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Development of Cost-Effective Inverter for Homes and Offices

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Abstract:
There are lots of imported inverters in the Nigerian markets which are reliable, but the costs of importing foreign inverters is very high for the average Nigerian and have problems associated with performance and maintenance spare parts. Hence, the need for cost effective transformer voltage source conversion inverter using locally available materials. A cost-effective transformer voltage source conversion that has a high efficiency as well as compact in size was designed and developed. The techniques for the design and construction of the low-cost automatic inverter system capable of converting 12V DC to 220V AC, 50 – 60 Hz with a power handling capacity of 650-volt ampere or Watts (VA or W) is presented with emphasis on the step-up transformer specification. The major modules of the inverter system consist of a driver and switching circuit; an automatic battery charger circuit; a battery voltage level indicator circuit; and a capacitive inductive filter. The proliferation of the gadget, apart from enhancing the local market, offers an instrument with readily available spare parts which can be repaired and maintained by our local technicians.

Keywords: Electricity, Inverter, Cost, Effective, Local, Spare parts, Maintenance

INTRODUCTION

During the past three decades, researchers have shifted their quest for abundant energy from fossil fuel sources and focused their concentration on renewable energy and actively looking for cost effective solutions to this problem. Solar energy is the one of the potential sources which is preferred over other renewable sources due to availability, ingenuousness, lower maintenance and reliability. Photovoltaic (PV) arrays drastically reduce energy expenditure and dependability on other non-renewable energy sources. It can provide a worthy, cost-effective solution for consumers requiring large amount of power. Inverter is an inevitable component of PV module. There are lots of inverters available in the markets which are reliable, but the cost of these inverters is high because of the micro-controller based SPWM generator. Average Nigerians find it difficult to afford these inverters. Again, many of the peoples are using inverter-less PV module with Direct current (DC) Light-emitting diode (LED) light. The brightness of LED is not enough to eradicate darkness. (Haque *et al.*, 2017).

An inverter can be taken as a crude form of Uninterrupted Power Supply (UPS). Obviously, the main use of an inverter is only for powering common electrical appliances like lights and fans during a power failure or the transmission of DC Solar power to Alternating Current (AC) for conventional use. As the name suggests "inverter" the basic function of an inverter is to invert an input direct voltage (12V DC) into a much larger magnitude of alternating voltage (generally 110VAC or 220VAC).

The following fundamental elements of an inverter and its operating principle are as follows:

1. **Oscillator:** An oscillator converts the input DC (Direct Current) from a lead acid battery into an oscillating current or a square wave which is fed to the secondary winding of a power transformer.
2. **Transformer:** Here, the applied oscillating voltage is stepped up as per the ratio of the windings of the transformer and an AC much higher than the input DC source becomes available at the primary winding or the output of the inverter.
3. **Charger:** During power backups when the battery gets discharged to a considerable level, the charger section is used to charge the battery once the AC mains are restored.

Despite its primary function, the roles of inverters have begun to expand as most has a display unit for monitoring the system as well as ease of diagnoses to help improve stability and efficiency. Some inverters are embedded with a build-in charge controller. Others have a smart circuitry feature for low battery indicator, temperature, overload and short circuit detection system. Inverters are of different types and can also be classified based on their output wave form. The three common types of inverters are the micro, string and central inverter which can come in any form as square, modified sine wave and pure or full sine wave. Generally, pure sine wave inverters remain the most preferred choice though most expensive over others because of its numerous benefits; its current is same as that of the grid; hence it guarantees the safety of motor, inductive device (microwave), and every sensitive electronic device. It eliminates the irritating audible electrical humming sound from fans, fluorescent lights, audio amplifiers, and televisions.

An Inverter system could be applied in our homes, offices, industries and remote areas. It could also find its applications on Recreational Vehicles (RV) marines, portable devices and emergency backups. A great deal of research has been done to improve the efficiency of inverters. Though the market is flooded with varieties of the inverters, they are very costly and some of them are very complicated to use while some are not efficient. The primary goal of this work is to develop an efficient cost-effective inverter that can store conventional electricity in the battery or convert solar direct current (DC) power to alternating current (AC), which every average person can use in their homes. In this research, only the essential switching and amplifying components to minimize the cost and losses are used.

