DESIGN AND CONSTRUCTION OF A 2KVA INVERTER SYSTEM

BY

BELLO A. ADEMOLA

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DEDICATION

This project is dedicated to almighty Allah and my late Mum

CERTIFICATION

I BELLO AFIS ADEMOLA, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna Niger State.

BELLO A. ADEMOLA
....
Name of student Signature and date

MR. O. J. TOLA
....
Name of Supervisor Signature and date

ENGR. DR. Y.A ADEDIRAN
....
Name of H.O.D Signature and date

....
Name of External Examiner Signature and date

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ABSTRACT

The erratic nature of power supply in Nigeria today and the high cost of power generating sets have made it necessary to seek an alternative and cheap means of electricity supply.

An inverter is an electrical device which converts the DC supply of the battery into AC power supply required by most of the electrical& electronics equipment..

Generally, when we talks about inverter, we talk about a combination of inverter circuit, charger circuit and a battery.

This project provides a detailed and comprehensive analysis, design and construction of a 2KVA Inverter System that takes an input of 12V and produces an output of 230V [AC]

The objective of the project is to detail how a DC-AC inverter could be used as an alternative power supply for households, offices e.t.c

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CHAPTER ONE

1. INTRODUCTION

The erratic nature of power supply in Nigeria today and the high cost of power generating sets have made it necessary to seek an alternative means of electricity supply.

An inverter is an electrical device which converts the DC supply of the battery into AC power supply required by most of the electrical/electronic equipment.

Generally, when we talk about inverter, we talks about the combination of inverter circuit, charger circuit and a battery.

An inverter needs to be designed to handle the requirements of energy hungry household yet remain efficient during periods of low demand. Inverters can be designed in a number of topologies depending on the situation and its requirements. The efficiency of the inverter is highly dependent on the switching device, topology and switching frequency of the inverter. The aim of this thesis is to produce an efficient 2.0KVA automatic change-over inverter power system with shut-down option that will produce an efficient DC to Single Phase 230 Volt AC inverter.

This project provides a detailed and comprehensive analysis, design and construction of a 2.0KVA Automatic change-over inverter power system that takes an input of 12V[DC] and produce an output of 230V[AC] at 50Hz.

The objective of this project is to detail how a DC-AC Inverter could be used as an alternative power supply for households and offices e.t.c. The device is also designed to switch automatically between the mains power and the inverter mode when power failure occurs.

1.1 HISTORICAL BACKGROUND

During the late nineteenth century through the middle of the twentieth century DC to AC power conversion was accomplishing using rotary converters or motor generator set [M-G sets]. In the early days, vacuums tubes began to be used as switches in inverter circuits. The most widely used type of tube was the thyraton.

The development of DC-AC inverters has made it possible to obtain AC batteries which are readily available. The world's first high performance power inverter was introduced in 1983 by "Heart Interface" who has been a leader in inverter technology.

The origins of electromechanical inverters explain the source of the term *inverter*. Early AC-to-DC converters used an induction or synchronous AC motor direct-connected to a generator (dynamo) so that the generator's commutator reversed its connections at exactly the right moments to produce DC. A later development is 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. With an M-G 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 M-G set or rotary converter can be "run backwards", converting DC to AC. Hence an inverter is an inverted converter.

In 1984, Heart Interface patented and introduced inverters using field effect transistor, [MOSFET] metal oxide silicon field effect transistors. For mains power output device the use of MOSFET made the design of a much smaller size.

As they have become available in higher voltage and current ratings, semiconductors such as TRANSISTORS, POWER MOSFETs or IGBTs that can be turned off by means of control signals have become the preferred switching components for use in inverter circuits.

1.2 METHODOLOGY OF THE PROJECT

1.2.1. PRINCIPLE OF OPERATION

In this inverter, we are using IC-CD4047 [Mono/Astable Multivibrator] in the oscillator circuit.

The frequency of the output at the output pins 10&11 of the IC-CD4047 depends on the value of resistance of pins 2 and capacitor at pin 1. Output from the output pins 10 and 11 are out of phase. As these outputs are weak signals to amplify them, cascade mode amplifier is used.

The output signals from pin 10 and 11 are given to transistor Q_1 & Q_2 through 220Ω resistor. Amplified signal from the emitters of these transistors are provided to base of the second stage amplifier Q_3 & Q_4 through 20Ω resistors to limit base biasing.

The final stages consist of MOSFET power transistors Q5&Q6 connected in push-pull mode. The supply to the gates of these Q5&Q6 is through the center-tap transformer of the primary of the inverter output transformer and the sources are connected to the negative of the battery.

