DESIGN AND CONSTRUCTION OF 1kVA POWER INVERTER

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DEPARTMENT OF ELECTRICAL ELECTRONICS ENGINEERING
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A FINAL YEAR PROJECT SUBMITTED TO THE DEPARTMENT OF ELECTRICAL ELECTRONICS ENGINEERING

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IN PARTIAL FUFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. Eng) DEGREE ELECTRICAL ELECTRONICS ENGINEERING

15TH OCTOBER, 2020

DECLARATION

I, ACHILIHU DANIEL UCHENNA with matriculation number 15050200005, a student of Electrical and Electronics Engineering, College of Engineering, Gregory University Uturu hereby declare that apart from the relevant references used, this work titled: "Design and Construction of 1kVA power inverter" was performed by me in the department of Electrical Electronics Engineering, under the supervision of Dr. O.E.K ONWUNTA. The information derived from the literature has been properly acknowledged in the text and a list of references provided.

..…….……………………………… …………………

ACHILIHU DANIEL UCHENNA **DATE**

(Scholar)

CERTIFICATION

This is to certify that this project work: “Design and Construction of 1kVA power inverter” carried out by ACHILIHU DANIEL UCHENNA with Matriculation number 15050200005 has been examined and found acceptable for the award of Bachelor Degree in the Department of Electrical Electronic Engineering, Gregory University Uturu, Abia State, Nigeria.

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(Head of Department)

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(Dean of engineering)

………………………………………………..   …………………………

ENGR. PROF. OKAFOR E.N.C   **Date**

(External Examiner)

DEDICATION

I dedicate this report first and foremost to the Almighty God the giver of wisdom and the sustainer of life who has been there right from the beginning to this very point. Special dedication also to my ever supportive and tireless parents, for their relentless support, financial assistance and compassion towards me during the course of my five years of study and to many more success yet to come.

To God be the glory.

ACKNOWLEDGEMENT

My profound gratitude goes to the almighty God for His infinite mercy upon my life throughout the period of this project, I would like to give all glory and praise to Him for making this work a smooth and successful sail.

With a heart full of gratitude, I appreciate the efforts of my wonderful supervisor in the person of Dr. O.E.K ONWUNTA who absorbed me, taught and corrected me throughout the period of this project work. I am extremely thankful to him.

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Finally, my gratitude goes to my family for their moral and financial support, to my friends and relatives who in one way or the other have helped me during the period of this project.

My prayer is that the almighty God reward you all abundantly. Amen

ABSTRACT

Inverters are widely used in domestic as well as industrial environments to serve as a second line of source of power cut from electricity utility grids. The purpose of this project is to Design and Construct a 1kVA 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. The inverter involves four stages which include the transformation stage (implemented with a 1000VA transformer), oscillator stage (implemented with SG3524 Pulse-Width-Modulator (PWM) IC), driver stage (implemented with MOSFET IRFP 250N) which controls the switching, and a feedback stage that monitors the output voltage to ensure it does not fall below IEEE recommended value of ±2.5% the nominal value. The circuit incorporated supervisory circuits such as inversion mode, low battery detection, revised battery connections, etc. Indicators LED were incorporated to monitor the inverter. Open-circuit and load tests were carried out. The efficiency and output power were also estimated. A 100W lighting bulb was connected as load and inversion lasted for 7.8hours before shutdown.
Overall, the circuit performed satisfactorily thereby providing an additional power supply to the public power system with the same power output at an affordable price.

Keywords: Inverter, integrated circuits, semiconductors, transformer, power supply.

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INTRODUCTION

1.1 BACKGROUND OF STUDY

In this modern society, electricity has great control over most daily activities, for instance in domestic and industrial utilization of electric power for operations. Electricity can be generated from public supply to consumers in different ways including the use of water, wind or steam energy to drive the turbine as well as the use of gas (around 1785 where the British used natural gas produced from coal to light houses and streets). (APGA community, 1785). Also, solar energy and nuclear energy are also sources of electricity.

In the last years, new energy sources have been proposed and developed due to the dependency and constant increase in costs of fossil fuels, and these fossil fuels have a huge negative impact on the environment. It is estimated that the electrical energy generation from renewable energy sources will increase from 19% in 2010, to 32% in 2030, leading to a consequent reduction of CO_2 emission. In rural areas particularly in the developing world, where most of the population of up to 80% is located, more than 1 billion people lack the essential energy services to satisfy the most basic needs and to improve their social and economic status. (Nazmul K. & co. 2015).

In Nigeria, there is an inconsistent supply of electricity by the power supplying company to the consumers thereby resulting in people buying generators for their own daily activities. The growing energy demand in Nigeria led us to utilize these renewable energy resources. In recent years, the efforts to spread the use of renewable energy resources instead of pollutant fossil fuels and other forms have increased. To utilize these renewable energy resources, an inverter is essential which converts direct current (DC) power to alternating current (AC) power as most of the renewable energy is found in DC form (Nazmul et al., 2015).

These alternative and renewable energy sources could also be used as an emergency backup power. Due to today's dependence on electricity and because of frequent power outage, backup power is becoming a necessity. Emergency backup power system can provide electrical power to critical loads or the whole house during power outages. These systems may include lighting and other apparatus, to provide backup resources in a crisis or when regular systems fail. They find uses in a variety of setting from residential homes to hospitals, scientific laboratories and computerized systems. Emergency power systems can rely on generators or uninterruptible power supplies. All types of electronic devices require power supply from electric power for their operations. This source can be either generator or a battery. In our society today, the need for steady power supply must be over emphasized, because the provision of goods and services could be completely cut off without adequate power supply.

This project deals more on DC to AC power inverters aimed at transforming a DC power source into an AC output of considerably higher voltage compared to the input. Inverters are used for many applications as in situations where low voltage DC sources such as batteries, solar panels or fuel cells must be converted, so that devices can run off on AC power. Power electronic solutions such as inverters which convert direct current (obtainable from renewable energy sources: solar and wind) to alternating current for domestic, commercial, industrial use are gaining increasing attention. (Akpan, 2012).

1.2 PROBLEM STATEMENT

The government is often unable, or unwilling, to direct its attention to the issue of power supply because the country is not yet economically or technologically matured enough to support a quality power system. Also, as a result of continuous power failure and fluctuation in power supply by Power Holding Company of Nigeria (PHCN), sensitive appliances and systems in offices, homes, industries, etc. are affected by interrupted power supply and this experience resulted in the introduction of backup system such as inverter.

There are many choices in the application of inverters in the market today. These ranges from the very expensive to the least expensive with varying degrees of quality, efficiency and power output capabilities. High quality which possesses high efficiency exists although they are usually at a more expensive monetary cost.

The target of this project is to provide a reliable power supply of 1kVA to serve as backup for powering domestic appliances in the event of power outages and energy crisis.

1.3 AIM OF STUDY

The aim of this project is to design and construct a 1kVA inverter with frequency of 50Hz that can collect an input DC voltage from a battery of 12V and convert it to 220V AC output which can be used to power AC appliances rated at 1kVA.

1.4 OBJECTIVES OF STUDY

- To review relevant literatures.
- To employ simple design principles (on simulation software) and analyze various theories in the design of an effective and reliable inverter of 1kVA capacity using locally sourced materials in the construction.
- To test the implemented project before connection and execute the project in a casing and load it AC loads.
- To build an inverter that is capable of serving as an alternative source of power supply for domestic consumption in the cause of power failures and energy crisis.
- For larger scale power production, the study can be incorporated with solar energy to provide energy to very distant and rural communities particularly in our part of the world where these alternative sources of energy are abundant.
- Also, this study involves producing a noiseless source of electricity generation with low maintenance cost which is capable of reducing carbon discharges and subsequently reduce global warming

particularly in a period when poor climate change has become a threat to human survival and life in general to all living creatures and hence even increasing concern to control it.

1.5 SIGNIFICANCE OF THE STUDY

The design and construction of a 1kVA inverter will be of great benefits in the following ways:

- The key importance of this study is to use low DC source to give out a high output AC power with the aid of low power switching devices.
- Also, the DC/AC inverter is one of the most efficient mobile power sources. Like in science laboratories, the inverter will be the "heart" of power supply as it offers another source of power apart from the grid and generators.

1.6 SCOPE OF THE STUDY

The main function of this project is to convert battery's Direct Current (DC) into pure sine wave Alternating current (AC) to provide backup during power outages. This work is said to be covered under;

- The design of the inverter circuit: a sketch is made indicating the diagram of construction for easy understanding and representations.
- The selection of the components: all the components needed were carefully selected with their ratings considered and they include: Resistors, Capacitors, Diodes, Transformer, Transistors, MOFSET and SG3524 PWM IC. etc.
- Transferring the design to printed circuit board (PCB) software: The design from the paper diagram will be implemented using simulation software.
- Construction: To understand the construction of a 1kVA inverter, the following construction samples can be discussed:
  - ✓ Carryout the assembling according to the circuit diagram.
  - ✓ Place the power transistors into the accurately pierced aluminum heat sinks.
  - ✓ A mica isolated kit is used to fix transistors in the aluminum heat sink, evading short circuiting and direct contact of transistors from ground and to each other.