OBJECTIVE

The main objective of this project is

1. To design a cost-effective inverter for homes and offices use in Nigeria.
2. To produce an inverter capable of converting 12v dc to 220v ac; using locally available materials.

STATEMENT OF THE PROBLEM

Incessant power failure is endemic to the power supply system in Nigeria today causing disruptions in almost all spheres of life including research institutions, in particular. Most experiments in our university laboratories and research institutes are not finalized and concluded due to the epileptic nature of our public power supply system. To curb power shortage problems occasioned by the Nigeria erratic power supply, energy is stored in power inverters and utilized during power outage. Also, there are lots of imported inverters in the markets which are reliable, but the costs of importing foreign inverters is so high and have problems associated with performance. Also, maintenance of imported inverters requires highly skilled personnel as they are mainly square wave and modified sine wave inverters. Hence, the need for cost effective transformer voltage source conversion inverter using locally available materials. A method of generating pure sine wave with Pulse Width Modulation (PWM) can be implemented in order to enhance efficient performance and lower costs.

LITERATURE REVIEW

Many engineers, technologist, and scientist have designed and tested several inverters of various capacities for different purposes used to convert DC to variable AC. This variation can be in the magnitude of voltage, number of phases, frequency or phase difference. Omitola, *et al.,* (2014), designed and constructed a 1000Watts (1KW) 220 Volts Inverter at a frequency of 50Hz. This device is constructed with locally sourced components and materials of regulated standards. The basic principle of its operation is a simple conversion of 12V DC from a battery using integrated circuits and semiconductors at a frequency of 50Hz, to a 220V AC across the windings of a transformer. An additional power supply to the public power supply with the same power output is thus provided at an affordable price. Musa and Galadanci (2009), designed and simulated 5 kVA power inverter base on two topologies; Boost converter and Half-bridge inverter topology. A 555 timer IC was used as the control at fixed frequencies of 25 kHz and 50 Hz for the two stages. The results of the simulation were obtained. The graphs for both stages were plotted and the results show a significant increase in the voltage and duty cycle. The wave form of the output gives a square wave form. Hamid *et al.* (2020) designed and simulated a single-phase inverter using sinusoidal pulse width modulation (SPWM) unipolar technique. The circuit has been designed and simulated using the Matlab/Simulink program. Metal Oxide Semiconductor Field Effect Transistor (MOSFET) was used as a switch. The project aims were to use Matlab/Simulink program to design, analyze and control switching for inverter circuits. Single-phase inverter circuits are divided into three main divisions which are the inverter part that consists of the MOSFET switch, the control circuit which generates switching pulses generated through the microcontroller and filter parts that contain inductors, capacitors and resistors to reduce harmonic. The results of the experiment show the output of the sine wave with the output voltage of 230 V and 50 Hz.

Also, Muttalib *et al.,* (2012), designed and simulated an inverter with high frequency sinusoidal PWM switching technique for harmonic reduction in a standalone/ utility grid synchronized photovoltaic system Inverters are one of the major parts of any Photovoltaic Systems which are intended to feed power to any isolated standalone ac loads or to synchronize with the utility power grid systems. Akhikpemelo *et al.,* (2016), developed an inverter circuit based on the operation of the IC CD4047. 12V AC is stepped up to 230V AC by using a step-up transformer. The assembled composite unit worked well. The oscilloscope measurement tallied with the set frequency of 50Hz and the square wave oscillator output. The inverter system is capable of providing power to the appropriate load for up to eight hours; depending on the state of the 12V batteries. Akpan and Ewetumo (2010), designed and constructed a low-cost automatic inverter system capable of converting 24Vdc to 220Vac 60Hz with a power handling capacity of 2 kVA have been presented with emphasis on the step-up transformer specification. The major modules of the inverter system consist of a driver and switching circuit; an automatic battery charger circuit; a battery voltage level indicator circuit; and a capacitive–inductive filter. Both solid-state and electromechanical relays were employed to provide automatic fast switching capabilities both in the presence or absence of public power supply (PPS) without voltage fluctuations supplied to the loads during the power switching process. Several experiments have been conducted with the automatic inverter system using different equipment with different power requirements. Analysis and results show that the designed and constructed inverter system has negligible output resistance with low power consumption and it is highly suitable for use in

