DESIGN AND FABRICATION OF A 3.5KVA INVERTER

BY

OGBORU VICTOR AGHOGHO

B.Eng. (Prod. Eng.)

MAT NO: ENG1704491

SUPERVISOR: ENGR. DR. O. IKPONMWOSA-EWEKA

DEPARTMENT OF PRODUCTION ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITY OF BENIN

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A REPORT SUBMITTED TO THE DEPARTMENT OF PRODUCTION ENGINEERING,

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DEGREE IN PRODUCTION ENGINEERING

SEPTEMBER, 2023.

CERTIFICATION

This is to certify that this study was carried out by **OGBORU VICTOR AGHOGHO** in the Department of Production Engineering, University of Benin, Nigeria.

ENGR. DR. O. IKPONMWOSA-EWEKA

(PROJECT SUPERVISOR)

DATE

ENGR. DR. E.M. ETUK

(PROJECT COORDINATOR)

DATE

PROF. R.O. EDOKPIA

HEAD OF DEPARTMENT

DATE

CERTIFICATION OF THESIS/DISSERTATION ON PLAGIARISM

We the undersigned attest and declare that the thesis of **OGBORU VICTOR AGHOGHO** "Design and fabrication of a 3.5kva Inverter", has successfully passed the anti-plagiarism test and does not violate any copyright regulations.

Engr. Dr. O. Ikponmwosa-Eweka

Chief Supervisor/ Sign & Date

Prof. R.O Edokpia

Head of Department/ Sign & Date

DEDICATION

This project is dedicated to God Almighty who is my protector and provider and my family.

ACKNOWLEDGEMENT

My greatest thanks goes to God Almighty for Divine provision and guidance all through my years in this prestigious University of Benin. Firstly, I would like to appreciate my parents **Mr. and Mrs. H.I OGBORU,** my siblings and all my friends for the support rendered all through this phase.

I would also appreciate my Project supervisor, **Engr. Dr. O. Ikponmwosa-Eweka**

ABSTRACT

The main purpose of the project was to design and construct a 3.5KVA inverter which makes use of both Solar and mains or grid supply for charging the batteries. This is to reduce the frequency of power outages experienced in our homes and businesses.

The project was carried out with the use of two 12V batteries connected in series to give a total of 24V DC which would serve as input for the inverter when on inverting mode and give an output of 220V AC for household appliances. Incorporated within the inverter was load control features, such that when the inverter stops charging and starts inverting, at a particular battery level set by the user, the heavy loads would be cut off while supply of power to the light loads continues. But when critical battery level is reached the light loads are also cut off and the inverter shuts down. This was done using Microcontroller in controlling relays which either powers on the load or cuts off the load when the battery is low. The proposed inverter design has two outputs through which load management was achieved. One of the outputs is designated to light loads and the other to heavy loads. The Microcontroller controls the load stage which can be programmed through the keypad to monitor the output power to the loads in output one and two, to ensure they do not draw power beyond the limits programmed by the user. To achieve this, the Microcontroller cuts off either of the outputs which exceed the set limit. With the help of a timer controller and by means of the keypad a particular load power duration can be programmed so that the output can be shut down at the end of the set time. This timer control and load power control are ways the user can control power consumption and help in power management.

The project was successful and the test results obtained was satisfactory and efficient. The inverter's operation was consistent with the design and the desired control of power consumption and power management was achieved.

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CHAPTER 1

Introduction

1.1. Background of study

In recent years, the demand for efficient and reliable power conversion systems has significantly increased due to the growing need for renewable energy sources, uninterruptible power supplies (UPS), and standalone power systems. One critical component in this context is the inverter, which converts direct current (DC) into alternating current (AC) for various applications.

The World bank estimates that Nigeria has a population of over 220 million Varrella (2022), recently, there has been a steady growth in energy demand, which has also resulted in an increase in renewable energy output. There are various energy sources in use today, but sadly, the majority of them are traditional fossil fuels Ross and Jordan (2012). The use of traditional fossil fuels for the production of power in Nigeria accounts for more than 90% of total consumption, making us the continent's largest polluter.IEA, (2019).

Nigeria is located in the west of Africa and has a tropical climate, which means there is plenty of sunlight throughout the year Udo, (1978). According to Hoffman (2006), PV solar electricity is one of the most significant ways to generate electricity without noise or emissions. Numerous applications use solar photovoltaic (PV) systems because they require little maintenance and emit no pollutants.

Renewable energy sources are better for supplying electricity since they can help the grid handle peak demand as a result of rising electricity consumption. The strain on the grid is lessened when more people and businesses generate their electricity using renewable sources Kasa*et al.,* (2016). The size of the solar resource exceeds all other resource industries and chokes the economy Lewis, (2007). The DC electricity from the panels travels through a DC distribution network to an inverter, which uses cutting-edge technology and MOSFET approach to convert the DC electricity into AC for single phase operation. The AC distribution system is then connected to the consumer load.

The majority of electrical appliances use a 220V, 50Hz AC power supply to run. However, due to frequent polarity changes in electric current, AC power cannot be stored in the event of a power outage. It can be hybrid powered by employing a solar panel, a charge controller, and an AC power source from the utility to charge the batteries. A device called an inverter is created and available to produce an AC output from a DC source. Using the right transformers, switching, and control circuits, the AC might be at any desired voltage and frequency. When utility power is unavailable, it ensures a constant flow of electricity to connected devices or loads by supplying power from a different source, such as a battery is positioned between the power source and the load it is guarding.

Thus, the goal of this project is to design and build a 3.5Kva pure sine wave inverter system.

1.2. Statement of the Problem

Electric power generation in Nigeria shouldn't be a huge worry given the abundance of renewable energy in the nation. According to research, Nigeria receives 5.08 × 1012 kWh of solar energy every day. If solar energy devices with a just 5% efficiency are employed to cover just 1% of the country's surface area, 2.54 x 106 MWh of electrical energy can be produced from solar energy. According to Sambo (2005), this amount of electrical energy is comparable to 4.66 million barrels of oil each day.

Power supply from the national grid in Nigeria is insufficient to fulfil the needs of the ever-growing population; independent power generation relies heavily on the burning of fossil fuels, which is both environmentally unfriendly and expensive in the long term.

As a result, it has become critical to investigate various approaches of enhancing the strategies of generating electrical power. Because Nigeria gets a large amount of sunshine all year, power generation using solar energy is a fairly reliable way to do this. The goal of this project is to design and build a 3.5Kva inverter that will aid in the storage of solar energy.

1.3 Aim and objectives

The aim of this project is to design and fabricate a 3.5Kva pure sine wave inverter system that can be powered a backup battery to provide a 220V output.

To accomplish this, the objectives that follow will be vigorously pursued:

i. review relevant literature and use this literature to create a framework for the project.
ii. identify and collect necessary components for the design of a functional inverter and
iii. fabricate a working inverter as cheaply as feasible using materials source from our local market.

1.4 Scope of Study

This power source makes it possible to provide a clean reliable supply of alternative electricity free of sags and surges which could be found in the line voltage frequency (50Hz). The project design aims at creating a 3.5kva power source which can be utilized as a regular power source by remote rural industries and private individuals at home or in the office. Furthermore, as a consumer generates his or her own electricity, they also benefit in the reduction of electricity bills. It will discuss the components utilised in the manufacture of the inverter, the methods used in the fabrication of the inverter, the connection of the inverter to batteries, and the maximum power output of the inverter.

This project will not address solar panels, but will use a literature review to establish how the inverter is connected to the panels.

1.5 Significance of work

Due to its advantages to the environment and the economy, as well as its reliability when employing a battery backup, the power inverter has grown to be a significant source of power. Since the solar power system has no moving parts, once it is installed, it practically doesn't need any maintenance. The entire energy conversion process is good to the environment. It makes no noise, negative emissions, or toxic gases. Burning natural resources can damage air and water, produce smoke, and cause acid rain. Burning fuels also results in the production of carbon dioxide, or CO2, one of the main greenhouse gases. Only the battery's electricity is used by the power inverter as fuel. It actively works to reduce global warming and has no hazardous by-products.

By connecting the gadget to a 24V DC battery and any other electrical energy sources, the hybrid solar inverter creates 220V AC as the required output, making it more versatile than other types. Solar energy utilisation can assist countries in meeting their sustainable development goals by providing access to clean, secure, reliable, and inexpensive energy, and hence increasing access to electricity and promoting development.

The successful completion of this study will make it significant for the following reasons:

i. It will make it beneficial to the economy by providing stable electricity.
ii. It will also help to protect the environment to make eco-friendly.
iii. To provide efficiency in the use of power appliances, by ensuring continuous availability of power supply even in the absence of mains.
iv. To eliminate all suspense from mains outage during the execution of an important and urgent assignment as may be required.
v. To design a simple and rugged technology; this will utilize the appropriate use of home or local electrical appliances.

CHAPTER 2

Literature review

In this section, a comprehensive examination of pertinent research will be undertaken. The aim is to thoroughly investigate these studies and subsequently leverage their findings to lay the groundwork for the development and production of our inverter technology. Pertinent research sources have been collected from various repositories including the Departmental Library, Faculty Library, and reputable institutes (via platforms like Google Scholar and Google Advanced Search). The process of curating these materials involved the application of specific evaluative criteria, as detailed in Appendix 2.1.