- ✓ Fasten the heat sink to the bottom of a properly ventilated gauge metal enclosed space.
- ✓ Fasten the power transformer next to the aluminum sinks using bolts.
- ✓ The suitable points of the assembled circuit board and power transformers on the aluminum sinks, connecting the power transistor's productions to the windings of the transformer.

- Testing: A meticulous testing is conducted before packing. This project is set to be achieved using hardware and software components.
  - ✓ The hardware part consists of several components like resistors, transistors, capacitors, transformers. Etc.
  - ✓ The software part of it is achieved using computer aided package such as AutoCAD, Livewire and PCB wizard.

1.7 LIMITATION OF THE STUDY

The limitation of the project therefore includes:

- The device is rated 1kVA that means any load more than the rated wattage should not be applied.
- The inverter cannot be operated on three-phase machines, domestic appliances with voltages higher than 220V/240V, and devices with frequency higher than 50Hz.
- The inverter tends to draw much current from the battery during on-load conditions resulting in a quick fall of the accumulator strength and so, can operate appliances with currents of 65Ah, 1000VA and below.

1.8 ORGANIZATION OF CHAPTERS

This work is organized in such a way that every reader of this work understands how inverters are being made. There are five chapters in all and they are;

- Chapter 1- this chapter explains the background of the project, the aim and objectives, the problem statement, scope and limitation and various components used.
- Chapter 2- this chapter talks on the literature review which entails history of inverters, different ways of generating electricity and reviews of related projects and so on.

- Chapter 3- this chapter explains the materials and methods used in the design of the inverter and the mathematical calculations of the various inverter units.
- Chapter 4- this chapter expatiates on the testing, results and discussion of the implemented project.
- Chapter 5- this chapter summarizes the whole work, draws a conclusion and states various problems encountered in the course of the work and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 REVIEW OF RELATED LITERATURE

Technological advancement brought us into new era when the whole world is now a global village, electronic components and appliances are not left behind. Since the need for generating electricity through "inverters" increases, there are various designs which have been carried out in the past to achieve this aim, so before we proceed, let us have a little introduction on what an inverter is. An inverter is an electrical device that converts DC power to AC power, and the resulting AC can be at a required voltage and frequency with the use of transformer, switching devices and control circuits. (Theraja, 2005). It can produce uninterrupted 220V AC supply to the load connected to its output socket. It provides constant AC supply at its output socket, even when the AC mains supply is not available.

The input of the inverter may come from a DC source or from rectified AC input. There are two main categories for switch mode voltage source inverters: square wave (Abolarinwa et al., 2010) and pulse width modulated (PWM) (Babarinde, 2010). The difference comes from how each switch gets turned on. Square wave inverters are the simplest to implement. The simplicity of the square wave inverter comes along with the disadvantage of harmonics close to the fundamental frequency. PWM inverters function by comparing a sinusoidal control signal at the desired output frequency with a triangular carrier signal at switching frequency. The harmonics of PWM inverters are located at multiples of the carrier signal frequency which is typically in the kHz range. This simply means the output waveform of PWM appears more sinusoidal than a square wave inverter. Also, higher frequency harmonics are easier to filter than harmonics near the fundamental frequency. The pulse width inverters can be broadly classified as analog bridge and digital bridge PWM inverters. The advantage of analog based PWM inverter controller is that, the level of inverter output voltage can be adjusted in a continuous range and the throughput delay is negligible. The disadvantages of analog based PWM inverters are as follows: Analog component output characteristics changes with the temperature and time. They are also prone to external disturbances. Analog controller circuitry is complex and bulky. They are non-programmable, hence not flexible. On the other hand, Microcontroller based PWM inverter controller (Digital bridge PWM inverter) makes the controller free from disturbances and drift, but the performance is not very high due to its speed limitation. (Prasad et al., 2009).

The inverter device has 2 modes of operation; charging mode (rectification) and discharging mode (inversion). The complete circuit is a combination of inverter circuit, charger circuit and a battery. The charger circuit keeps the battery charged by rectifying the AC to DC when the mains supply is available and when the mains AC fails, the inverter circuit takes the DC power stored in the battery and converts it into 220V/50Hz AC supply, which can be used to power any common electronic equipment or computer systems. (Omitola et al., 2014). It performs the reverse role of rectifier where the AC power is converted into DC power and functions by chopping DC voltage through various means.

Most of the electrical equipment works with the 220V AC supply but internally, their circuitry work on the DC supply. Hence the external AC supply is converted into DC supply by the power supply unit on this equipment. (Omitola et al., 2014). Any device that works on DC supply can be used during the mains power breakdown by connecting them to batteries, but batteries have a fixed life. Also, running power consuming equipment using the battery could be very expensive. Hence, rechargeable batteries can be used in this type of situation to reduce the cost. An inverter is used to power a device that does not have the facility to connect to a DC power source or a device that requires AC power source for its operation.

The use of semiconductor power devices such as bipolar transistors, thyristors for voltage amplification, particularly the MOSFET as the power switches, makes the inverter a better additional power supply. The inverter is less noisy, provides complete automatic switchover function, possesses no environmental threats, less bulky and less expensive to maintain. (Brown, 2002).

2.2 HISTORICAL DEVELOPMENT OF AN INVERTER

From the nineteenth century through the middle of the twentieth century, DC to AC power conversion was accomplished using rotary converters or motor generator sets (MG sets). In the early twentieth century, vacuum and gas filled tubes began to be used as switches in inverter circuits. As at then, the most widely used type of tube was the Thermatron.

The origin of electromechanical inverters explains the source of the inverter. Early AC to DC converters used an induction or synchronous AC motor directly connected to the generator (dynamo) so that the generator's commutator reverses its connections at exactly the right moments to produce DC. A later development was the synchronous converter, in which the motor and generator windings are combined into one armature, with slip rings at one end and a commutator at the other and only one field frame, the result which is either an AC -in or DC-out with an MG set. The DC can be considered to be separately generated from the AC, with a synchronous converter, in a certain sense it can be considered to be "mechanically rectified AC" given the right auxiliary and control equipment, an MG set or rotary converter can be "run backwards" converting a DC to an AC, hence an inverter is an inverted converter.

David (1925), in his article which contained nearly all-important elements required by modern inverters and is the earliest of such publication was the first to use the term "invert" in open literature. Prince explained that an inverter is used to convert direct current into single or poly phase alternating current. The article explains how the author took the rectifier circuit and inverted it, turning in direct current at one end and drawing out alternating current at the other.

Anlin and Ranganath (2010) in their work, presented a Peripheral Interface Controller (PIC microcontroller) based Pulse Width Modulation (PWM) inverter controlled Four Switch Three Phase Inverter (FSTPI) fed induction Motor drive. The advantage of these 4 switched inverters over the conventional 6 switches is its lesser switching loss, lower electromagnetic interface (EMI), less complexity of control algorithms and reduced interface circuits. The implementation of their work showed the practical application of the FSTPI.

According to Pankaj et al. (2012) in their work on carrier-based Sine Pure Wave Modulation (SPWM) or sinusoidal pulse width modulation theorized that SPWM is widely used in power electronics to digitize the power so that a sequence of voltage pulses can be generated by the on and off power switches. The pulse width modulation inverter has been the main choice in power electronic for decades, because of its circuit simplicity and rugged control scheme. SPWM switching technique is commonly used in industrial applications; the techniques are characterized by constant amplitude pulses with different duty cycle for each period. The width of these pulses is modulated to obtain the inverter output voltage control and to reduce its harmonic content. According to them, SPWM is the mostly used method in motor control and inverter application. In this development a unipolar and bipolar SPWM voltage modulation type is selected because this method offers the advantage of effectively doubling the switching frequency of the inverter voltage, thus making the output filter smaller, cheaper and easier to implement.

Conventionally, to generate this signal, triangle wave as a carrier signal is compared with the sinusoidal wave, whose frequency is the desired frequency. In their journal, single-phase inverters and their operating principles were analyzed in detail. The concept of Pulse Width Modulation (PWM) for inverters is described with analyses extended to different kinds of PWM strategies. In their paper, a single phase SPWM microcontroller-based 300VA inverter was designed and tested for a fixed modulation index of 0.6 and unipolar voltage switching and was reported to have given different results of currents and voltages for different resistive loads. They also found that it gave a maximum efficiency for 80W load up to 89%.