The amplified output from this final stage is applied to the step-up inverter output transformer to drive the load. Two 1N4007 diodes are used to reduce the back e.m.f

1.2.2. OUTPUT WAVEFORMS

The switch in the simple inverter described above produces a square waveform as opposed to the sinusoidal waveform that is the usual waveform of an AC power supply. The sine wave that has the same frequency as the original waveform is called the fundamental component. The other sine waves, called harmonics that are included in the series have frequencies that are integral multiples of the fundamental frequency. The wave shape of the inverter output voltage influence the load connected to the inverter. Mains AC voltage is generally in the form of a pure sine wave which has a nominal RMS value of between 220 to 240V and a 1.4 times peak value. The RMS value determines the brightness of bulbs and the working of transformer. The quality of output waveform that is needed from an inverter depends on the characteristics of the connected load. Some loads need a nearly perfect sine wave voltage supply in order to work properly.

1.2.3 SECTIONS OF THE INVERTER

This inverter consist of three main component functions

1.5.2 Pulse-width modulated inverters: In these inverters the input DC is constant in magnitude. The inverter must hence control the magnitude and frequency of the AC output voltage. This is achieved by pulse width modulation at the inverter switches.

1.5.3 Single-phase inverter with voltage cancellation: These inverters have a single – phase output, the inverter controls the magnitude and frequency of the inverter output. The inverter to be design is a square inverter which is able to supply power to a number of appliances such as computers, radio, and video e.t.c

1.4 INVERTER APPLICATION

I. DC power source utilization

An inverter converts the DC electricity from sources such as batteries, solar panels, or fuel cells to AC electricity. The electricity can be at any required voltage; in particular it can operate AC equipment designed for mains operation, or rectified to produce DC at any desired voltage. Grid tie inverters can feed energy back into the distribution network because they produce alternating current with the same wave shape and frequency as supplied by the distribution system. They can also switch off automatically in the event of a blackout.

II. Uninterruptible power supplies

An uninterruptible power supply (UPS) uses batteries and an inverter to supply AC power when main power is not available. When main power is restored, a rectifier is used to supply DC power to recharge the batteries.

1.5 SCOPE OF WORK

This is the design and consruction of a 2.0KVA AUTOMATIC CHANGE-OVER INVERTER POWER SYSTEM WITH SHUT-DOWN OPTION that takes in 12volts DC from a car battery and produces an output of 240volts AC to supply the load.

1.6 AIMS AND OBJECTIVES

Hence, the aims and objective of this project is to produce an alternative utility power that will perform the following function,

I. To produce device that will work noiselessly without producing any smell or other harmful emissions.

II. To produce a device that will not required any special maintenance, only the battery used will require some routine service.

III. To produce a device that will provide a completely automatic switch-over function between DC battery source and AC main supply.

1.7 ADVANTAGES OF INVERTERS

The inverter is a very reliable alternative to generating set because

I. It is easily maintained.

II. It is portable.

This project is rated 2KVA, meaning it would be able to power a total load of 2000VA

CHAPTER TWO

2. THEORETICAL BACKGROUND

There have been a large number of literature reviews written concerning power conversion in recent years. This can be attributed in part to the rise in popularity of high voltage DC transmission systems - and their integration with existing AC supply grids. There is also a consistent demand for high efficiency inverter devices for lower power applications -like houses, UPS and remote areas of the world. This chapter will discuss and contrast recent literature concerning high power inverters and their control

During the late nineteenth century through the middle of the twentieth century, DC to AC power conversion was accomplished using rotary converters or motor generator set [M-G sets]. In the early days, vacuums tubes began to be used as switches in inverter circuits. The most widely used type of tube was the thyraton.

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In 1984, Heart Interface patented and introduced inverters using field effect transistor, [MOSFET] metal oxide silicon field effect transistors. For mains power output device the use of MOSFET made the design of a much smaller size.

As they have become available in higher voltage and current ratings, semiconductors such as TRANSISTORS, POWER MOSFETs or IGBTs that can be turned off by means of control signals have become the preferred switching components for use in inverter circuits.

An inverter is a device that produces an alternative means of generating power by converting DC from a battery into AC power supply. There are different types of inverters according to the operating voltages. Examples are 12Vdc- 230Vac inverters, 24Vdc- 230Vac, 6Vdc- 230Vac

2.2. DESIGN CONSIDERATION

2.2.1 DC-AC Inversion

In the scope of this project, the DC-AC inversion stage will be the most critical. With quality design of the DC-DC stage it should have a stable DC supply to work with, but it will have to cope with other issues such as reactive power correction and maintain a good level of voltage regulation in the most efficient manner possible.