2.1Inverter Overview

An inverter plays a crucial role in delivering a continuous 220V AC power supply to connected devices, ensuring a stable power source even when the main AC grid is unavailable Rocabert *et al.*, (2012). This system comprises an inverter circuit, a charger circuit, and a battery. While the charger circuit keeps the battery charged when AC mains power is accessible, the inverter circuit takes over in the event of a mains AC power failure. It converts the stored DC power from the battery into a usable 220V/50Hz AC supply, capable of powering common electronic equipment and computer systems Gunther, (2015).

Essentially, an inverter reverses the function of a rectifier, which converts AC power into DC power. Many electrical devices operate on 220V AC power externally, but internally, their circuits require DC power. Thus, the external AC power is transformed into DC power through the equipment's power supply unit Badrzadeh, (2011). During mains power breakdowns, devices that operate on DC power can be powered by connecting them to batteries. However, conventional batteries have a limited lifespan, making it costly to operate power-hungry equipment with them. Therefore, rechargeable batteries are recommended in such situations to reduce expenses Gray and Smith, (2009).

Inverters are especially useful for powering devices that lack the capability to connect to a DC power source or those that specifically require an AC power source for operation. The use of semiconductor power components, such as bipolar transistors and thyristors for voltage amplification, with the MOSFET as the primary power switch, enhances the performance of inverters. These semiconductor components result in reduced noise, automatic switchover capabilities, environmental friendliness, a more compact design, and cost-effective maintenance (Weber *et al.*)

2.2 Origin of Inverter (A brief history of inverters)

Inverters have a long history that has progressed tremendously from their early origins to the advanced technology we have today. Inverters are devices that transform direct current (DC) electricity into alternating current (AC). They are essential in a variety of applications, including solar power systems, uninterruptible power supplies (UPS), electric cars, and others.

Inverting DC to AC was first proposed in the nineteenth century Goodstal, (2013). Michael Faraday developed electromagnetic induction in 1831, laying the groundwork for understanding alternating current. Around 1880, an American inventor named Charles Francis Brush created one of the first forms of an inverter. His "constant current dynamo" used a commutator to create alternating current from a direct current source Arfken, (2012). Rotary converters were used to convert between AC and DC power in the late nineteenth and early twentieth century. These machines were mechanical in nature and had limited efficiency and applications.

The development of tubes capable of handling higher power and frequencies paved the way for practical inverter designs Kaneko *et al.*, (2016).

The invention of the transistor in the late 1940s marked a significant milestone in inverter technology. Transistors were smaller, more efficient, and reliable than vacuum tubes. By the 1950s, solid-state inverters were being used in various applications, such as military equipment and early computers Khanna, (2021). The 1970s saw the adoption of pulse width modulation techniques in inverters. PWM allowed for more precise control over the AC output waveform and improved efficiency. This era also witnessed the rise of microprocessors, which enabled sophisticated control algorithms (Matsui *et al.*).

In recent decades, advancements in semiconductor technology, particularly insulated gate bipolar transistors (IGBTs) and metal-oxide-semiconductor field-effect transistors (MOSFETs), have led to the development of highly efficient and compact inverters. These inverters are used in various applications, including renewable energy systems, electric vehicles, and industrial motor drives Milnes, (1980)

2.3 Review of Past Projects and Works

A modified sine waves 0.75KVA inverter was designed and implemented for a viewing center in Iloro community, Ondo state, Nigeria to provide a backup alternative source of electric power to the community Nwobodo *et al.*, (2021). The inverter design applied three units or stages namely-oscillation and driver amplifier units, power MOSFET amplifier unit, and center-tapped isolated step-up Transformer unit. The results obtained from the load test show that the higher the load, the higher the input direct current power drawn from the battery. According to Nwobodo *et al.,* (2017), the average efficiency of the inverter was about 70%.

A 600VA DC-AC inverter system was also designed and developed to provide an alternative backup power supply for a community in Rwanda Nwobodo, (2021). The result showed that the inverter worked very well in meeting the objective of the design.

An inverter system usually has different parts, with some parts compulsory and others necessary. Amongst these parts are the transistors for switching, the transformer and 555 timer IC as an oscillator has been the basic constituent of a power inverter system. According to Abioye *et al.,* (2017), an oscillator is a device that will accept direct input and give oscillating output. In this case, it takes direct current to give an oscillating current. This oscillating current is not a perfect sine wave current, so there is a need for current modification and filtering to achieve the sinewave required for an oscillating current. This oscillating current is not a perfect sine wave current, so there is a need for current modification and filtering to achieve the sine wave required for an oscillating current. Transistors are basically used for the current modification and in combination with resistors for filtering to achieve the sine wave. A.E Abioye et al., (2018). This output is stepped up by a transformer of a certain power rating. The power rating of this transformer gives is the power rating of the inverter system. The inverter system requires a battery to function Usman et al., (2014). The Direct Current (DC) is obtained from a DC battery supply. The current rating of the DC battery must be of high rating so as to carry the power required by the inverter. The battery supply is 12V DC. A combination of any type of DC batterytoachievethe12Vcannotbeusedbecauseofthecurrentrating.Usually, a lead Acid accumulator battery or a dry cell battery of the required current rating is used for the battery. When this battery is low, there will be a need for the battery to be charged. The charger is a rectifier and a step-down transformer input Abioye *et al.,* (2018). The step-up transformer has secondary winding that is a couple of the primary winding in a number of turns, depending on the output voltage required and the current rating for which it is meant for. The core area of the transformer is calculated based on the power rating to be achieved as well. The wire for the primary winding is made very thick so as to carry the power and bear the heat coming from the transistors. The wire to be used for the secondary winding is dependent on the type of load for which it is meant. For household appliances, a 2.5mm laminated cable is used for the secondary winding. The inverter is commonly known as an ‘Uninterrupted Power supply’ (UPS). Usually, a heatsink is used to cool down the transistors. The heat sink is not sufficient to cool the transistors, so a DC fan can be in corporate into the circuit for better heat management.

According to Riskiono *et al*, (2021), the School Solar Panel System (SSPS) was designed to improve electricity supply in order to encourage teacher professionalism in classrooms. This design assures a consistent energy supply, even during power outages. Das *et al*offered a case study including a hybrid Energy Neutral Home (ENH) intended for deployment and cost-effectiveness analysis in both rural and urban parts of Bangladesh, emphasising the system's flexibility for a variety of geographical contexts. In their study, a hybrid source of clean energy for power generation was mostly used as a combination of biogas and solar systems.

Yang, *et al*described the idea and implementation of an intelligent microgrid on Pulau-Ubin Island, which is heavily reliant on clean and sustainable energy resources to fulfil present and future electricity demands.

Power conversion from one or more AC or DC sources to one or more AC or DC loads is controlled by power electronic circuits, which can occasionally be bidirectional. This conversion is carried out by two functional modules known as the control stage and the power stage in the majority of power electronics systems Mehta and Mehta, (2005).

A power processor (also known as the "power stage") and a controller (also known as the "control stage") are included in the topology of a single source and single load converter application. The converter, which consists of passive devices (an inductor and a capacitor) as well as power semiconductor devices acting as switches, manages the transfer of power from the input to the output or vice versa.

The controller is in charge of managing physical quantities (often voltages and currents) detected at the system input or output while controlling the switches in accordance with predetermined algorithms Erickson and Maksimović, (2001).

2.4. DC and AC Current

In the realm of electrical transmission, we encounter two primary modes: Direct Current (DC) and Alternating Current (AC).

Direct current (DC) denotes the unvarying flow of electric charge in a single direction. Within a DC circuit, the electric current maintains a constant polarity, moving from the positive terminal to the negative terminal of the power source. Notably, batteries and cells are common sources of DC power. DC finds extensive application in electronic devices such as laptops, cell phones, and digital cameras, as well as within automotive systems Dragan and Ahmed, (2015).

Conversely, Alternating Current (AC) signifies the flow of electric charge that cyclically changes direction. In an AC circuit, the current continuously oscillates in both direction and magnitude, often conforming to a sine wave pattern. AC power generation predominantly occurs in power plants and stands as the prevailing form of electrical power harnessed for residential, commercial, and industrial purposes. AC power exhibits an advantage in long-distance power transmission due to its adaptability through transformers to different voltage levels Ndreko et al., (2015)

The core distinction between DC and AC is the directional flow of the current. DC maintains a constant flow in one direction, while AC periodically reverses its direction. Each type of current serves specific purposes and holds unique advantages. DC is commonly employed in low-voltage applications, portable electronic devices, and certain industrial settings. In contrast, AC dominates power distribution, operates household appliances, and efficiently drives motors and generators Akhter et al., (2015). Historically, the pioneering commercial electrical transmission was spearheaded by Thomas Edison and employed DC power lines. However, these DC lines delivered low voltage, which limited their capacity for long-distance power transmission due to voltage transformation challenges at the time Kuncoro *et al*., (2021).