Vinodini et al. (2013) in their work design and analysis of digital PWM controller for DC-DC power converter which is aimed at using simple digital current mode control techniques for DC-DC converters. In their proposed current mode control method, the inductor current is sampled only once in a switching period. A compensating ramp was used in their modulator to determine the switching instant analytically from the steady state condition. The trajectory of inductor current during the switching period was not estimated in this method. It effectively increases the maximum switching period of the converter when a particular controller is used to implement the control algorithm. It was showed that the digital method is versatile enough to implement the control algorithm any one average, peak and valley current mode by adjustment of the sampling instant of the inductor with respect to turn-on instant of the switch. Their digital current mode control algorithm was tested on a 12-V input and 1.5-V, 7A output buck converter which was switched at 100 kHz. The simulation result of their buck converter switched at 100 kHz proved the validity of proposed digital current mode control and also shows the stability condition.

Metua (2014) in his project designed and implemented a single-phase inverter which can convert DC voltage to AC voltage at high efficiency and low cost. A low voltage DC source is inverted into a high voltage AC source in a two-step process. First the DC voltage is stepped up using a boost converter to a much higher voltage. This high voltage DC source is then transformed into an AC signal using Pulse Width Modulation. Another method involves first transforming the DC source to AC at low voltage levels and then stepping up the AC signal using a transformer. A transformer however is less efficient and adds to the overall size and cost of a system.

His work was concluded to have achieved a satisfactory output waveform with the frequency at 50Hz, sine pulses with modulation circuit much simplified by the use of PIC16F877A microcontroller and the high flexibility of the programming made it easier to alter the switching pulses without further changes on the hardware.

Olusegun et al. (2014) in their project designed and constructed a 1KVA power inverter. Their device was 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. This gave an additional power supply to the public power supply with the same voltage output and thus at an affordable price.

Their work in view of the inconsistence and unreliable public power and high cost of electric power generators coupled with the high cost of maintenance was found to offer a better constant additional power supply for a sustainable duration. It is noiseless, harmless and cost effective. 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, thus reduces system breakdown, prevents hard disk damages and data loss. In addition, the lifespan of the computer and other devices connected to either a standby or a continuous inverter is prolonged.

2.3 DEFINITION OF POWER INVERTER

A power inverter, or inverter, is an electrical device or circuitry that converts DC power to AC power, and the resulting AC can be at a required voltage and frequency with the use of transformer, switching devices and control circuits (Theraja, 2005). It can produce uninterrupted 220V AC supply to the load connected to its output socket. It provides constant AC supply at its output socket, even when the AC mains supply is not available.

The input voltage, output voltage and frequency, and overall power handling depend on the design of the specified device or circuitry. The inverter does not produce any power; the power is provided by the DC source. The inverter convert the DC voltage produced from the energy stored in the batteries into AC voltage. The inverter could also charge the batteries by using sources from the mains or generator connected to the inverter when they are available.

2.3.1 SIMPLE SCHEMATIC DIAGRAM OF A POWER INVERTER

Generally, inverter is a combination of a battery, a charger circuit and an inverting circuit as shown in the Figure 2.1 below;

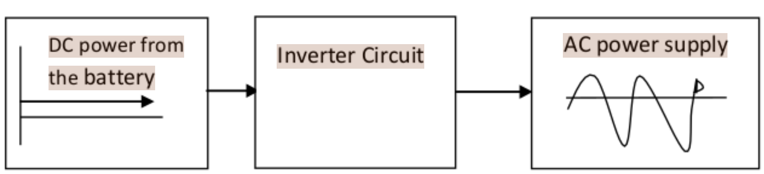

Fig 2.1 Simple schematic diagram of an Inverter

2.3.2 CLASSIFICATIONS OF INVERTER

Inverter can be classified into many types based on the output, source, type of load etc. Below is the complete classification of the inverter circuits.

(I) According to the output characteristics

- Sine wave (sometimes referred to as a “true” or “pure” sine wave) inverter,
- Modified sine wave (actually a modified square wave) inverter,
- Square wave inverter.

- **Sine wave Inverter**

A sine wave is what we get from our local utility company and (usually) from a generator. This is because it is generated by rotating AC machinery and sine waves are a natural product of rotating AC machinery. The major advantage of a sine wave inverter is that all of the equipment which is sold on the market is designed for a sine wave. This guarantees that the equipment will work to its full specifications. Some appliances, such as motors and microwave ovens will only produce full output with sine wave power. A few appliances, such as bread makers, light dimmers and some battery chargers require a sine wave to work at all. Sine wave inverters are always more expensive from 2 to 3 times as much. (Ravi Kansagara, 2018).

- **Modified sine wave inverter**

A modified sine wave inverter actually has a waveform more like a square wave, but with an extra step or so. A modified sine wave inverter will work fine with most equipment, although the efficiency or power will be reduced with some.

Motors, such as refrigerator motor, pumps, fans, etc. will use more power from the inverter due to lower efficiency. Most motors will use about 20% more power. This is because a fair percentage of a modified sine wave has higher frequencies, so the motors cannot use it. Some fluorescent lights will not operate quite as bright, and some may buzz or make annoying humming noises.

Appliances with electronic timers and/or digital clocks will often not operate correctly because the modified sine wave is noisier and rougher than a pure sine wave, clocks and timers may run faster or not work at all. Items such as bread makers and light dimmers may not work at all, in many cases appliances that use electronic temperature controls will not control. The most common is on such things as variable speed drills which only have two speeds – on and off. (Ravi Kansagara, 2018).

- **Square wave Inverter**

Very few but the cheapest inverters are square wave. A square wave inverter will run simple things like tools with universal motors without a problem, but not much else because if we supply square wave to sine wave based appliance, it may get damaged or losses are very high. Square wave inverters are seldom seen any more. (Ravi Kansagara, 2018).

(II) According to the source of inverter

- Current source inverter.
- Voltage source inverter.

- **Current source inverter**

  In current source inverter, the input is a current source. The CSI uses inductive energy storage- that is, they use inductors in their DC link to store DC energy and regulate current ripple between the converter and the inverter. Also, the CSI typically make use of gate turn-off thyristors(GTOs) or symmetrical gate commutated thyristors (SGCTs), which are semi-conductor switches that are turned on and off, creating a pulse width modulated (PWM) output with regulated frequency as it power switching device. This type of inverters is used in the medium voltage industrial application, where high-quality current waveforms are compulsory. But current source inverters are not popular. (Ravi Kansagara, 2018).

- **Voltage source inverter**

  In voltage source inverter, the input is a voltage source. The VSI uses capacitive storage with capacitors in their DC link, which both stores and smooths the DC voltage for the inverter. Also, the VSI commonly make use of insulated gate bi-polar transistors (IGBTs), which create a PWM voltage output with regulated frequency and voltage. This type of inverter is used in all applications because it is more efficient and higher reliability and faster dynamic response. Voltage source inverter is capable of running motors without de-rating. (Ravi Kansagara, 2018).

(III) According to the type of load

- Single phase inverter (half bridge inverter and full bridge inverter).
- Three-phase inverter (180-degree mode and 120-degree mode).

- **Single phase inverter (half bridge inverter and full bridge inverter).**

  Generally, residential and commercial load uses single phase power. The single-phase inverter is used for this type of application. It is divided into single phase half-bridge and single phase full-bridge inverter. (Ravi Kansagara, 2018).

- **Three-phase inverter (180-degree mode and 120-degree mode).**

  In case of industrial load, three phase ac supply is used and for this, we have to use a three phase inverter. In this type of inverter, six thyristors and six diodes are used. It can operate in two modes according to the degree of gate pulses; 180-degree mode and 120-degree mode.

  (Ravi Kansagara, 2018).

(IV) According to the PWM control Technique

- Simple Pulse Width Modulation (SPWM).
- Multiple Pulse Width Modulation (MPWM).
- Sinusoidal Pulse Width Modulation (SPWM).

- Modified Sinusoidal Pulse Width Modulation (MSPWM).

- **Simple Pulse Width Modulation (SPWM).**

  For every half cycle, the only pulse is available in this control technique. The reference signal is square wave signal and the carrier signal is triangular wave signal. The gate pulse for the switches is generated by comparing the reference signal and carrier signal. The frequency of output voltage is controlled by the frequency of the reference signal.

  (Ravi Kansagara, 2018).

- **Multiple Pulse Width Modulation (MPWM).**

  The drawback of single pulse width modulation technique is solved by multiple PWM. In this technique, instead of one pulse, several pulses are used in each half cycle of the output voltage. The gate is generated by comparing the reference signal and carrier signal. The output frequency is controlled by controlling the frequency of the carrier signal. The modulation index is used to control the output voltage.

  (Ravi Kansagara, 2018).

- **Sinusoidal Pulse Width Modulation (SPWM).**

  This control technique is widely used in industrial applications. In above both methods, the reference signal is a square wave signal. But in this method, the reference signal is a sine wave signal. The gate pulse for the switches is generated by comparing the sine wave reference signal with the triangular carrier wave. The width of each pulse varies with variation of amplitude of the sine wave. The frequency of output waveform is the same as the frequency of the reference signal. The output voltage is a sine wave and the RMS voltage can be controlled by modulation index.

