter Components and Configuration

A. Power Semiconductors: Inverters utilize power transistors or insulated gate bipolar transistors (IGBTs) as switches to control the flow of DC through the inverter circuit.
B. Oscillator Circuit: An oscillator generates a high-frequency signal that determines the switching frequency of the power semiconductors, contributing to the creation of the AC waveform.

 By supplying a constant 12Volt DC through a voltage regulator to the IC SG 3524 PWM, the frequency of the oscillating signal was determined using a 10KΩ variable resistor connected in series with another 56KΩ resistor and both connected in parallel with 0.22µF to form the RC time constant network.

 Frequency, $f = \frac{1}{1.1 \times C_T R_T}$ where

 Time Capacitor (C_T) = 0.22µF

 Fixed Resistor (R_T) = 56KΩ

 Variable Resistor (V_R) = 10KΩ

 Time Resistor (R_T) = 56KΩ + 10KΩ = 66KΩ

 Therefore, $f = \frac{1}{1.1 * 0.22 * 10^6 * 66 * 10^6}$

 $f = 62.6$Hz

C. Control Logic: Inverters often include control logic to manage the switching sequence of the power semiconductors, ensuring proper synchronization and regulation of the AC output.
D. Resistor: A resistor is a passive two-terminal electrical component that is used to reduce Current flow, adjust signal levels, to divide voltages, bias active elements, among other uses. High power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators. Resistors can be connected in series (to increase Resistance), parallel (to decrease resistance) or the combination of both. The ability of a resistor to oppose the flow of current is called resistance, and it is measured in Ohms.
E. Diode: This is a two-terminal electronic component that conducts current primarily in one Direction. It has low (ideally zero) resistance in one direction, and high (ideally infinite) resistance in the other. This unidirectional behavior is called rectification and is used to convert AC to DC.
F. Capacitor: This is an electronic component that stores electric charge. It is made up of two Parallel plates separated by a dielectric. The two conductive plates act like electrodes and the dielectric acts like an insulator. The ability of a capacitor to Store electric charge is called capacitance, and it is measured in Farads. Capacitance can also be seen as the ratio of electric charge on each conductor to the potential difference between them. Capacitors are used for blocking DC and allow AC to pass through. Capacitors can be used as a filter [3]. Capacitors are of various types namely:
G. Inductor: An inductor is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it. It is made up of a coil of insulated wire wound around a core material, such as iron or ferrite. The inductor's ability to store energy in the magnetic field when current flows through it is called inductance, and it is measured in units of Henry. The core material used in the inductor plays a crucial role in its performance. Iron and ferrite are commonly used because they increase the strength of the magnetic field and thus, the inductance of the inductor. Other materials, such as air or powdered iron, may also be used as the core. Inductors have the property of blocking AC (alternating current) while allowing DC (direct current) to pass through. This is because the inductance opposes changes in current flow, which results in an impedance to AC signals. As a result, inductors are often used as filters to separate signals of different frequencies.
H. Transistors: A transistor is a three-terminal semiconductor device that can be used to amplify or switch electronic signals and electrical power [4]. By applying a voltage or current to one pair of its terminals, the current

flowing through another pair of terminals can be controlled. Transistors are the fundamental building blocks of electronic devices and are used as electrically controlled switches to turn current on or off in a circuit and for signal amplification. There are different types of transistors, including Bipolar Junction Transistors (BJT) and Field Effect Transistors (FETs). BJT has three terminals known as the base, collector, and emitter. The BJT can be further classified as PNP or NPN. FETs have three terminals known as the gate, source, and drain. They are also classified as N-channel or P-channel. MOSFETs and IGFETs are two other types of FETs.

I. Integrated Circuit (IC): An Integrated Circuit (IC) is a collection of electronic circuits fabricated on a small piece, or chip, of semiconductor material, typically silicon. The IC comprises thousands or millions of tiny resistors, capacitors, diodes, and transistors that are integrated onto a single semiconductor wafer [5]. The IC can be used for various applications such as amplification, oscillation, timing, counting, microprocessors, and microcontrollers, among others.

J. Transformer: A transformer is a crucial component responsible for voltage regulation. A transformer consists of a primary winding, a secondary winding, and an iron ferrite core [6]. The transformer does not generate power; rather, it transfers or transforms the available power from one circuit to another. Ideally, the power input is equal to the power output, but in the real world, some power loss occurs. The transformer operates on the principle of electromagnetic induction. When an alternating current flow through the primary winding, it induces a magnetic flux in the iron ferrite core, which is then transferred to the secondary winding, thereby causing current to flow out of the device [6].

K. MOSFET: A metal–oxide–semiconductor field-effect transistor (MOSFET, MOS-FET, or MOS FET) is a field-effect transistor (FET with an insulated gate) where the voltage determines the conductivity of the device. It is used for switching or amplifying signals. The ability to change conductivity with the amount of applied voltage can be used for amplifying or switching electronic signals [9]. Their primary use is to control conductivity, or how much electricity can flow, between its source and drain terminals based on the amount of voltage applied to its gate terminal

III. RESULTS

Measurement and testing of an inverter and solar cell

Measurements	Expected Values	Achieved Values
V_{OUTPUT} for Solar Cell	100V	100V
P_{OUTPUT} for Solar Cell	150W	150W
V_{OUTPUT} for inverter	220V	220V
I_{OUTPUT} for inverter	10A	9.8A
P_{OUTPUT} for inverter	3.5KVA	3.42kva
Frequency	50Hz	50Hz

IV. DISCUSSION

The table above presents the measurement and testing of the inverter and solar cell. The AC Output voltage from the inverter is 220V with sine wave and the frequency is 50Hz. It was observed that 7.8 % of the total output power was lost during the testing and measurements which resulted from components used. As shown in table, the output voltage (V_{OUT}) for both expected and achieved values of the solar cell is 100V, the output current (I_{OUTPUT})for the inverter is 10A for expected value and 9.7A for the achieved value

CONCLUSION

Design and construction of 3.5kva solar power inverter system was carried out with the solar panels installed free from trees/building shade and aligned to receive maximum sun rays at 450 North-East. The panels were then connected to the charging controller and the circuit was wired to the battery. The output current (I_{OUTPUT}) for the inverter is 10A for expected value and 9.7A for the achieved value. The final system was successfully built and tested, and it was found to meet the design requirements. The project also provided valuable insights into the challenges involved in building an inverter system and the various considerations that need to be considered during the design and implementation stages.

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