Power loss in electrical transmission is influenced by the square of the voltage and the resistance of the transmission line. Increasing voltage leads to reduced current, resulting in a substantial decrease in power loss. Consequently, electricity generation at power stations and its delivery to residences and businesses was predominantly achieved through AC power. AC, characterized by its oscillating voltage and current, facilitates easy voltage transformation using transformers. William Stanley Jr.'s development of the transformer in 1886 played a pivotal role in enabling long-distance electrical transmission via AC power. As a result, the world primarily relies on AC power, with most households receiving a 240-volt AC supply Renner, (2023).

It is worth noting that since 1954, there have been numerous high-voltage DC transmission systems globally, made feasible by the advent of DC/AC converters that enable efficient voltage transformation. AC power operates a plethora of devices, including power tools, radios, and TVs, alongside DC power sources.

Thus, the coexistence of both forms of electrical transmission is imperative, as a one-size-fits-all approach is unfeasible. This necessitates the development of efficient means to convert DC to AC power and vice versa. Inversion serves as the process of converting DC power into AC power at desired voltage, current, and frequency levels, achieved through static semiconductor inverter circuits Dragan and Ahmed, (2015).

Voltage-source inverters (VSIs) maintain a nearly constant DC input voltage, while current-source inverters (CSIs) predetermine the load current, with load impedance dictating the output voltage. CSIs rely on a series of DC supply inductors to prevent rapid current changes and exhibit resilience to output short circuits. Voltage control may be necessary in instances of poor DC input voltage regulation or to manage power delivery to a load. Inverters can produce single-phase, three-phase, or multi-phase outputs, with variable output frequency often required for AC motor speed control Alcala *et al*., (2010).

Typically, inverter output waveforms are rectilinear and may contain harmonics, which can be mitigated through filtering, harmonic reduction techniques, or pulse-width modulation (PWM) to enhance load efficiency and performance.

In summary, the world of electrical transmission is shaped by both DC and AC, each with its distinct characteristics and applications. The ability to convert between the two is vital for accommodating diverse electronic devices and power transmission needs. Inversion plays a crucial role in this conversion process, enabling the efficient transformation of DC power into AC power as required Rubio, (2006).

2.5. Types of Inverters

Inverters are available in a variety of configurations and have a wide range of uses. Here are some examples of popular inverter types and their applications:

Modified Sine Wave Inverters: These inverters produce an AC output waveform that is a modified square wave. They are suitable for powering basic appliances and equipment but may not be compatible with more sensitive electronics. Example: Camping equipment, some power tools, and basic home appliances.

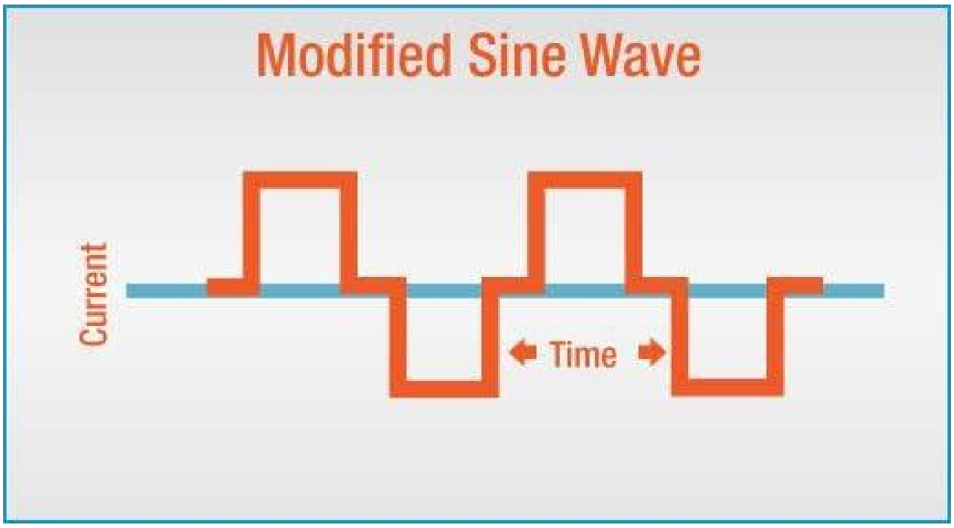


Figure2.1: Modified sinewave

source:https://www.greentechrenewables.com/article/inverters-sine-wave-or-modified-sine wave

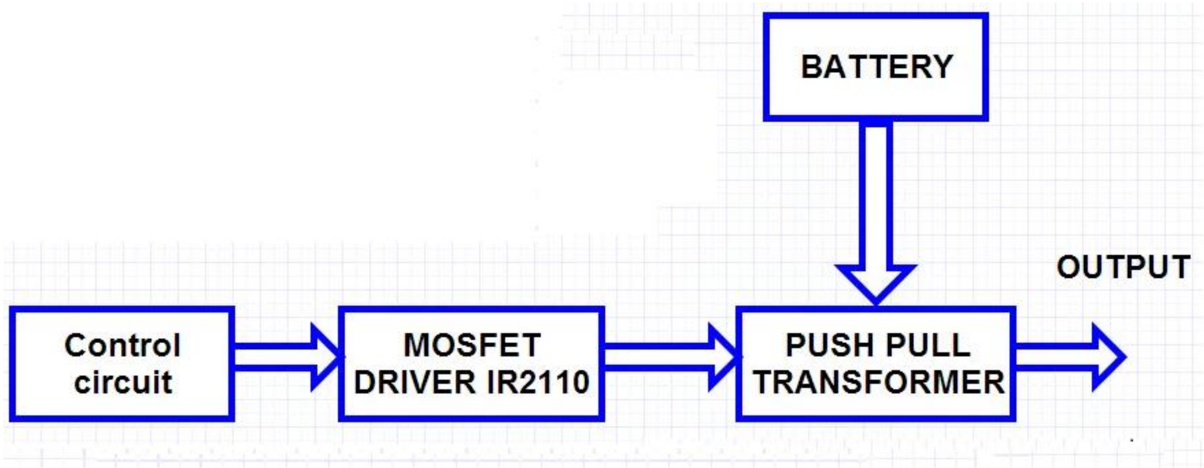


Figure 2.2: Block diagram of a Modified Sine Wave Inverters

2.5.1Pure Sine Wave Inverters: Pure sine wave inverters produce a smooth, clean AC waveform similar to what is provided by utility companies. They are suitable for powering a wide range of devices, including sensitive electronics, and are often used in residential and commercial applications. Example: Home backup power systems, medical equipment, and high-end electronics.

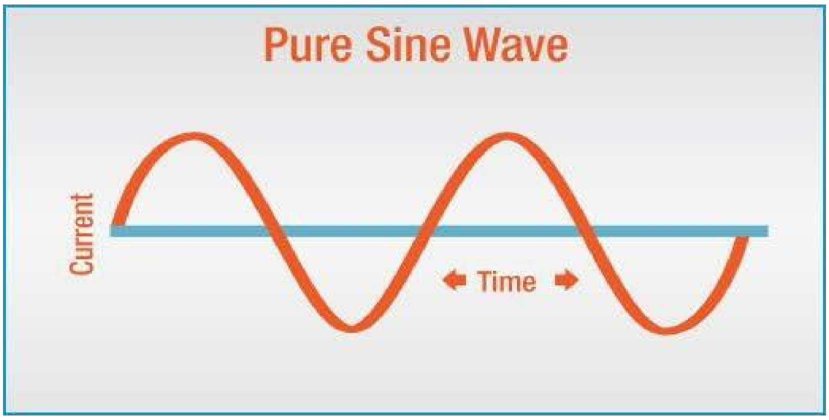


Figure2.3: Pure sinewave

Source: https://www.greentechrenewables.com/article/inverters-sine-wave-or-modified-sine-wave

2.5.2 Off-Grid Inverters: These inverters are used in off-grid solar power systems where there is no connection to the utility grid. They convert DC power from solar panels or batteries into AC power for appliances and equipment in remote locations or during power outages. Example: Off-grid cabins, RVs, and remote telecom towers often use off-grid inverters

2.5.3 Grid-Tie Inverters: Grid-tie inverters are designed for use in grid-connected solar power systems. They convert DC power from solar panels into AC power that can be fed into the utility grid or used in the home. They often incorporate features like Maximum Power Point Tracking (MPPT) for optimizing energy production. Example: Residential and commercial solar power systems connected to the grid typically employ grid-tie inverters.