  (Ravi Kansagara, 2018).

- **Modified Sinusoidal Pulse Width Modulation (MSPWM).**

  Due to the characteristics of sine wave, the pulse width of the wave cannot be changed with variation in the modulation index in SPWM technique. That is the reason, MSPWM technique is introduced. In this technique, the carrier signal is applied during the first and last 60-degree interval of each half cycle. In this way, its harmonic characteristics are improved. The main advantage of this technique is increased fundamental component, reduced number of switching power devices and decreased switching loss. (Ravi Kansagara, 2018).

(V) According to the number of output level

- Regular Two-Level Inverter.
- Multi-Level Inverter.

- **Regular Two-Level Inverter.**

  These inverters have only voltage levels at the output which are positive peak voltage and negative peak voltage. Sometimes, having a zero-voltage level is also known as a two-level inverter.

  (Ravi Kansagara, 2018).

- **Multi-Level Inverter.**

  These inverters can have multiple voltage levels at the output. The multi-level inverter is divided into four parts; flying capacitor inverter, diode- clamped inverter, hybrid inverter, cascade H-type inverter. (Ravi Kansagara, 2018).

2.4 INVERTER SPECIFICATIONS

The various features of the proposed inverter are: 1000VA, SINGLE PHASE 220-240V AC, 50Hz, 12V DC and VOLTAGE SOURCE INVERTER.

2.5 INVERTER SECTIONS

The inverter sections are: Power unit, Transformer circuit, Power MOSFET circuit, Oscillator (Multi-vibrator) circuit, Regulator and sensor circuit and indicators.

CHAPTER THREE

MATERIALS AND RESEARCH METHODOLOGY

3.1 PROJECT METHODS

The methods and processes involved in the design and construction of the 1kVA power inverter are highlighted below:

i. The review of relevant literature to power inverters has been carried out in the previous chapter.

ii. Designing of the project using a computer aided package and appropriate selection of components based on their specifications to achieve the required output.

iii. Constructions are made based on the specified design.

iv. Test will be carried out to ascertain if the constructed work matches the expected design.

3.2 MAJOR COMPONENTS INVOLVED

The major components for the design and construction of 1kVA power inverter are as follows:

3.2.1 BATTERIES

This is a device used to store the converted DC from the mains for use by the inverter and other DC devices. The battery is a two-terminal device that provides DC supply to the inverter section when the AC mains is not available. This DC is then converted into 220V AC supply output at the inverter output socket. The backup time provided by the inverter depends on the battery type and its current capacity. Therefore, the battery used was a 12V 65Ah lead-acid type which is commonly used in automobiles because they provide good quality power for a long duration and can be recharged once the power stored in them are consumed. The sample of battery used for this project is shown below:

Fig. 3.1 A 12V 65Ah Battery

3.2.2 CHARGE CONTROLLER

When the inverter section receives AC supply, it stops operation but the charger section in the inverter starts its operation. This circuit charges and discharges the battery when there is AC supply and when the AC supply is not available respectively. The charge controller or charge regulator is basically a voltage regulator used to keep batteries from overcharging. It regulates the voltage coming from the mains and going to the battery. If there is no regulation, the batteries will be damaged from overcharging. The battery used in this design needs around 13 to 13.5 volts to get fully charged.

3.2.3 THE AC MAINS SUPPLY

The AC input supplies a 220V AC, 50Hz from the public supply. This is connected to the charger circuit where it is stepped down and rectified to DC voltage and through the relay switch to the output of the inverter to bypass the inverter when there is public electric power supply while the battery is charging.

3.2.4 THE AC MAINS SENSOR

This inverter uses a 0 - 18V/1A triggering transformer and a regulator to sense the AC mains supply. When the AC supply is available, this supply is given to the primary winding of the triggering transformer to give 18V AC supply at the secondary winding. It is then rectified by bridge rectifier and input to the filter capacitor which converts the 26V DC supply to 12V DC supply. The 12V supply stays constant even when there is a change in the AC mains because of the regulation and the inverter is informed about the availability of the AC mains whenever there is.

3.2.5 THE OSCILLATOR

This section uses a pulse width modulator PMW IC SG3524 to generate the 50Hz frequency required to generate AC supply by the inverter. The IC SG3524 PWM functions as oscillator to generate the oscillating signal that controls the switching ON and OFF of the gate of an 8 -numbered MOSFETS connected in parallel to a center-tapped transformer. This switches the 12V DC from the battery, across the windings of the transformer to produce a 220V AC at 50Hz frequency for the use of computers and other domestic appliances with maximum power rating of 1000VA.

The relationship between the frequency, resistance and capacitance is given as:

$$\text{Frequency, } f = \frac{1}{1.1 \times C_T R_F}$$

Where: C_T = Timer Capacitor

R_F = Fixed resistor

The battery supply is connected to the IC SG 3524 through the inverter ON/OFF switch. The flip-flop converts the incoming signal into signals with changing polarity such that in a two-signal with changing polarity, the first is positive while the second is negative and vice versa. This process is repeated 50times per second to give an alternating signal with 50Hz frequency at the output of SG3524. This alternating signal is known as "MOS Drive Signal ". The sample of oscillator used for this project is shown below;

Fig. 3.2 A SG3524 PWM IC

3.2.6 THE DRIVER AND THE OUTPUT AMPLIFIER

The MOS drive signals are given to the base of MOS driver transistor which results in the MOS drive signal getting separated into two different channels. The transistors amplify the 50Hz MOS drive signal at their base to a sufficient level and output them from the emitter.

The 50Hz signal from the emitter of each of the transistor is connected to the gate G of all the IRFP 250N MOSFETS in each of the MOSFET channel, through the appropriate resistor. The sample of MOSFET used for this project is shown below:

Fig. 3.3 An IRFP 250N Metal-Oxide Semiconductor Field Effect Transistor (MOSFET)

3.2.7 THE INVERTER TRANSFORMER

The transformer is an electrical device that transfers energy from one circuit to another by electromagnetic induction, either to step up or to step down AC or DC voltage. The one used for this project is a 12V-0-12V DC at the primary winding and 220V AC at the secondary winding and has a center-tapping which divides the primary voltage of 12V into two equal sections. This center-tapping is connected to the positive terminal of the battery. The sample of transformer used for this project is shown below:

Fig. 3.4 A 12V-0-12V DC, 220V AC step up Transformer

Two ends of the primary are connected to the negative terminal of the battery through switches S1 and S2. These switches S1 and S2 are turned ON/OFF alternately to generate current in the primary coil. When the switch S1 is closed and S2 is opened, the current flows in the first part of the primary winding and the EMF is induced in the secondary winding. When the switch S2 is closed and S1 is opened, the current flows in the second part of the primary winding and the EMF of opposite polarity is induced in the secondary winding. Thus, if the switches S1 and S2 are alternately opened and closed at constant rate, then the output from the secondary winding is a square wave of the frequency at which the switches S1 and S2 are opened and closed. In the circuit of Figure 3.5 the transformer is said to be connected in "push-pull-mode" and this mode refers to a type of DC-to-DC converter that uses a transformer to change the voltage of a DC power supply. The distinguishing feature of a push-pull converter is that the transformer primary is supplied with current from the input line by pairs of transistors in a symmetrical push-pull circuit. The transistors are alternately switched on and off, periodically reversing the current in the transformer as stated above. (Saturno, 2018)

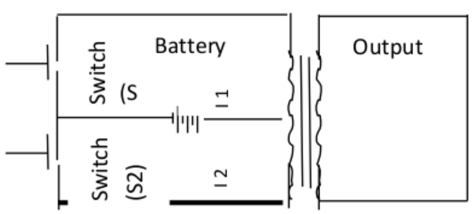

Fig. 3.5 Basic circuit of an inverter transformer

3.2.8 THE CHANGE OVER

This section is used to switch ON the inverter when the AC mains supply is OFF and to switch OFF the inverter when the AC mains supply returns (ON). During changeover, when the inverter receives AC mains supply, it stops drawing the battery supply and the AC mains supply at the inverter input is directly sent to the inverter output socket. This is done using a two-pole 12V 30A relay. The sample of relay used for this project is shown below:

Fig. 3.6 A two-pole 12V Relay

3.2.9 INVERTER AC OUTPUT

The AC output gives a 220V AC, 50Hz either directly from the input when the AC supply is available or from the inverter circuit action on the battery when the AC supply is not available. A 100W lighting bulb was connected to this circuit for confirmation of output voltage.