The circuitry used in the standard DC-DC Converter is re-used in AC-DC Converters – with the exception of the isolating step-up/step-down transformer. In the same manner, the choice of topology depends entirely on the situation and tradeoffs need to be made with regards to limitations on power, efficiency and cost. The most important part of the DC-AC Conversion process is in the generation of the sinusoidal input signals to the gates of the MOSFETs

2.2.2 Power Switching

Designing power inverters can be summarized into attempting to meet two primary objectives:

I. Supply harmonic free electrical power at a constant voltage for a variety of loads, and have the ability to cope with a non-ideal supply.

III. Supply this power as efficiently as possible with negligible electro-magnetic interference.

The two main sources of loss are switching power loss and conduction loss. These losses can be simply explained by their relation to power loss as given:

I. Switching Loss varies linearly with switching frequency and rise/fall times. Hence switching frequency can be increased provided devices with small rise and fall times are used.

II. Conduction loss is directly proportional to the on-state voltage. Clearly, a device needs to be chosen that minimizes the on-state voltage to reduce conduction loss. Clearly then, the switching device chosen should meet the above criteria as closely as possible so as to maximize total efficiency of the device.

The ideal gate drive is one that:

I. Provides sufficient drive power to keep the power switch in the on-state over the complete range of operating voltages and currents.

II. Ensure that the switch remains in its off-state and is not triggered by noise from other switching devices.

III. *Drive circuitry should be directly coupled to the switching device*

IV. Ensure that the switch turns on and turn off times is kept to a minimum.

In a standard MOSFET, the switching speed is directly related to the rate of supply of charge to the gate-input capacitance [1]. The resulting drive circuitry, while remaining as simple as possible, should attempt to use this fact to maximize the switching speed of the MOSFET's.

2.3 PROJECT REVIEW

This chapter will give a concise and complete coverage of all the theory relevant to the design of this 2.0KVA/50Hz/12V,Automatic change-over inverter power system with shut-down option. It will begin with a theoretical overview of various components that make up the DC power supply unit, the battery charging unit and the inverting unit of the inverter

This project is divided into three sections,

2.3.1 The power supply unit

2.3.2 The battery charging unit

2.3.3 The inverter unit

2.3.1 POWER SUPPLY UNIT

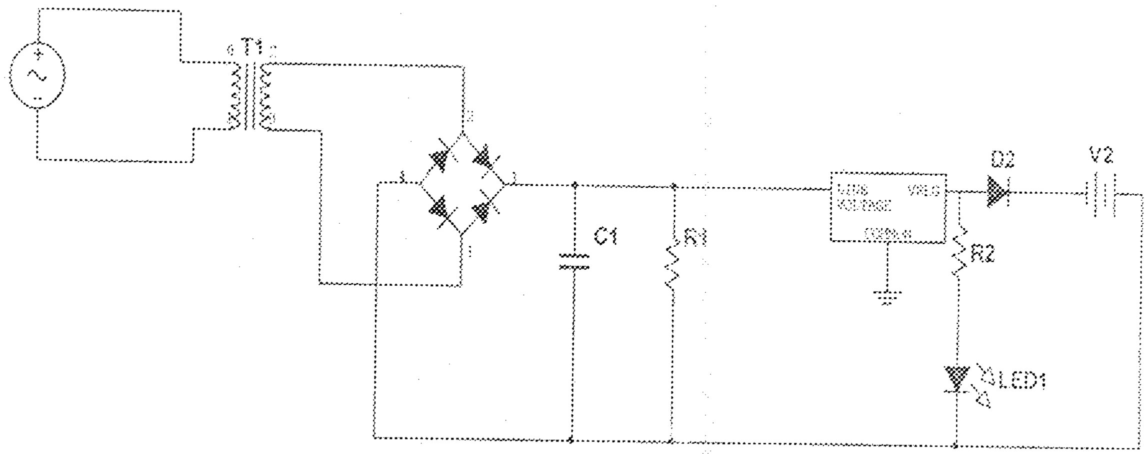

Fig 2.1: circuit diagram of the power supply unit

In this section, we are going to study how DC main supply is converted into the AC supply required for operating many of the common electrical/ electronic equipment.

The components that make up the DC power supply units are,

I. Transformer

Working principle of a transformer

A transformer is a static piece of apparatus by means of which electric power in one circuit is transfer into electric power of the same frequency in another circuit. It can raise or lower the voltage in a circuit but with corresponding decrease or increase in current. The physical basis of a transformer is mutual inductance between the two circuits linked by a common magnetic flux. It consists of two inductive coils which are electrically separated but magnetically linked through a path of low reluctance.

The first coil, in which electric energy is fed from the AC supply mains, is called primary winding and the other from which energy is drawn out is called secondary winding.

Transformer construction

The simple elements of a transformer consist of two coils having mutual inductance and a laminated steel core.

In all type of transformer, the core is constructed of transformer sheet steel lamination assembled to provide a continuous magnetic path with a minimum of air gap included. The steel used is of high silicon content, sometimes heat treated to produce a high permeability and a low hysteresis loss at the usual operating flux density.