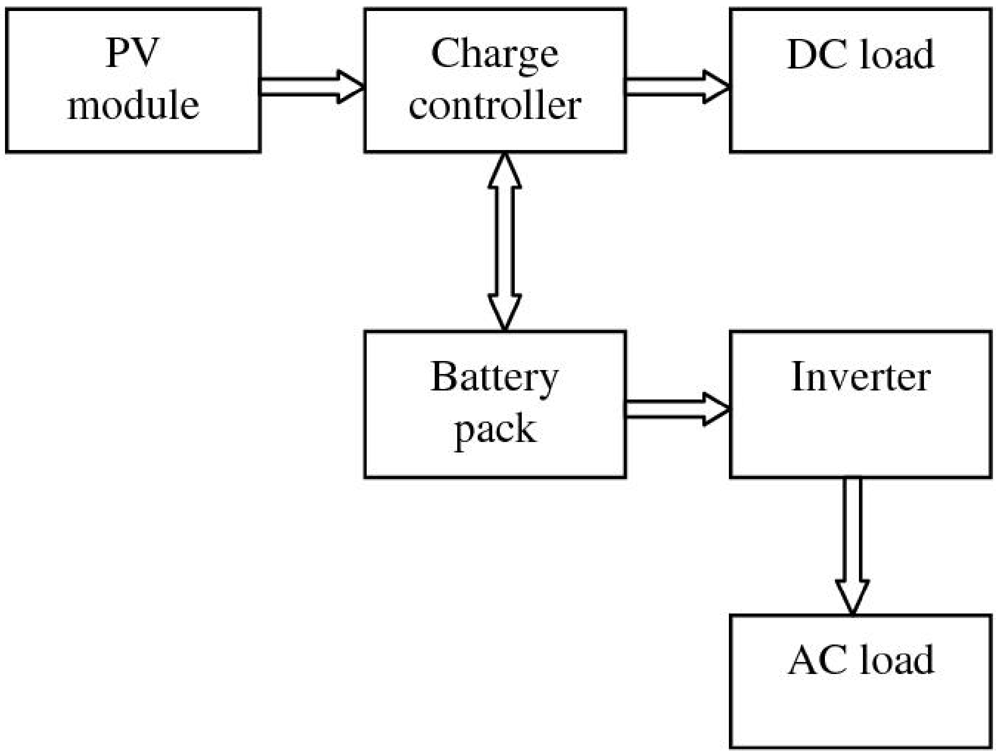


Figure 2.4: Block diagram of a standalone inverter.

2.5.4 Hybrid Inverters:

Hybrid Solar Inverters: These inverters combine the functions of a solar inverter and a battery inverter in one unit. They can manage energy from both solar panels and batteries, making them suitable for grid-connected systems with energy storage. Example: Solar-plus-storage systems used in homes to maximize self-consumption of solar energy.

Figure 2.5: A Hybrid Inverter

source: Voltronic Axpert VMII 3KVA 24V Hybrid Offgrid Inverter With Built in Solar Charge Controller (80A) | Shopee Philippines

2.5.5 Three-Phase Grid-Tie Inverters: These inverters are designed for three-phase electrical systems commonly found in industrial and commercial settings. They convert DC power from solar panels into three-phase AC power to offset energy usage or feed into the grid. Example: Large commercial buildings and industrial facilities with three-phase power supply.

Figure 2.6: Three-Phase Inverters
Source: Three Phase Inverters - efficient power conversion | Solar Edge AUS

2.5.6 Micro-inverters:

Micro-inverters are small inverters that are installed on each individual solar panel. They convert DC power from each panel into AC power, providing panel-level optimization and monitoring. Example: Residential and small-scale commercial solar installations looking for enhanced performance and monitoring.

Figure 2.7: Micro-inverters
Source: 600W Micro Inverter_600W Micro Inverter Yangtze Solar Power Co.,Ltd (yangtze-solar.com)

2.5.7 Vehicle Inverters: These inverters are designed to convert DC power from a vehicle's battery into AC power. They are commonly used in recreational vehicles (RVs), boats, and trucks to power appliances and electronics. Example: RVs equipped with inverters to run household appliances while on the road.

Figure 2.8: Vehicle Inverters
Source: Best Power Inverter for Cars | Buying Guide (carupgrade.co)

These are just a few examples of the different inverter kinds that are offered, each one designed to meet certain uses and specifications. The power source (such as solar panels, batteries, or car batteries), the kind of load or equipment being powered, and the required output waveform and voltage all play a role in the decision of which inverter to use.

2.6. Importance of Inverters

The importance of inverters is a well-documented topic in various fields, including electrical engineering, renewable energy, and power electronics. Inverters play a critical role in modern electrical systems, and their significance is underscored in the following literature:

2.6.1 Renewable Energy Integration:

Grid Integration of Renewable Energy Sources: The Role of Power Electronics Technology

IEEE Transactions on Industrial Electronics Narain and Gyugyi (2000) discussed the pivotal role of power electronics, including inverters, in integrating renewable energy sources like solar and wind into the grid. It emphasizes the importance of inverters in managing variability and ensuring the reliability of renewable energy systems.

2.6.2 Efficiency and Energy Savings:

Energy Efficiency Improvement of Solar Inverter Systems IEEE Transactions on Power Electronics Hong-Tzer, et al. (2011) discussed how high-efficiency inverters contribute to improving the overall energy efficiency of solar power systems. It discusses the importance of inverter design and control for maximizing energy yield.

2.6.3 Electric Vehicles:

Design and Control of an Electric Vehicle Charger With PV and Battery Energy Storage IEEE Transactions on Industrial Electronics Veerachary *et al.,* (2012) emphasized the critical role of inverters in electric vehicle (EV) charging systems that integrate photovoltaic (PV) panels and battery energy storage. Inverters play a crucial role in efficient power conversion and control.

2.6.4 Microgrids and Energy Access:

Renewable Energy-Based Mini/Micro grid Power Systems; A Review of Configurations, Control Strategies, and Operational Challenges Access Mohamed (2019) discussed the importance of inverters in renewable energy-based mini/micro grid systems. Inverters are essential for grid-forming and grid-following operation modes, enabling reliable and stable micro grid operation.

2.6.5 Industrial Applications:

High-Power Converters and AC Drives; IEEE Industrial Electronics Magazine in Wu, Mehdi Narimani, and Bo Zhang (2017) discussed the significance of high-power inverters in industrial applications, including motor drives and manufacturing processes. Inverters are crucial for achieving precise control and energy efficiency in industrial systems.

2.6.6 Resilience and Backup Power:

Design and Implementation of an Inverter-Based Backup Power System;

Cheol-Hee et al., (2018) discussed the importance of inverter-based backup power systems in ensuring resilience and continuity of power supply during grid outages.

The significance of inverters in numerous areas of electrical engineering, energy systems, and technology is highlighted by these chosen literary works. The cornerstone of contemporary electrical systems and sustainable energy solutions, inverters are essential to the integration of renewable energy sources, the enhancement of energy efficiency, electric vehicles, microgrids, industrial applications, and backup power solutions.

2.7. Theory of Components

A 3.5KVA (kilovolt-ampere) inverter design requires numerous critical components and considerations. An inverter is a device that transforms direct current (DC) power to alternating current (AC), which is widely used to power domestic appliances and electronic devices when grid power is unavailable. An introduction to the concepts and parts used in creating a 3.5 KVA inverter is given below:

2.7.1 Metal Oxide Semi-Conductor Field Effect Transistors (MOSFETs)

MOSFETs, or Metal Oxide Semiconductor Field Effect Transistors, belong to the family of Field Effect Transistors (FETs). These transistors regulate the flow of electrical current by controlling the conduction within a channel. The key factor in controlling this conduction is the gate electrode. Unlike other types of transistors, such as bipolar junction transistors (BJTs), MOSFETs do not have forward-biased junctions. This means that the gate of a MOSFET does not draw any current during its operation.

The development of power MOSFETs became possible with the advancement of Complementary Metal-Oxide-Semiconductor (CMOS) technology. CMOS technology, initially designed for manufacturing integrated circuits in the late 1970s, played a crucial role in making power MOSFETs feasible. It's important to note that power MOSFETs share the same fundamental operating principle as their low-power counterpart, the lateral MOSFET.

Power MOSFETs are widely used in low-voltage applications, typically for voltages below 200 V. You can find them in a variety of electronic devices such as power supplies, DC-to-DC converters, and low-voltage motor controllers. Their versatile application makes them important semiconductor devices in numerous circuit designs.

MOSFETs have several terminals:

a) Source: The source is where the majority of charge carriers enter the MOSFET. It's aptly named because it serves as the source of these carriers.
b) Drain: Conversely, the drain is where the majority of charge carriers exit the MOSFET. This terminal essentially "drains" the carriers away. The voltage between the drain and source (VDs) drives the flow of current from the drain to the source.
c) Gate: The gate consists of two internally connected regions that form P-N junctions.
d) Channel: The channel is the space between the two gates through which most carriers pass when a voltage is applied across the drain and source terminals (VD).

Understanding how MOSFETs operate requires knowledge of different types:

a) Depletion-Enhancement MOSFET (DE-MOSFET): DE-MOSFETs can operate in both depletion and enhancement modes, depending on the polarity of the gate-to-source voltage (VGs). A negative VGs results in depletion mode operation, while a positive VGs results in enhancement mode operation. In enhancement mode, a channel forms between the drain and source, allowing current flow even when the gate-to-source voltage VGS is zero.
b) Enhancement Only MOSFET (E-MOSFET): E-MOSFETs exclusively operate in the enhancement mode and require large positive gate voltages to do so. They differ in construction from DE-MOSFETs because there's no inherent channel between the drain and source. Therefore, E-MOSFETs do not conduct current

when VGs = 0; they only allow current to flow when VGs exceeds a certain threshold.