3.2.10 PROTECTIONS

The AC input to this device was fused with a 5A 250V fuse to protect the transformer as well as the rectifying circuit in case of short circuit current flow into the transformer. The sample of fuse used for this project is shown below:

Fig. 3.7 A 5A Fuse

3.2.11 INDICATORS

Four indicators are connected to the front of the inverter: the first is a blue indicator to show that the inverter is on AC supply, and the connected battery is charging; the second is a green LED to show that the inverter is using battery as supply; the third is a yellow LED to show that the battery is low and needs charging and lastly the red LED shows that the battery connection is revised and should be connected properly to avoid damage. The various sample of indicators used for this project is shown below:

Fig. 3.8 LED indicators

3.2.12 SWITCH

A 16/32A 250VAC switch is connected to the front of the inverter. This red switch controls the AC voltage input and output of the inverter. The sample of switch used for this project is shown below;

Fig. 3.9 A 16/32A 250VAC Switch

3.3 OTHER COMPONENTS/TOOLS USED IN THE DESIGN

For this project to be complete there is a need to know the other components or tools used in the design. In electronics, the power system is designed in such a way that the equipment always has power so that it can function effectively. These components include:

- Integrated Circuit (IC) SG 3524 PWM
- Bipolar Transistor
- Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

- Relay Switch
- Rectifier
- Capacitors
- Diodes, Light-Emitting Diodes (LEDs), Zener diode
- Resistors
- Circuit Breaker
- Pair of pliers
- Soldering iron
- Multi-meter
- Side cutter
- Connecting cables
- Dc fan
- Wires (cables) Etc.

3.4 BLOCK DIAGRAM OF A POWER INVERTER

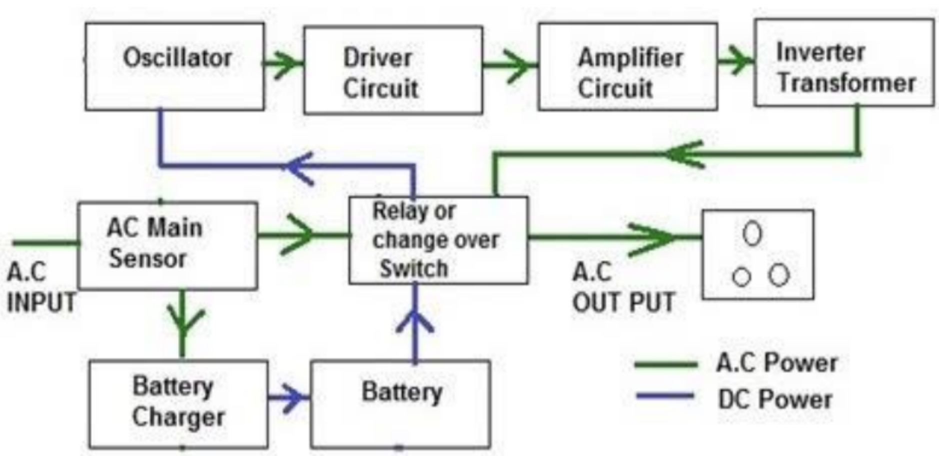

Fig 3.10 Basic Block Diagram of an Inverter

From Figure 3.10 above, energy is gotten from the mains/generator. The source is connected into the inverter where, the output of the charge controller goes to the battery. If the inverter is connected to mains/generator, it supplies directly to the load while the remaining energy is fed to the battery. The battery tends to supply the load if the energy gotten from the mains/generator is no more available. The inverter also has an inbuilt AC charger controller which controls the charging of the battery through the mains/generator.

Also, the inverter circuit uses IC SG3524 PWM whose function is to generate the oscillating signal that controls the switching ON and OFF of the gate of an 8-numbered MOSFETS connected in parallel to a center-tapped transformer. This switches the 12V DC from the battery, across the windings of the transformer to produce a 220V AC at 50Hz frequency for the use of computers and other domestic appliances with maximum power rating of 1000 VA.

3.5 DESIGN TECHNIQUES (CALCULATION AND CONSTRUCTION METHODS FOR THE INVERTER).

This section deals with the actual calculation/computations used to obtain parameters required for the design. All components used in the construction were sourced locally through careful component selection such as equivalent component utilization for components not readily available.

- Power rating: 1kVA
- Frequency: 50Hz
- Number of Phases: Single
- Input Voltage: 12V DC(Inverter), 220V AC(Mains)
- Output Voltage: 220V AC
- Circuit Supervisory Indicators: Low battery Charge, Inversion, Mains supply.
- Energy sources: Deep cycle rechargeable battery

3.5.1 BUILDING OF TRANSFORMER

The step by step approach taken in the construction of this project started with the building of the transformer from the laminating core, followed by the rectification stage, sensing and monitoring stage, comparator and transistor switching. The tools and instruments used include: bobbin, winding machine, stamping, transformer clamp, lead and soldering iron, lead sucker, copper stripping, knife, cutter, razor blade, plier, digital multi-meter, Vero and bread board. Etc.

The transformer design involves the core, and coil design. The transformer is a single phase step up transformer of 1kVA, 12V-0-12V, at the primary winding and 220V at the secondary winding, air cooled, frequency 50Hz.Taking the magnetic flux density to be 1.4T, constant of proportionality (K) = 1.0, current density J = 3.0A/mm^2 and window factor Kw = 0.35

- **Design of Core:**

(a) Voltage per turn, $E_t = K\sqrt{S}$ kVA

Where S = Output kVA (1.0kVA)

Choosing K=1, for shell type single phase

E_t = 1.00Volts per turn

(b) Net Core Area, $A_i = \frac{E_t}{4.44 f B_m}$

Where, E_t = 1.00V/N, f = 50Hz, Bm = 1.4,

$$Ai = 3.217 \times 10^{-3}\ mm^2$$

(c) Magnetic Flux, $\phi = B_m A_i$

$$\Phi = 4.50\times 10^{-3}\ Wb.$$

(d) Window space factor, K_w

$K_w = 0.1 + 0.07\log_{10}\frac{kVA}{0.1} - 0.2\log_{10}KV$

$K_w = 0.314$

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(e) Window Area, A_w

$S = 2.22fB_m A_i A_w K_w J \times 10^{-3}$

$$A_w = \frac{S}{2.22 f B_m A_i K_w J \times 10^{-3}}$$

Current density $J = 3A/mm^2$,

$Aw = 2123.5mm^2$

Window Length is given by:

$A_w = L \times W$, where $L = 3W$,

$W = \sqrt{\frac{A_w}{3}} = 26.6mm^2$, $L = 3(26.6) = 79.8mm$

$A_i = 0.9A_g$ (stacking factor = 0.9)

$A_g = \frac{3217}{0.9} = 3574.4mm^2$

Ag (gross core cross sectional area)

$$\text{Stack height} = \frac{A_g}{width\ of\ central\ limb}$$

$$= \frac{3574.4}{54}$$

$$= 66.2mm^2$$

(f) Lamination pieces, (n) = $\frac{Stack\ height}{Lamination\ thickness}$

For a thickness of 0.5, n = 132 laminations

3.1.2 Design of Coil

(a) Number of turns:

Primary turns $N_1 = \frac{V_1}{E_t} = \frac{12}{1.00} = 12$ turns

Secondary turns $N_2 = \frac{V_2}{E_t} = \frac{220}{1.00} = 220$ turns

15

Since the winding is wound twice on the primary side for both halves of the switching period, the total primary winding will be $N_1 = 2 \times 12$turns = 24turns

Total number of turns = 24 +220 = 244 turns

(b) Winding calculations:

Primary Current = $\frac{kVA}{input\ voltage} = \frac{1000}{12}$ = 83.33Amps

Secondary Current = $\frac{1000}{220}$ = 4.54Amps

(c) Conductor size:

Conductor cross sectional area A = $\frac{I}{J}$

For the primary winding $A_1 = \frac{83.33}{3} = 27.78mm^2$

$d_1 = \sqrt{\frac{4A_i}{\pi}} = \sqrt{\frac{4 \times 27.78}{\pi}} = 5.95mm^2$

For the secondary winding $A_2 = \frac{4.54}{3} = 1.51mm^2$

$d_2 = \sqrt{\frac{4A_i}{\pi}} = \sqrt{\frac{4 \times 1.51}{\pi}} = 1.39mm^2$

53

(d) Winding height:

The height occupied by the winding coils is approximately 5% less than window length

= 0.95L

= 0.95 ×66.2 = 62.89mm

(e) Turns/layer = $\frac{winding\ height}{Diameter\ of\ conductor}$

For primary = $\frac{62.89}{5.95}$ = 11turns/layer

For secondary = $\frac{62.89}{1.39}$ = 45turns/layer

Total number of layers = $\frac{number\ of\ turns}{turns\ per\ layer}$

Number of layers in primary = $\frac{24}{11}$ = 2 Layers

Number of layers in secondary = $\frac{220}{45}$ = 5 Layers

(f) Mean Length of Turn = 2 x (width of central limb + stack height+ window width)