Haque *et al.*, (2017), designed and implemented a 100 Watt, 220 and 50 Hz Voltage Cost Effective Inverter. The system was designed without any microcontroller and it has a cost-effective design architecture. The elementary purpose of this device was to transmute 12 V DC to 220 V AC. Snubber technologies was used to diminish the reverse potential, transients and excessive heat of transformer winding and transistor switches. Switching pulse generated by NE 555 timer circuit and comparator circuit was used to take signal strength input from its rear as well as from both sides for triggering the MOSFET switches. Another switch is used to invert pulse between two switching circuitries. A 5 volts regulator (IC: 7805) was used to supply fixed 5V for biasing the switching and amplifying circuitry. Rashid *et al.* (2017), designed and implemented a Low-Cost Solar Inverter for Home Uses and Agriculture System. Further, AL-Rawi (2019), designed and developed a low-cost transformer-less voltage source conversion that has a higher efficiency as well as compact in size. The complete design consists of DC-DC converter and a DC-AC inverter. The converter is dependent on switched capacitor techniques and steps 12Vdc to 240Vdc. The inverter is dependent on a full-bridge configuration which produces a 240Vac output from 240Vdc. To achieve the improvement in inverter efficiency and a reduction in cost, the power transformer and magnetic components such as inductors are eliminated. In addition, inverter voltage control techniques such as pulse width modulation (PWM) and switching of MOSFETs are optimized through digital control using ATtiny26L microcontroller unit.

The foregoing and other literature shows that lots of work have been done in the area of inverter development and simulation. The main purpose of this project is to design a solar inverter that will enable the inversion of a DC power source, supplied by Photovoltaic (PV) Cells, to an AC power source that will be either used to supply a load or connected directly to the utility grid. The benefit of this project is to give access to an everlasting and pollution free source of energy. It offers the user the option to use the system in two possible operating modes; the stand-alone mode which is used to satisfy his needs, and the grid connected mode which used to sell electricity to utility when in excess; thus, eliminating the need of battery storage. The local need to fashion a cost-effective inverter produced from available local materials in Nigeria informed this work. It is also crafted in readily available technologies for ease of production and maintenance.

MATERIALS AND METHOS

Figure 1 depicts the block diagram of the cost-effective inverter. The computer aided drawings of the assembly are shown in Figure 2. ICs, capacitors, variable resistors, transistors, transformer, relay and circuit board were selected in the design of this inverter. IC 4047 produces the oscillation. It performs the primary function of supplying square waves to the inverting section.