2.7.1.1 Working Principle of MOSFET

Consider a P-channel MOSFET. Its gate functions as a small capacitor, with the gate forming one plate and the channel forming the other, separated by a metal oxide dielectric layer. When a positive voltage is applied to the gate, it accumulates electrons. These electrons repel the conduction band electrons within the n-channel, reducing the number of available conduction electrons. Consequently, less current can flow from the source to the drain.

Conversely, applying a negative voltage to the gate adds more electrons to the n-channel, increasing the available conduction electrons and, consequently, the current flowing from the source to the drain. Key points to remember about MOSFETs:

a) In MOSFETs, the source-to-drain current is controlled by the electric field of the capacitor formed at the gate.
b) MOSFETs do not have a gate diode, so they can operate effectively with both positive and negative gate voltages.
c) Since the gate acts as a capacitor, there is negligible gate current flow when voltage is applied.

MOSFETs find extensive use in inverter circuits as switching devices for several reasons:

i. They can operate efficiently with minimal drive power.
ii. ii. Their efficiency is higher at higher frequencies.

iii. MOSFETs have very high input impedance, allowing them to function without DC current.

iv. Unlike ordinary transistors, MOSFETs are less affected by temperature variations.

v. They have a larger "safe operating area" compared to bipolar transistors, making them more resistant to damage.

2.7.2 Capacitor

Capacitors are essential passive components found in nearly every electronic circuit. They have the ability to store electrical energy in the form of an electrostatic charge. A basic capacitor consists of two conductive plates separated by an insulating material known as a dielectric. The capacitance of a capacitor is determined by the properties of the dielectric.

Figure2.9: Typical Capacitor
source:https://www.tme.eu/tw/en/news/library-articles/page/22156/how-to-safely-discharge-a-capacitor/

Capacitance is the measure of a capacitor's ability to store electrical charge and is measured in units called Farads (F). When voltage is applied across the terminals of a capacitor, it causes charges to accumulate on the plates. These charges can be released later when needed.

One notable characteristic of capacitors is that they can't dissipate electrical energy like resistors do; instead, they store energy in their internal electric field. Capacitors also have the unique property that the current they draw is not directly proportional to voltage but to the rate of voltage change. Because of this, capacitors can store and release energy effectively and are commonly used in various circuit applications, including as energy storage devices, signal filters, and timing elements.

2.7.3 Bipolar Transistor

A Bipolar Junction Transistor (BJT) is a type of semiconductor device used for both switching and amplification purposes. BJTs consist of three semiconductor layers forming two P-N junctions and have three terminals: The Emitter (E), Base (B), and Collector (C).

BJTs function by regulating the flow of current from the Emitter to the Collector terminals in proportion to the voltage applied to the Base terminal. This is achieved through the injection of a small current into the Base, which controls a much larger current flowing from the Emitter to the Collector. This behavior makes BJTs useful as current-controlled switches.

There are two main types of BJTs: PNP and NPN, which differ in the arrangement of P-type and N-type semiconductor materials. The operation of BJTs can be categorized into three regions:

Active Region: In this region, the BJT functions as an amplifier.

Saturation: The BJT operates as a fully ON switch.

Cut-off: The BJT operates as a fully OFF switch.

BJTs are versatile and can be used in both digital (switching) and analog (amplification) applications. They are essential components in many electronic circuits and play a fundamental role in modern electronics.

The term "Transistor" is derived from "Transfer" and "Resistor," reflecting their initial purpose and mode of operation. PNP and NPN BJTs share the same underlying principle but differ in their biasing and power supply polarities

2.7 Resistors

Resistors are passive electronic components that are used to restrict or limit the flow of electric current in a circuit (Sinclair, 2001). They commonly represented by the symbol "R" in circuit diagrams. Resistors have several important characteristics and applications; these includes power supplies, amplifiers, filters, signal conditioning circuits, and more.

Figure 2.10: A Resistor

Source: Carbon Film Resistors - China Carbon Film Resistors and Bulk Resistors (made-in-china.com)

CHAPTER 3

METHODOLOGY

3.1 COMPONENTS OF THE INVERTER

An inverter requires various components for its proper operation. Some of these components are:

i. Transformer
ii. Integrated Circuits (ICs)
iii. Relay
iv. Battery
v. Fuse/Circuit Breaker
vi. Switches
vii. Panel Indicator (Light Emitting Diode)
viii. Output display meter
ix. Transistor
x. MOSFETs
xi. Voltage Regulators

3.1.1 TRANSFORMER:

The transformer is one of the most important components of an inverter. It is a centre tapped transformer which converts the battery supply 24V into 240V supply.

The primary winding of the transformer is 24V and secondary winding is 240v (a step-up transformer).

Figure 3.1: A Transformer
Source: Inverter

3.1.2 INTEGRATED CIRCUITS:

Inverters use various ICs in its different section. Some of the ICs used are:

(1) PWM controller/oscillator

(2) Operational amplifier

(3) Regulator ICs

3.1.3 RELAY:

A relay is an electromagnetic switch. The switching on/off of relay is based on flow of current through its coil. A relay is used for switching on/off various high voltage circuits. In inverters, relays are used in various cut-off circuits and to switch the output between AC mains supply and inverter generated supply.

Figure 3.2: A Relay

Source: 6 Pin Mini Power Relay SRS-05V 12V 3A 4100 Relays PCB | Satistronics

3.1.4 BATTERY

A deep cycle lead accumulator (battery) provides DC supply to the inverter section of the inverter when the AC mains fail. This supply is converted into 240v AC supply at the inverter output socket.

Figure 3.3: A Battery

Source: GT12B-4 GT12B-B4 battery replacement motorcycle 12v rechargeable (batterytrader.com)

3.1.5 FUSE/CIRCUIT BREAKERS

These are self-destruct devices and protect the circuit from flow of heavy Current.

Figure 3.4: A fuse

Source: Connecticut Electric UBIF230N UBIF Thick 30 Amp 2 in. 2-Pole Federal Pacific Stab-Look NA230 Replacement Circuit Breaker (dkhardware.com)

3.1.6 SWITCHES

On/off switches and reset switches are commonly used in inverters. The reset switch is used to cut-off and restarts the supply.

Figure 3.5: A Switch

Source: Rocker Switches | Cricklewood Electronics

3.1.7 PANEL INDICATOR (LED):

Light emitting diodes are small semiconductors devices which emit light when a small forward current is applied to them.

Figure 3.6: A Panel indicator (LED)

Source: LED Panel Mount Indicator White .688" Round Flex Voltage Wire Leads IP67 - VCC (vcclite.com)

3.1.8 OUTPUT DISPLAY METER (VOLT/AMPERE):

Voltmeter is used in inverters to indicate and measure output voltage values.

Figure 3.7: A multimeter

Source: What is an Electronic Voltmeter? (with pictures) (aboutmechanics.com)

3.1.9 TRANSISTORS:

Transistors are used in the inverter circuit to generate oscillation signals, amplification of signals and to switch various circuits on/off.

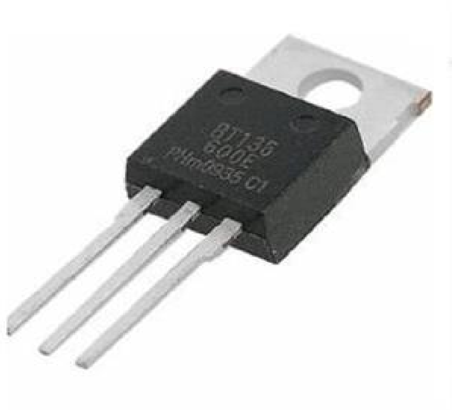


Figure 3.8: A Transistor
Source: transistors - Bing images

3.1.10 MOSFET

A metal-oxide-semiconductor (MOS) structure is obtained by depositing a layer of silicon diode (SiOz) and a layer of metal (polycrystalline silicon is actually used instead of metal) on top of a semiconductor die. As the silicon dioxide is a dielectric material its structure is equivalent to a plane capacitor with one of the electrodes replaced by a semiconductor. When a voltage is applied across a MOS structure, it modifies the distribution of charges in the semiconductor.

Power MOSFETs simplify circuits since they are voltage controlled devices which operate with very low instantaneous input current. The output from the circuit is alternating which is useful when power fails. They are very robust due to absence of the secondary breakdown phenomenon peculiar to the bipolar transistor.

Power mosfets are much faster than bipolar transistor of comparable dimensions as they are not subjected to delays and storage times due to minority carrier. The mosfet has a positive temperature coefficient and protects itself by imposing a uniform distribution of currents in the silicon chip. In a bipolar transistor, especially when the collector emitter voltage is high, there is a current concentration in the base, giving rise to hot spots.

These hot spots tend to constitute pits which swallow up the current, causing instant destruction of the chip.

3.1.10.1 MOSFET STRUCTURE

A metal-oxide-semiconductor field effect transistor is based on the modulation of charge concentration caused by a MOS capacitance. It includes two terminals (source and drain) each connected to separate highly doped regions. These regions can be either P or N type, but they both are of same type. The highly doped regions are typically denoted by a '+'following the type of doping. These two regions are separated by a doped region of opposite type known as the body. This region is not highly doped denoted by the lack of a '+' sign. The active region constitutes a MOS capacitance with a third electrode the gate, which is located above the body and insulated from all of the other regions by an oxide.