= 2(26.6+26.6+66.2+26.6)

= 292mm

(g) Total Length of Winding T_L = mean Length of turns × total number of turns

For primary turns, L_1= 292 × 24

= 7008mm

For secondary turns, L_2 = 292 × 220

= 64240mm

Total length = L_1+ L_2 = 7008 + 64240

=71248mm

3.5.2 DETERMINATION OF THE OSCILLATING FREQUENCY

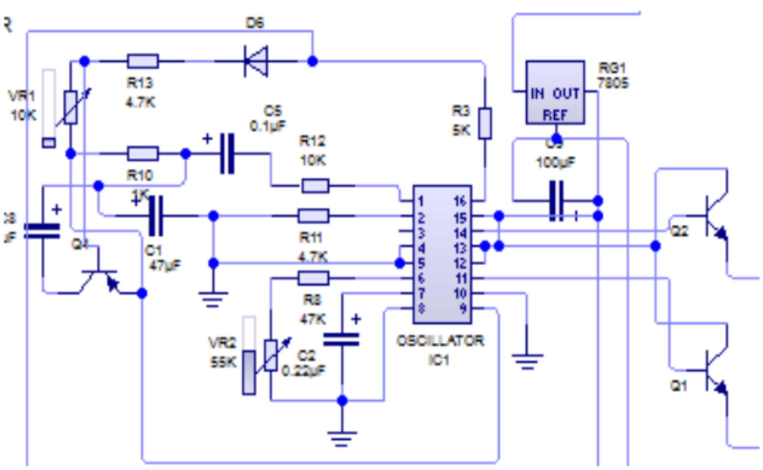

Fig. 3.11 Oscillator Section

To generate the required frequency 50Hz, an oscillator is used (a stable multi-vibrator IC **SG3524,** a dedicated pulse width modulator). The oscillator circuit is shown in Fig. 3.11. It is also known as "free-running relaxation oscillator" and it has no stable state, but two half-stable states between which it keeps oscillating continuously on its own without any external excitation (Abolarinwa and Gana, 2010). This versatile PWM controller can be used in a variety of isolated and non-isolated switching power supplies such as inverters.

By supplying a constant 12Volt DC through a voltage regulator to the IC SG3524 PWM, the frequency of the oscillating signal was determined using VR_1, comprising a 10kΩ variable resistor, connected with a 56kΩ resistor and both connected in parallel with a capacitor (0.22µF) to form the RC time constant network.

- **Calculation of Component Values**:

(i) Chosen values: Frequency of Oscillation = 50Hz, and Timer Capacitor (C_2) = 0.22µF

(ii) Input voltage V_{in} for the pulse width modulator is taken from the battery source (12V DC)

(iii) The chip is powered with a 5V positive voltage regulator IC 7805.

(iv) Pin 16 is connected to an internal +5V regulator and it was used to set the voltage reference of 2.5V for the pulse-width control through voltage divider resistors to pin 1. R_3 (5k) and R_{13} (4.7k) were used as the closest available values and connected to form a voltage divider, C_1 (47µF) was connected for stability.

(v) C_2 and R_8 were used for compensation to cancel a pole at frequency f = 200Hz, as recommended by the data sheet for stability. C_2 is chosen as 0.22µF and R_8 is given as;

$$R_8 = \frac{2.2}{f \times C2}$$

$$= \frac{2.2}{200 \times 0.22\mu} = 50000\ \Omega$$

Hence R_8 = 50,000Ω. A value of 47kΩ was used as the closest available standard.

(vi) A voltage divider comprising of resistors VR_2 (fixed resistor) and VR_1 (variable resistor) aids manual pulse-width variation through compensation pin 9.

(vii) Diode D_6 (1N4004) was connected to prevent VR_1 and R_{13} from affecting compensation by R_8, C_2.

It should be noted that the variable resistor was varied until the frequency of the signal was 50Hz.

3.5.3 DETERMINATION OF THE TRANSISTOR (MOSFET) SWITCHING CURRENT

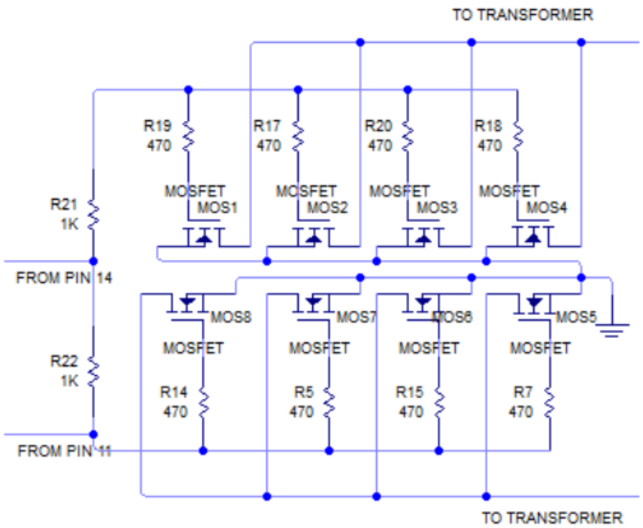

Fig. 3.12 MOSFET Section

The MOSFET stage is shown in Fig 3.12 above. It conducts the load current through the centre-tapped, step up transformer.

(i) MOSFET used in this design is IRFP 250 N-Channel in the power switching circuit due to high switching speed and the specifications from the datasheet are given below:

- Type designator: IRFP250N
- Type of transistor: MOSFET
- Type of control channel: N- Channel
- Maximum power dissipation (P_D): 214W
- Maximum Drain- source voltage (V_{DS}): 200V
- Maximum Gate- source voltage (V_{GS}): 20V
- Drain current at 25°C: When V_{GS} =10V then I_D = 30A

- Drain current at 100°C: When V_{GS} =10V then I_D = 21A
- Total Gate charge (Q_G): 123nC
- Maximum Drain-Source On State Resistance (R_{DS}): 0.075Ω
- Package: TO247AC

(ii) Fixed resistors of 1kΩ were connected between the gate and source to aid fast switching by discharging any residual charge at the gate.

(iii) A total of 8 MOSFETs were used for the design of the MOSFET driver. Four for each half of the full period.

3.5.3 SUPERVISORY SECTION

- **LED limiting resistors**

The key to maximizing a LED life is limiting the current that runs through it. This is frequently done with a simple resistor whose value is calculated using Ohm's Law. (Mark Dobrosielski, 2018)

The formula is given by:

$$R = \frac{Vbatt - Vled}{Iled}$$

Where; V_{BATT} = 5V

V_{LED} for green and red LED = 2.5V

I_{LED} = 20mA

Therefore, $\frac{5-2.5}{0.02A}$

$$= \frac{2.5}{0.02}$$

$$= 125\ \Omega$$

A 100Ω resistor was used in this design.

- **Low Battery Indicator/Shutdown**

The battery status monitor circuit is designed to give a visual indication using a LED for low battery condition during operation. The circuit consists of a comparator and a voltage reference set by a Zener diode and a passive delay circuit. It compares the battery charge coupled to it by variable resistor. The reference voltage is determined by the Zener diode, rating is:

Power rating = 300mW,

Breakdown voltage = 6.2V.

Thus $I = \frac{300 \times 10-3}{6.2} = 48.3mA$,

$2R_{24} = \frac{V}{I} = \frac{6.2}{48.3 \times 10-3} = 128\Omega$,

A value of 120Ω is chosen as the closest standard value.

- **Voltage Detection/Changeover Unit**

An automatic changeover switch was designed for this work. A 220V operating relay was connected to serve as mains voltage detector and switchover. When mains power is interrupted, this activates the relay switch contact to changeover the supply from mains to inverter mode supply. The action reverses when mains power is restored, thus providing automatic changeover action.

The circuit uses a half wave rectifier circuit. The MOSFET bank drain-to-source diode was used for the rectification, and has the same specification as the MOSFET. Since this is a PWM system, calculations for the value of the output filter capacitor will be done at the chosen frequency since the ripple voltage will be greatest at this frequency. Since capacitor values are determined by the output current, a capacitor of 250V, 2200µF rating was used in the design, as a higher value is preferable for better ripple rejection.