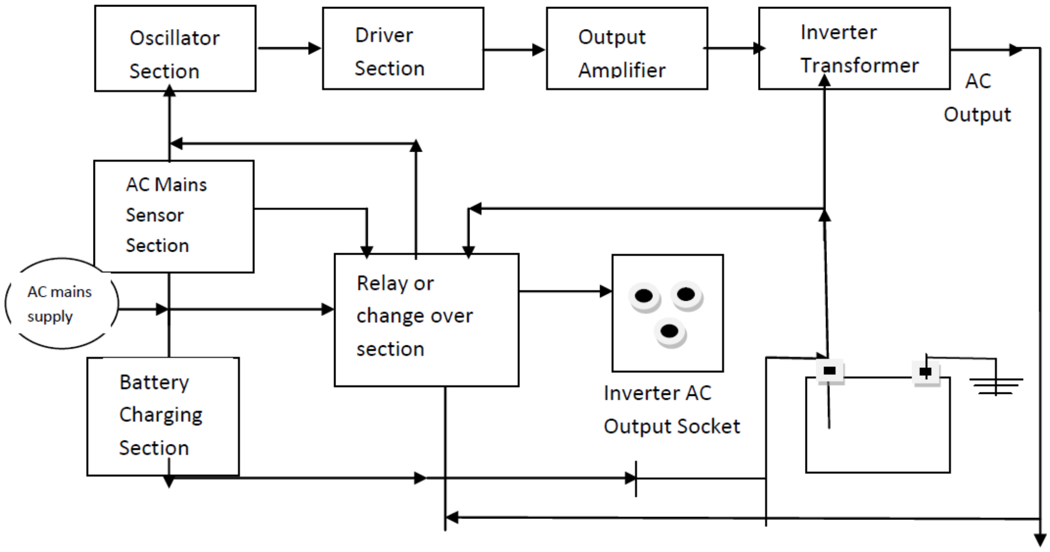

Figure 1: Block diagram of a low-cost inverter

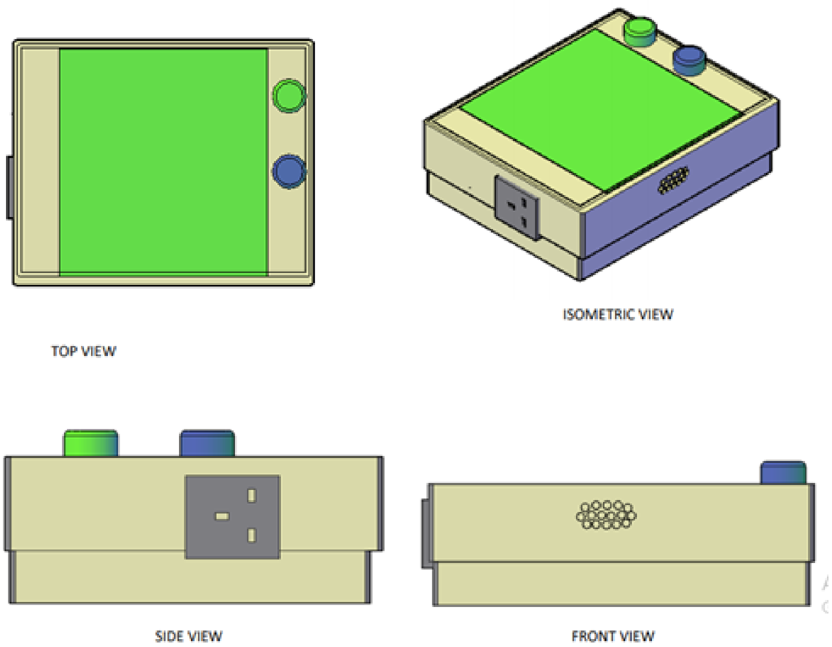

Figure 2: CAD diagram of a low-cost inverter

A voltage regulator is employed as buffers so that the circuit is not load dependent. In other words, absorb surge during the operation of the system. Variable resistor is used for the biasing of the IC to produce the required signal for the MUSFET multi vibrating state. Alternating voltage from the buffer stage is applied to the base of the current amplifier transistors which conduct in accordance with the applied alternating voltage and amplify it to the transformer. These output power transistors oscillate at a full swing, delivering the entire battery voltage into secondary winding of the transformer alternately. The secondary voltage is induced in the primary winding of the transformer and is stepped-up into a powerful 220 volts (AC). The voltage is used to power the output load. A 12V relay was incorporated for switching over from grid supply to inverter to power needed load. The components that were used to construct the inverter consist of, MOSFET and a center tap transformer. Few capacitors, resistors, and variable resistor port were also used. The design and development were done using locally sourced components. The basic principle of operation was based on an oscillator designed to produce an alternating EMF of known frequency of about 50 - 60HZ and wave form using IC 4047 whose frequency is set to 50Hz and 12V DC from a regulated DC power supply to produce a 220V AC at the output of a transformer. A 10W bulb was connected as load to the inverter. A digital multi meter reads 220V AC. Overall, the circuit performed.

RESULTS

The coupling and installation of the various components sourced from the electrical/ electronic market in Nnewi, Anambra State are shown in Plate 1 and Plate 2. The three circuit of the pure sine wave with Pulse Width Modulation (PWM) Cost effective inverter, are independent. The use of locally sourced materials is to enhance reproducibility and easy maintainability. The Inverter is therefore highly adaptable. Plate 3 is the picture of the Cost-effective Inverter while Plate 4 depicts the instrument during testing.