If the MOSFET is an N-channel or MOSFET, then the source and drain is N+ region and the body is a P region. When a positive gate-source voltage is applied, it creates an N-channel at the surface of the p region, just under the oxide. This channel spreads from the source to the drain and provides conductivity of the transistor. When zero or negative voltage is applied between gate source, channel disappears and no current can flow between the source and the drain.

3.1.11 REGULATORS:

The regulator is a component with an internal standard voltage with which it continually compares the actual output of the supply and makes appropriate adjustments by electronically controlling the resistor as connected in the circuit.

The regulator is useful because many electronic circuits impose a varying load on their power supplies which will not function properly when the supply voltage alters.

The regulator IC provides internal thermal overload protection and internal short circuit current limiting. It has 3 terminals: input, ground and output.

The voltage is specified by the last two digits of the IC part number. The regulator used in this inverter is the IC 7812 and it supplies 12Vdc

3.2 BASIC WORKING PRINCIPLE OF THE INVERTER

When the AC mains is available, the AC mains supply goes to the mains sensor informs the relay about availability signal from the AC mains sensor, it passes the AC mains signals directly to the inverter output socket. The battery charging section converts this AC main supply into DC supply. The DC supply is then regulated to provide required voltage and current to charge the inverter battery.

When the AC mains supply is not available, an oscillator section inside the inverter generates a 50Hz frequency MOS drive signal. This MOS drive signal is amplified and sent to the output section. The output section uses MOSFET devices for switching operation. These MOSFETs are connected to the primary winding of the inverter transformer.

When these MOSFETS receive the MOS drive signal from the driver section, they start to switch on and off at the speed of 50Hz. This switching on/off of MOSFET starts an alternating current with 50Hz frequency at the primary winding of the inverter transformer. This result in a 240V AC supply (with 50Hz frequency) at the secondary winding is sent to the output socket of the inverter through a changeover relay.

3.3 CIRCUIT DESCRIPTION OF PWM BASED 24V MOSFET INVERTER

PWM or Pulse Width Modulation is used to keep the AC supply output of the inverter to a constant 240V. In an ordinary inverter, the inverter output changes with any change in the value of the load connected at the inverter output. The PWM based inverter corrects the output value based on the value of the load connected at the inverter output socket. This is done by changing the width of the switching frequency generated by the oscillator. In a PWM based inverter, the AC supply at the inverter output depends on the width of the oscillator frequency generated by the oscillator section.

In this inverter, a small part of the inverter output is given as reference voltage to the PWM controller IC. Based on this reference voltage, the PWM section will increase or reduce the width of the oscillation pulse generated by the oscillator section. This change in the width will compensate any change in the inverter output, and the inverter output will always stay constant, even if there is any change in the load at the inverter output.

3.4 TO OBTAIN 50Hz FREQUENCY BY THE OSCILLATION SECTION

The oscillation section of this inverter uses a PWM controller IC (SG3525). This IC is used to generate the 50Hz frequency required to generate AC supply by the inverter. To start this process, battery supply is applied to the pin-15 of IC, through the inverter on/off switch and diodes.

Pin-8 of the IC is connected to the negative terminal of the battery. A voltage regulator used to regulate the 24V supply from the battery. Pin-6 and pin-7 are oscillation section pins. The frequency produced by the IC1 depends on the value of the capacitor and resistance at these pins. The capacitors determine the 50H1z frequency output by IC. Pin-6 is the timing resistance pin. A resistance at this point keeps the oscillator frequency constant. The signal generated by the oscillator section of IC, reaches the flip-flop section of IC. This section converts the incoming signal into a signal with changing polarity. In two signals with changing polarity, when the first signal is positive, the second signal will be negative and when the second signal becomes positive, the first signal will be negative. This is repeated 50 times per second, i.e. an alternating signal with 50Hz frequency is generated inside the flip-flop section of the IC. This alternating signal is known as the MOS Drive Signal.

3.5 OUTPUT SECTION

The 50Hz alternating MOS drive signal reaches each MOSFET channel separately.

This results in the MOSFET channels being alternatively on and off. This on/off switching process is repeated 50 times per second.

The drains (middle pint) of all the MOSFETs of one channel are connected together to the heat sink which absorbs and dissipates the heat in the circuit. The gates of the MOSFETs of one channel are connected via resistors to the input signal; the resistors limit the pulses going into the gates. The sources of the MOSFET are connected together to form the ground.

Because the polarity of the 50Hz MOS drive signal at pin-11 and pin-14 are different, only one channel from the output remains on at a time, the other channel stays off.

When the first MOSFET channel is on, the current flows through the first half of the center tapped winding of the inverter transformer. When the second MOSFET channel turns on, the current flows through the second half of the inverter transformer's winding.

This switching on and off of the MOSFET channels will start an alternating current in the winding of the inverter transformer. This AC current in the winding will induce a 50Hz AC current in the 240V tapping of the transformer.

3.6 DRIVER SECTION

The MOS Drive signal from pin-11 and 14 of IC are given to the base of the MOS driver TI and T2. This results in the MOS drive signal getting separated into two different channels. Transistors TI and T2 amplify the 50Hz MOS drive signal at their base to a sufficient level and outputs them from the emitter.

The 50Hz signal from the emitter of TI is given to the gate G of the first MOSFET channel through a resistance. Likewise, the 50Hz signal from the emitter of T2 is given to the gate G of the second MOSFET channel via resistance.

But,

$Ns/Np = Vs/Vp = Ip/Is = n$

Where n = transformer turns ratio

If $Vp = 24V$; $Vs = 240V$; $Ns = 600$ turns

Therefore, $Vs/Vp = 240/24 = 10$

And $n = Ns/Np$

$NP = 600/10 = 60$ turns

The transformer is a centre tap at its primary, with the number of turns (Np)

= 60 in each winding.

3.7 BATTERY CHARGING SECTION

When the inverter section receives AC mains supply, it stops operation, but the charger section in the inverter starts it operation and starts charging the battery.

3.8 FABRICATION PROCESS

After testing the transformers and the output of the ICs, the components of the control, MOSFET and charging circuits were soldered onto vero-boards as shown in the circuit diagrams attached. The component assembly was done in stages to allow for signal test at the output of individual stages. All the circuits, transformers and switching panel were bolted into the metal casing with other necessary accessories such as the power switch, a circuit breaker, output socket, fuse and voltmeter. Aluminum heat sinks were attached to the MOSFETs to quicken heat radiation. Extra care was taken to ensure that the casing is strong enough to carry the heavy components and provide ventilation and there is no partial contact or short circuit between the components of the circuit.

3.9 DESIGN ANALYSIS OF THE DRIVER CIRCUIT

$V_{in} - V_{BE} = I_B R_B$

$H_{fe} = I_C / I_B$

From Above,

$R_B = (V_{IN} - V_{BE}) / I_B$

Where,

I_C = collector current

I_B = base current

V_{IN} = input voltage

V_{BE}= Base-Emitter voltage

H_{FE} = current gain

From the data sheet,

I_C=100 mA

hfe = 700

V_{BE} = 0.7 v

Therefore,

I_B = 100mA / 700

I_B = 0.1429 mA

V_{IN}=7.5v

$R_B = (7.5- 0.7)0.1429 \times 10^3$

= 47,585.7252Ω

= 47.59kΩ

The nearest preferred value to 47.59kΩ was chosen, therefore 50kΩ was used in the design of the inverter for the base resistors of the NPN transistors of the driver stage.

3.10 PRINCIPLE OF OPERATION

During the first(positive) half-cycle of the oscillator operation, the signal turns on transistor A because its base is driven positive and it draws collector current upwards from the battery while transistor B remains off because its base has a negative voltage and therefore has no collector current. Hence the signal output is that of a positive half-cycle. During the negative half-cycle, transistor B conducts while transistor A remains off because transistor B has a base driven negative.

Hence the output signal appears as that of a negative half-cycle. A combination of these two signals gives the desired output waveform in square or sinusoidal forms.

3.11 ADVANTAGES OF THE PUSH-PULL CONFIGURATION

a) It has high efficiency, theoretical limit being 78.5% which is primarily due to the fact that there is no power drawn by the circuit under zero-signal condition.

b) In a push-pull arrangement, a 180 degrees' phase difference exists between even-order harmonics produced by each transistor which cancel out thereby giving an almost distortion-free output.

c) This double-ended amplifier provides practically four times the power supplied by a single-ended amplifier provided signal load resistance remains the same.

3.12 THE POWER CIRCUIT

The N-channel enhancement Hi-speed MOSFET transistor IRPF 150N was made use of in designing the power amplifier stage and this requires a center-tapped transformer in the MOSFET push-pull arrangement of switching as shown.

The power circuit as shown above consists of a center-tapped (24-0-24) step-up transformer which increases the circuit voltage to match the actual A.C requirements of devices. The chosen transformer must be able to handle the inverter wattage output. Since the design is a 3.5 KVA inverter, a 3.5 KVA rated transformer would be appropriate, hence the choice of a 3.5 KVA rated center-tapped transformer.