3.6 THE PRINCIPLE OF OPERATION

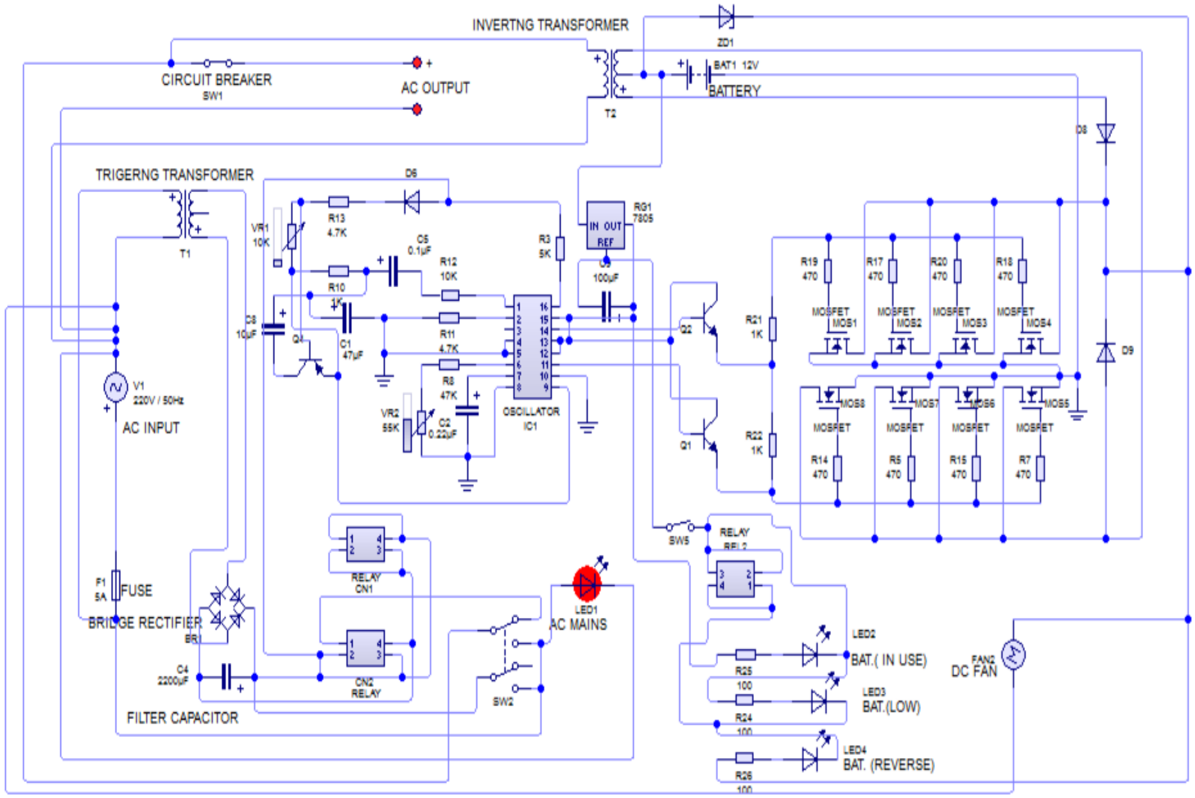

Fig. 3.13 Complete circuit diagram of a 12V PWM inverter

When the AC mains supply is available, this supply is given to the primary winding of the triggering transformer to give 18V AC supply at the secondary winding. It is then rectified by bridge rectifier and input to filter capacitors which convert the 18V supply to 26V DC supply. This is connected through the relay switch and to the output of the inverter to bypass the inverter when there is public electric power supply while the battery is charging.

When the AC mains supply is not available, the inversion process of converting the energy stored in the battery to AC takes off. Here, the IC_1 (SG3524) which is the pulse-width modulator IC functions to generate the 50Hz alternating pulses from pin 14 and 11, needed to drive the MOSFET banks (M_1 to M_4) and (M_5 to M_8).

The MOSFET banks (M_1 to M_4) and (M_5 to M_8) make up the power drivers. The alternating pulse output from IC_1 is fed to the MOSFETS banks which switches the DC voltage at the primary of centre-tapped transformer T_2, which is serving as the step-up transformer to create the alternating voltage effect and flux change needed for transformation by the transformer. The transformer then would step up the now converted 12V DC to 220V AC.

The supervisory stage comprises of the low battery detection and switch/change over.
The changeover switch is the relay. The coil of the relay serves as the mains voltage detector, as it energizes when there is supply. The relay controls the load (output) to supply whenever mains is restored. IC_1 is instantly shutdown by cutting off power to it by relay SW2 switching contact. LED1 comes on to indicate mains while LED2 indicates inversion.

The next supervisory circuit is the low battery charge detector. There is a comparator (LM358) that detects the low battery charge by comparing a sampled DC charge voltage set by zener diode. When the low voltage limit is reached, the comparator output goes positive and LED3 comes on, to indicate low battery charge.

CHAPTER FOUR

SYSTEM TESTING, RESULT, PACKAGING AND PROJECT ANALYSIS

4.1 TESTING

After the design and implementation phase, the system built had to be tested for durability, efficiency and effectiveness and also ascertain if there is need to modify this design. To ensure proper functioning of components expected data, the components were tested using a digital multi-meter (DMM). All components used were tested to ascertain their conformity with the required standard of the objective of this project. The output voltage of the inverter was a square wave, filtered by a $2\mu F/400V$ capacitor connected across the output terminals to remove the unwanted harmonics and leaving smooth sine waveform output voltage.

4.1.1 TEST PLAN AND TEST DATA

This chapter entails an overall system testing of the integrated design of the voltage measurement device. The testing and integration are done to ensure that the design is functioning properly as expected thereby enabling one or even intended users for which the project was targeted for, appreciate its implementation and equally approaches used in the design and integration of the various materials of the project. However, this involved checks made to ensure that all the various units and subsystems function adequately such as the existence of a good interface between the input/output unit subsystems.

4.1.2 COMPONENTS TEST

Similar components like resistors were packed together. Other components include capacitor, fuse, transformer, diodes (rectifier), etc. Reference was made to resistor color code data sheet to ascertain the expected values of resistors used. Each resistor was tested and the value read recorded. Also, for transistor test, the DMM was switched to the diode range with the symbol. The collector, base and emitter junctions were tested in the following order. The collector, emitter and base pins were gotten from the data analysis on power transistor.

4.1.3 SYSTEM TEST

The system was tested under load and no load conditions.

- **TESTING OF THE INVERTER UNDER NO LOAD CONDITION**

The 12V sealed and rechargeable battery was connected to the inverter circuit. The positive terminal of the battery was connected to the center-tapped transformer, while the negative terminal was connected to the overall ground of the inverter circuit. The inverter was switched on, and the variable resistor VR_1 in the control circuit was adjusted until the output voltage of 220V was recorded.

- **TESTING OF THE INVERTER UNDER LOAD CONDITION**

This test was done to ensure that the inverter was working as expected. The test helped to ascertain the behavior of the inverter under load condition, with respect to output voltage stability. The duration at which the inverter discharges under load condition depends on the total power of load connected to its output terminal and the power rating of the battery connected to its input terminal. Bearing in mind that total load must not exceed 1000VA.

A 100W lighting bulb was connected to the inverter output socket to check functionality and it was certified.

DISCHARGE DURATION

(1) Battery power rating = 12volts, 65Amperes per hour

When total load =100watts

Then duration = $\frac{12 \times 65}{100}$

= 7.8hours

(2) Battery power rating = 12volts, 65Ampere per hour

When total load = 10watts

Then duration = $\frac{12 \times 65}{10}$

= 78hours

4.2 PACKAGING/CASING

The electronic industries nowadays are faced with competitions, each trying in one way or the other to out match their competitors. To this end, a well thought out packaging not only uplifts the image of a firm but also have attractive luster attached to it. People attach great importance to the shape and design of the casing without considering the contents. In this project, the casing was built in such a way that the components are easily accessible in terms of maintenance and repairs. The casing has screw-able cover and the provision for the components or circuit fittings are made. In preparing the casing, a plain sheet of metal was obtained and a given dimension measured out with the measuring tape (height of the casing 200mm, base 220mm and length

270mm). The dimensions were marked out with a scriber and then cut with a cutting machine to the dimensions marked on the metal. The whole centers were punched with a center punch and drilled into appropriate size with the drilling machine. After this, the metal was bent with the help of a vice, hammer and some other small accessories and the screw nails were used to screw the necessary joints together to place the casing intact.