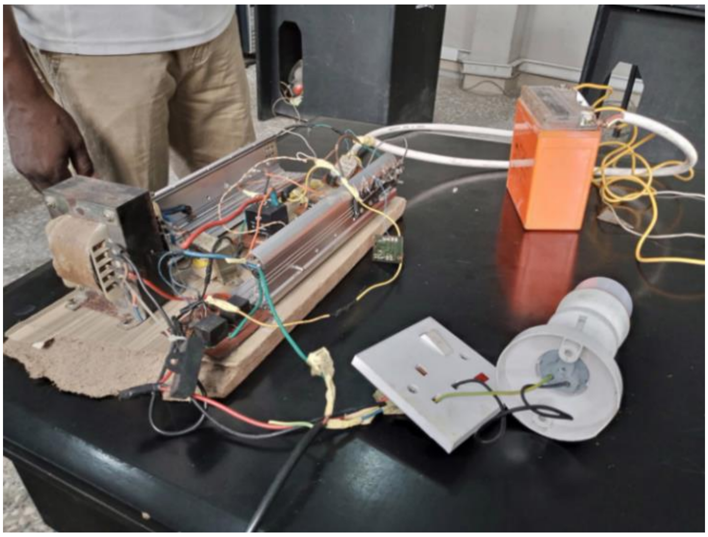

Plate 1: Picture showing skeletal assembly of the inverter on the circuit board.

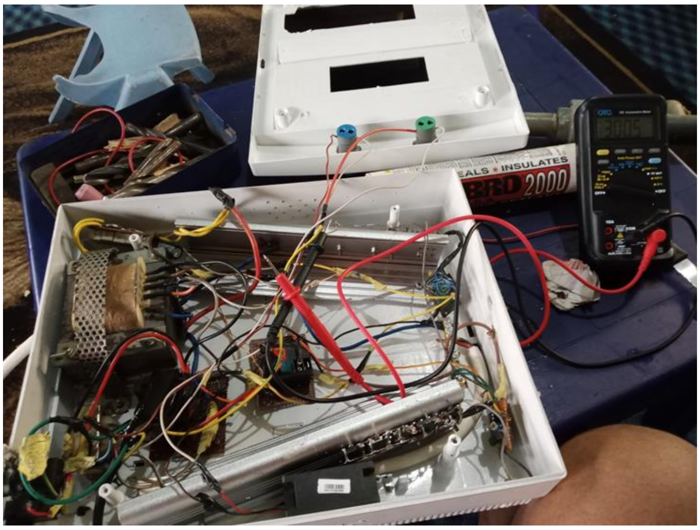

Plate 2: Picture showing the assembly being transferred to its casing

Plate 3: The completed Cost-effective inverter

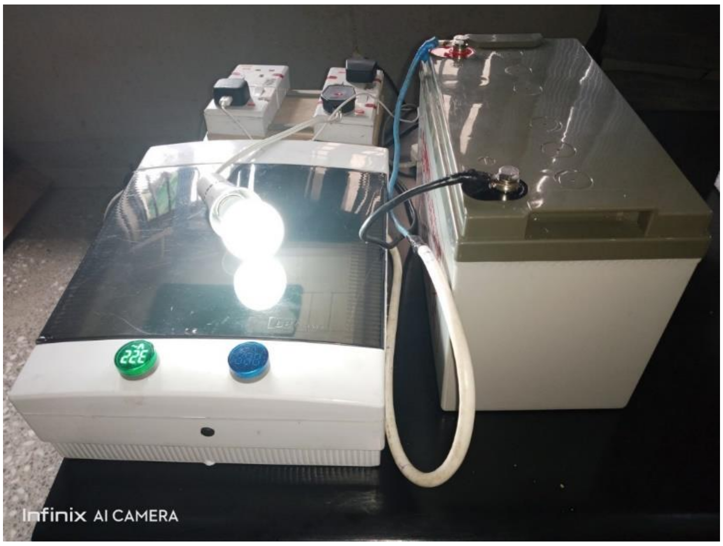

Plate 4: Completed Cost-effective inverter undergoing testing

CONCLUSION

The Department of Electrical/Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli Campus, Anambra State in collaboration with the National Board for Technology Incubation (NBTI), Federal Secretariat designed and produced a Cost-effective Inverter for home and office use in Nigeria. The components employed in design and building of the inverter were sourced locally from the Electrical/Electronics market in Nnewi, Anambra State. Testing and evaluation of the instrument shows: Overall Dimension: 110 mm x 350 mm x 285 mm while operational Efficiency is 87.6%. It is hoped that the work will enhance the local production of cost-effective inverters in Nigeria thereby saving much in foreign reserve.

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