The MOSFETS are connected in parallel to increase the power within the circuit. The primary side of the transformer is rated 3.5 KVA, 24 V, hence the current rating of the transformer can be determined, and hence the required current rating of the MOSFETS can be calculated.

3.13 DESIGN ANALYSIS OF THE POWER CIRCUIT

DC Voltage Rating = 24A

Power rating =3500 VA

Current rating (1) = P/V =3500/24=145.83A

A center-tapped transformer is being used; hence the current rating per side can be calculated i.e.

Per side current rating = 145.83/2 = 72.92A

Having 7 identical MOSFETS, the required current rating for each of the

MOSFETS, for each side of the center-tapped transformer can also be determined.

Required current rating for each MOSFETS = 72.92/7 = 10.42A

To prevent the MOSFETS from burning out due to excessive current, it is advised to use a MOSFETS of three times the required MOSFETS current rating.

Therefore:

10.42x3=31.26A

Hence 14 MOSFETS of 30A were used, with 7 on each side of the center tapped transformer for protection of the MOSFETS.

3.14 THE TRANSFORMER

This is a static equipment or device through which electric power in one circuit is transformed into electric power in another circuit with no change in frequency. It can increase or lower voltage in a circuit but with a correspondent decrease or increase in current.

The working principle of a transformer is based on mutual induction between two circuits linked by a common magnetic flux i.e. two coils which are electrically separated but magnetically linked through a path of low reluctance.

CHAPTER 4

TEST RESULT AND DISCUSSION

4.1 OSCILLATING CIRCUIT OUTPUT WAVEFORM

With the aid of an oscilloscope, the output of the oscillating circuit was confirmed to be 50Hz.

4.2 IMPLEMENTATION

The implementation of this project was done on a breadboard. Stage by stage testing was done according to the block representation on the breadboard before soldering of the circuit commenced on the vero board.

4.3 ARRANGEMENT OF THE COMPONENTS

All the components used were arranged on Vero boards using the circuit diagrams shown previously. Each circuit was tested before being added to the overall inverter circuit.

4.4 CASING

The unit was housed in a metallic red casing. Battery terminals for positive and negative, power switch, handle and output meter 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.

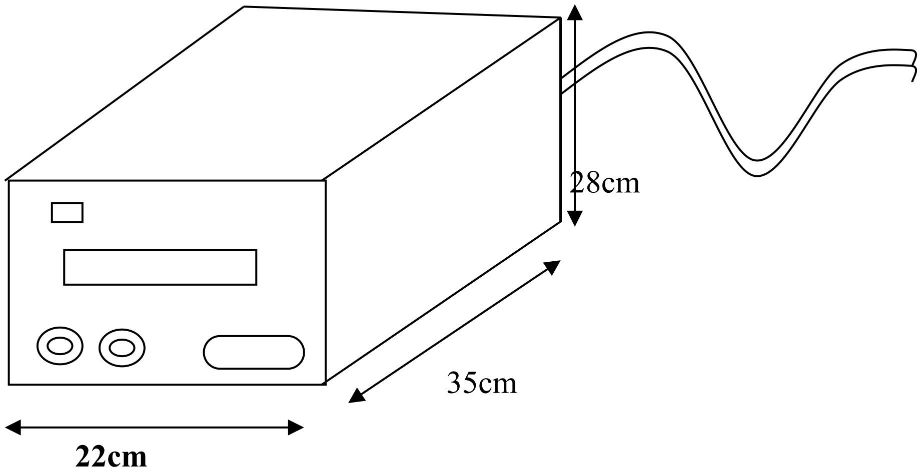


Figure 4.1: An Inverter Casing

Figure 4.2: Top view of a designed Inverter and Front view of a designed Inverter

Figure 4.3: Back view of a designed Inverter

4.5 The Battery

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 and output at the inverter output socket. It is pertinent to state that lead-acid batteries used in automobiles are very good for this purpose as they provide good quality power for a long duration and can be recharged once the power stored in them are consumed. The backup time provided by the inverter depends on the battery type and its current capacity.

4.6 The Inverter Circuit

This circuit charges and discharges the battery when there is AC mains supply and when the AC mains is not available respectively. The basic block and circuit diagram of this project is as shown in figure 4.5 and 4.6 below.

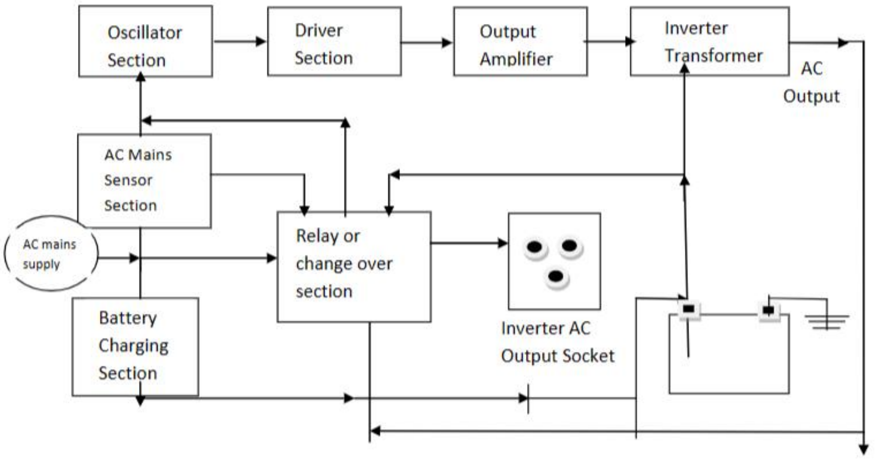


Figure 4.4: Basic Block Diagram of an Inverter

Source: Design

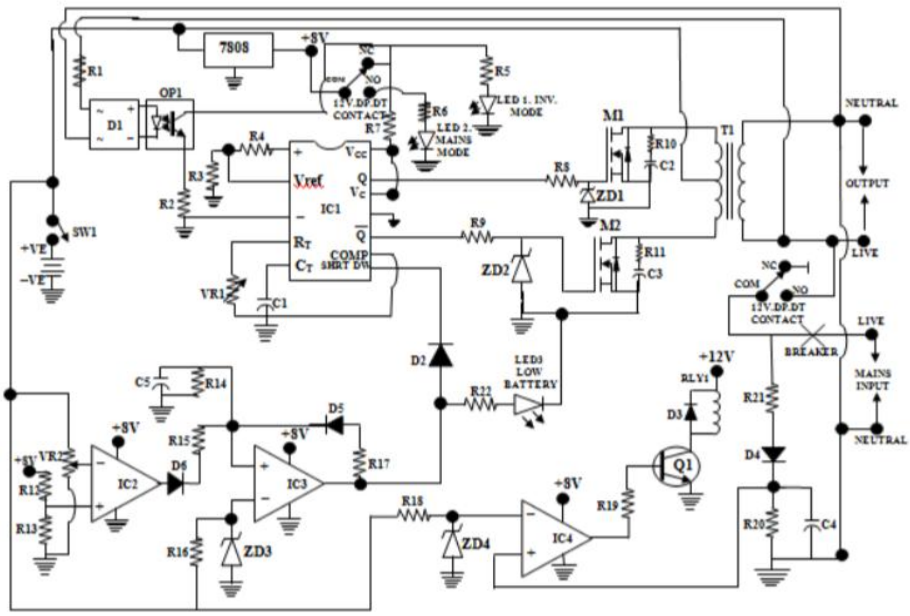


Figure 4.5: The complete diagram of an Inverter system

Source: Design

4.5 NO-LOAD TEST

Two 12-V sealed rechargeable battery in series with each other, were connected to the inverter circuit. The positive terminal of the battery was connected to the center tap of the inverter transformer while the negative terminal of the battery was connected to the overall ground of the inverter circuit.

When the inverter was switched on, a loud humming noise from the transformer was observed which indicated that the output voltage was too high. A screwdriver was used to adjust the pulse width output by turning the variable resistor in the control circuit figure 6. The exact value of the output voltage was determined by inserting the terminals of a digital mustimeter into the socket. This way the output voltage was reduced to 240V.

4.6 LOAD TEST

The 3,500w inverter was tested under a load of 1130W; a refrigerator (300w), 4

High energy bulbs (25W each), a standing fan (110W), a television (120W), and Air conditioner (500), (total power of 1,130 W) and lasted for about five hours at the stated load of 1,130W. The humming of the transformer was tolerable.

Equipment No.	Equipment's (Load) specifications	Equipment power rating(watts)
1	Refrigerator	300W
2	4 High energy bulbs (25W)	100 W
3	Standing Fan	110W
4	Television (LG 32inch)	120W
5	Air Conditioner	500W
	Total	1,130 W

Table 4.1: Equipment's (Loads in Watt) used for testing the automatic inverter system

Experiments	Equipment combinations to form higher power load	Loads (in Watts)	Approximate time duration (in hours)
Day 1	1 and 2	400 W	24:00
Day 2	3 and 4	230 W	42:13
Day 3	3 and 2	210 W	46:11
Day 4	1,2,3 and 4	630 W	15:24
Day 5	1,2,3,4 and 5	1130 W	8:50

Table 4.2: Loads and time duration for different load combinations

Test Calculation;

Battery rating = 200AH; 12V

For two batteries, 2x (200AH;12v) = 400AH;24V while connected in series.