Finally, the complete unit was housed into the metallic casing. Battery terminals for positive and negative, power switch, side handle, indicators, circuit breaker, fuse box, DC fan and AC input/input point were fixed in their allotted slots and connected to their respective points on the circuit. The casing was earthed and each stage carefully arranged inside and connected together. Some pictorial views of the inverter are shown below:

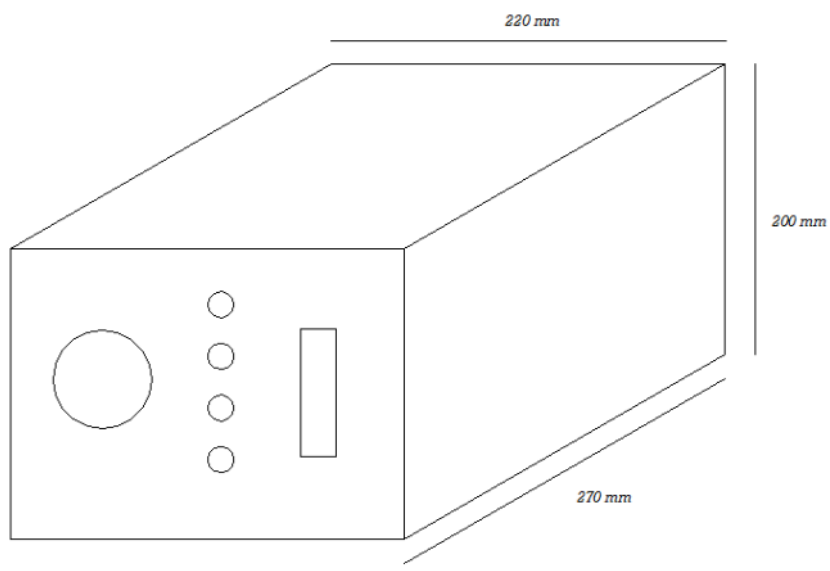

Fig 4.1 Inverter Casing

Fig 4.2 Front view of the Inverter

Fig 4.3 Side view of the Inverter

Fig 4.4 Back view of the Inverter

4.3 PROJECT MAINTENANCE PRESCRIPTIONS

The following steps can be taken to get the inverter working in case of faults. The possible fault symptoms, causes and remedies are tabulated below:

FAULT SYMPTOMS	CAUSES	REMEDIES
1. No output when battery is full	• Battery disconnected • Switch is open • Oscillator IC may be faulty • Transformer may be open circuited • Relay may be faulty	• Check battery contacts • Check the switch • Change the IC SG3524 • Check the relay base and the transistor driving the relay
2. Inverter still working when the mains supply is restored	• Relay may be faulty	• Check the relay base and the transistor driving the relay
3. Inverter generating noise	• Bad filter capacitor	• Replace filter capacitor

Table 4.1 Project maintenance prescriptions

4.4 SAFETY AND PRECAUTIONS

The following maintenance practices and safety precautions are suggested to improve the life span of the system and prevent hazards to the users:

- Dead batteries should not be used with the inverter.
- The battery terminals should not be removed too often. When it is removed, replacement of correct polarity must be ensured.
- The inverter must be kept in a moderate temperature environment.
- The inverter should always be shut down when not in use.
- The inverter should always be partially loaded (not more than 80% of its maximum capacity will be enough).
- The use of inductive loads like refrigerator, induction machine, etc. on the inverter should be avoided due to the heavy load they draw for their operations.
- The input plug of the inverter should be plugged to a three-pin, properly earthed socket.

4.5 PROBLEMS ENCOUNTERED AND SOLUTION

During the course of the design of this system, there were series of problems in the way of achieving the design goals of this project. Most of them where overcame via share troubleshooting, in some cases some parts required redesigning and the software debugging also created a bit of a problem. One major setback of this project is the availability of components required to build the hardware of the system. In most cases we had to look through electrical catalogs to obtain replacements or equivalents of some of the components which are not available in the market. The final packaging of the design was also another trouble. This was actually one of the most challenging aspects of the circuit implementation phase.

4.6 BILL OF ENGINEERING MEASUREMENT AND EVALUATION (BEME)

The table below shows the components used in the project construction, the quantity and also the prices.

COMPONENTS	DESCRIPTION	QUANTITY	UNIT PRICE (Naira)	AMOUNT (Naira)
1. Resistors	• 4.7kΩ	• 5	• 10	• 50
	• 1kΩ	• 10	• 10	• 100
	• 22kΩ	• 5	• 10	• 50
	• 470Ω	• 10	• 10	• 100
	• 100Ω	• 10	• 10	• 100
	• 27kΩ	• 5	• 10	• 50
	• 33kΩ	• 5	• 10	• 50
2. Capacitors	• 4700µf	• 1	• 100	• 100
	• 2200µf (filter C)	• 1	• 500	• 500
	• 1µf	• 5	• 100	• 500
3. IC	• SG 3524 IC	• 1	• 1600	• 1600
	• LM 7805	• 1	• 500	• 500
	• IRFP 150N (MOSFET)	• 8	• 1000	• 8000
	• TIP42	• 4	• 500	• 2000

4. Electric Socket (twin)	• 13Amps	• 1	• 600	• 600
5. Switch	• 13Amps • 16/32Amps 250VAC	• 1 • 1	• 300 • 200	• 300 • 200
6. Aluminum heat sink			• 3500	• 3500
7. Diodes	• IN4148 • IN4007	• 4 • 4	• 100 • 100	• 400 • 400
8. Screws			• 500	• 500
9. Lighting bulb	• 100watts	• 1	• 150	• 150
10. Lamp holder		• 1	• 150	• 150
11. Wood			• 500	• 500
12. Battery	• 12V	• 1	• 25000	• 25000
13. Electric plug	• 13Amps	• 2	• 250	• 500
14. Circuit breaker	• 10A,240/415	• 1	• 800	• 800
15. Variable resistor	• 10KΩ • 56KΩ	• 1 • 1	• 100 • 100	• 100 • 100

16. Cables/wires	• 2.5mm • 1.5mm • Connecting cables	• 1yd • 1yd	• 200 • 100 • 500	• 200 • 100 • 500
17. Small transformer		• 1	• 2000	• 2000
18. Relays	• JQX-59 30A,12VDC/230 • JZC-20F 4088 10A,12VDC/230 V	• 1 • 1	• 2700 • 1700	• 2700 • 1700
19. LED	• Green • yellow • red • blue	• 1 • 1 • 1 • 1	• 30 • 30 • 30 • 50	• 20 • 20 • 20 • 40
20. Electronic fan	• DC 12V, 0.23A	• 1	• 500	• 500
21. Oil paint (slate grey)			• 1000	• 1000
22. Glass diode		• 4	• 100	• 400
23. Rectifier diode		• 2	• 1700	• 3400

24. Metal			• 3500/Sq meter	• 3200
25. Fuse box		• 1	• 250	• 250
26. Fuse	• 5Amps	• 1	• 50	• 50
27. Vero board			• 500	• 500
28. Soldering iron		• 1	• 2000	• 2000
29. Lead			• 500	• 500
30. Transformer	• 12V to 220V	• 1	• 15000	• 15000
31. Miscellaneous				• 5000
TOTAL				• 86,000

Fig. 4.2 Bill of Engineering Measurement and Evaluation (BEME)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

In view of the inconsistence and unreliable public power supply and high cost of electric power generators coupled with the high cost of maintenance, the inverter is found to offer a better constant additional power supply for a sustainable duration. It is noiseless, harmless, and cost effective. It is also a preferred power backup to a computer and other appliances because it switches automatically to the battery when the AC mains are not available thus reduces system breakdown, prevent hard disk damages and data loss. In addition, the life span of the computers and other devices connected to either a standby or a continuous inverter is prolonged.

This project which is to design and construct a 1kVA power inverter was based on the following factors: efficiency, economy, compatibility, portability, durability and the availability of the components and research materials. The design and construction of this 1000VA, 220Volts inverter at a 50Hz frequency was a gradual process from gathering of materials to testing of components. It is to be noted that the efficiency of this project depends on the power rating of the battery connected to the input and on the total power of the load connected to its output terminals. Thus, the inverter could deliver constant power for a calculated number of hours.

The construction was done in such a way that it makes maintenance and repairs an easy task and affordable for the user should there be any system breakdown. The general operation of the project and performance is dependent on the user, who is prone to human error such as overloading of the system, making wrong battery connection or using the wrong battery voltage and improper handling of the device. Also, the operation is dependent on how well the soldering is done and the position of the components on the Vero board (if ICs are soldered near components that radiate heat, overheating might occur and affect the performance of the entire system), but in a long run the result will pay off.

In summary, after the complete design of the system, the deviation between the expected result and the actual result was very close. The performance and efficiency were beyond expectation and from every stage involved, the design of this project was a huge success.

5.1 RECOMMENDATIONS

This project is highly recommended not only to researchers and student but also to anyone who may wish to know the operation, construction and principles of a power inverter. It deals with a convenient way of producing an alternative means of power supply to supplement the mains failure which is noiseless and does not use fuel, making it environmentally friendly. Although the objectives of this project have been achieved, it is good to know that the inverter cannot be used to power any device of higher power rating. Therefore, any further increase in the voltage will require a regulating circuit to regulate the voltage to 12 volts that will be feed to the oscillating circuit. To further load the inverter beyond its rated capacity, change in the internal circuit of the inverter must be done (regulating the voltage to a required voltage). In addition, when the inverter is operating on mains supply, any fluctuation of the AC input gets to the inverter output.

In the event of a problem, a good technician will need to troubleshoot the device and make repairs.

Finally, for improvement on this project, further research can include:

- Increasing the power rating of the inverter by increasing the number of the power switching devices and the current rating of the transformer.
- Converting the inverter to act like a UPS (Uninterrupted Power Supply) through an additional Automatic Voltage Regulator (AVR).

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