However, there are two batteries, hence when connected in series to have the 24V supply, the battery rating will be 400AH; 24V.

Power rating of battery in Vehar

= 400AHX24V

=9600VAHr

Total Load for testing =1130W=1130VA

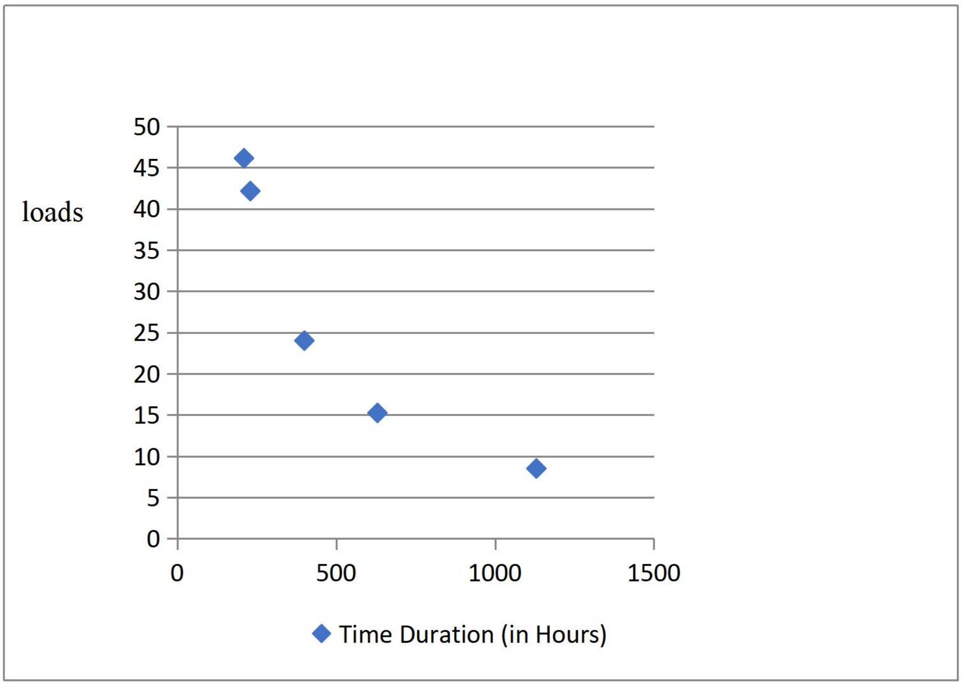
Time required for battery to discharge,

= 9600/1130

= 8.4956HRS

=9Hrs Approximately

Figure 4.6: Graph of load power (in Watts) consumption against time duration (in hours)



CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

At the end of this research work we have been able to design and fabricate a 3.5kva (3500 W) inverter.

i. Consequently, identified and collected necessary components for the design of a functional inverter.
ii. Fabricated a working inverter as cheaply as feasible using materials source from our local market.
iii. We have successfully reviewed the right literature.

The construction of this (3.5KVA), 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. 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 is not available. Thus reduce 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.

5.2 RECOMMENDATION

This project can be used as an alternative power supply source for home and medical appliances. It is highly recommended for use in rural areas where there is no electricity; solar energy can be utilized in this case. Future designs of the inverter should include more efficient charging circuits with better overload, over current protection, the use of digital displays and faster, switching devices.Although the objectives of this project has been achieved, the inverter cannot be used to power any device of higher power rating. In addition, when the inverter is operating on mains supply, any fluctuation of the AC input gets to the inverter output.

References

Akhter, F. et al. (2015) ‘DC Voltage Droop control implementation in the AC/DC Power Flow Algorithm: Combinational approach’, 11th IET International Conference on AC and DC Power Transmission [Preprint]. doi:10.1049/cp.2015.0096.

Alcala, J., Cardenas, V. and Vicario, N. (2010) ‘Input - output linearization control for a three - phase AC/DC/AC voltage source converter for bidirectional power flow’, 12th IEEE International Power Electronics Congress [Preprint]. doi:10.1109/ciep.2010.5598900.

Arkin, G. (2012). University Physics. Academic Press.

Badrzadeh, B. (2011) ‘Power Conversion Systems for Modern AC-DC Power Systems’, European Transactions on Electrical Power, 22(7), pp. 879–906. doi:10.1002/etep.611.

Das, C.K., Ehsan, M.A., Kader, M.A., Alam, M.J. and Shafiullah, G. (2016). Publisher’s Note: ‘A practical biogas based energy neutral home system for rural communities of Bangladesh’ [J. Renewable Sustainable Energy 8, 023101 (2016)]. Journal of Renewable and Sustainable Energy, 8(2), p.029902 doi:https://doi.org/10.1063/1.4944480.

Dragan Jovcic and Ahmed, K. (2015). High Power DC/DC Converters and DC Power-Flow Controlling Devices. doi:https://doi.org/10.1002/9781118846704.ch27.

Erickson, R.W. and Maksimović, D. (2001) Fundamentals of Power Electronics [Preprint]. doi:10.1007/b100747.

Fan, Y. et al. (2012) 'Design and implementation of stand-alone smart grid employing renewable energy resources on Pulau Ubin Island of Singapore', 2012 Asia-Pacific

Goodstal, G. (2013). Electrical Theory for Renewable Energy. Cengage Learning.

Gray, F.M. and Smith, M.J. (2009) 'Secondary batteries – lithium rechargeable systems lithium polymer batteries', Encyclopedia of Electrochemical Power Sources, pp. 169–176. doi:10.1016/b978-044452745-5.00040-x.

Gunther, W. (2015) Evaluation of battery and battery charger short-circuit current contributions to a fault on the DC distribution system at a nuclear power plant [Preprint]. doi:10.2172/1188216.

Hoffmann, W., 2006. PV solar electricity industry: Market growth and perspective. Solar Energy Materials and Solar Cells, 90(18-19), pp.3285–3311

IEA. "Nigeria Energy Outlook – Analysis - IEA." IEA, 2019, www.iea.org/articles/nigeria-energy-outlook

Kaneko, K., Okamoto, T. and Goyal, A. (2016) 'MV drive inverter development for higher capacity and higher reliability', 2016 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES) [Preprint]. doi:10.1109/pedes.2016.7914565.

Kasa, S. et al. (2016) 'Effective grid interfaced renewable sources with power quality improvement using dynamic active power filter', International Journal of Electrical Power & Energy Systems, 82, pp. 150–160. doi:10.1016/j.ijepes.2016.03.002.

Khanna, V.K. (2021) ‘Metal-oxide semiconductor field-effect transistors’, Practical Terahertz Electronics: Devices and Applications, Volume 1 [Preprint]. doi:10.1088/978-0-7503-3171-5ch6.

Kuncoro, C., Permana, A. and Adristi, C. (2021) ‘Wireless power transmitter apparatus for low-voltage DC power transmission applications’, Proceedings of the 4th International Conference on Applied Science and Technology on Engineering Science [Preprint]. doi:10.5220/0010939500003260.

Lewis, N. S. “Toward Cost-Effective Solar Energy Use.” Science, vol. 315, no. 5813 9 Feb. 2007, pp. 798–801, https://doi.org/10.1126/science.1137014Accessed 01 Aug.

Matsui, K. et al. (no date) ‘Asymmetrical modulation and over-modulation techniques of parallel connected NPC-PWM inverters for AC Motor Drives’, Proceedings of 4th IEEE International Workshop on Advanced Motion Control - AMC ’96 - MIE [Preprint]. doi:10.1109/amc.1996.509423.

Mehta, V.K. and Rohit Mehta, (Writer On Electrical Engineering (2005). Principles of electronics : for diploma, AMIE, degree & other engineering examinations. New Delhi: S. Chand.

Milnes, A.G. (1980) ‘Insulated gate field-effect-transistors: Mosfets, igfets and related devices’, Semiconductor Devices and Integrated Electronics, pp. 377–467. doi:10.1007/978-94-011-7021-5_7.

Mohan, N., Robbins, W.P. and Undeland, T.M. (1989). Solutions manual : power electronics : converters, applications, and design. New York ; Chichester: Wiley.

Ndreko, M., van der Meijden, M.A.M.M. and Popov, M. (2015) ‘Short circuit current contribution from MTDC grids to the AC power system under AC system faulted conditions', 11th IET International Conference on AC and DC Power Transmission [Preprint]. doi:10.1049/cp.2015.0060.

Renner, R.H. (2023) 'AC power system stability with voltage source converters', 19th International Conference on AC and DC Power Transmission (ACDC 2023) [Preprint]. doi:10.1049/icp.2023.1302.

Riskiono, S.D., Oktaviani, L. and Sari, F.M. (2021) 'Implementation of the school solar panel system to support the availability of electricity supply at SDN 4 Mesuji Timur', IJISCS (International Journal of Information System and Computer Science), 5(1), p. 34. doi:10.56327/ijiscs.v5i1.