Constructionally, the transformer is of two general types, distinguished from each other merely by the manner in which the primary and secondary winding coils are placed around the laminated core. The two types are known as;

I. Core type- the winding surrounds a considerable path of the core,

II. Shell type- the core surrounds a considerable portion of the winding

Types of transformer

The transformer can be differentiated according to

I. Output voltage

II. Usage

I. Output voltage

i. Step-up transformer: this transformer is used to increase the secondary [output] voltage in proportion to primary [input] voltage. The number of primary winding is less than the number of secondary winding and secondary voltage is given as

$$V_s = \frac{V_p}{N_p} \times N_s$$

ii. Step-down transformer: this transformer is used to decrease the secondary [output] voltage in proportion to primary [input] voltage. The primary winding is greater than the secondary winding and secondary voltage is given by

$$V_s = \frac{V_p}{N_p} \times N_s$$

II. Usage

i. Voltage or Potential Transformer- it is used to step up a very low voltage or step down a high voltage for use in measuring instruments and power supplies. It is design to achieve the accurate voltage ratio and transformation over its load range.

ii. Power Transformer- it is essentially a voltage transformer used to achieve the voltage ratio constant over its range of loads. It have good regulation and are most widely used in industries and domestic instrument.

iii. Current or Series Transformer: this transformer are connected in series with the input supply and step down the current to drive the low current device, these are used to supply wattmeter and over-current relays

iv. Isolation Transformer: these are used to isolate the current from the input supply thus the only contact is magnetic flux. These are normal transformer with a primary and secondary turn ratio of 1:1

v. Auto Transformer: this is made of single winding which acts as both primary and secondary. It is used to obtain small increment or decrement of voltage. This transformer is divided into numbers of tapping as per instruction. It has one common wire for input and output. The output is connected to the required voltage tapping and the common wire.

Different types of winding

I. Layer winding- in this winding, the wire is rotated from one end to another forming a layer. This layer is insulated by a paper or tape and the second layer wound on it, this process is continued till the required number of turns is completed.

Transformer with this kind of winding has higher load bearing capacity and are used to construct the power transformer.

II. Random winding- in this winding, enameled copper wire is used and hence isolation is not required. After completing the primary winding, insulation paper is used and after completing the secondary, another insulation paper is used.

III. Bifilar winding-in this type, two wires is rotated along till the required turn are completed, then the two wires having continuity are connected together. The point where they are joined is known as center tap. If the resistance of winding is 100ohms, then in bifilar winding, the resistance from center tap to each end will be equal to 100ohms.

II. **Rectifier circuit**

After stepping down the power supply, the reduced DC supply is converted into AC, by rectifier circuit; the full-wave bridge rectification is used. In a full wave bridge rectifier, both the cycle, positive and negative cycles of AC is rectified.

Rectification is carried out by the circuit above. During the cycle diodes D2 and D4 are forward biased (ON) while diodes D1 and D3 are reversed biased (OFF). During the second half cycle diodes D1 and D3 are forward biased (ON) and diodes D2 and D4 are reversed biased (OFF). The efficiency of full-wave rectifier is double the efficiency of the half wave rectifier.

III. **Filtering circuit**

To remove the pulses from the DC supply and make it a clean DC supply, the pulsating DC supply is next fed to a filter to a filter circuit. Its job is mainly to convert the DC with pulses to a pure DC

V. **Regulation circuit**

To keep the DC output constant irrespective of change in AC input mains voltage and the load, regulator circuit is used

2.3.2 BATTERY CHARGING UNIT

A battery is a device that supplies DC power through chemical reaction. The battery we use nowadays are divided into two categories

i. Primary battery: are for single use as chemical reactions that produce the electric current in them are irreversible. These batteries are cheap and simple to use. Some of the common types are the Zinc-Carbon battery, Zinc-Manganese alkaline battery

II. Secondary battery: they are rechargeable batteries i.e. they can be used multiple times, after using the charge stored in them, they can be recharged and reused. Some common examples are Nickel-Cadmium battery, Lead-Acid battery

Battery for Inverter

One of the most important parts of an inverter is the battery. The battery is the source of power when the mains supply fails.

Proper working inverter depends on the condition and capability of the battery being used. Proper selection and maintenance of the battery is very useful for the proper working of the inverter.

Battery charging in inverter

In an inverter, when the mains AC are available, the main supply is connected to the 0-230V taping of inverter transformer, through a relay. In this situation, the transformer works as a step-down transformer, which has 0-230V taping at the primary and 12-0-12V at the secondary.

This voltage at the secondary is used to charge the battery connected to the inverter.

When the mains AC supply fails, the relay makes 12-0-12V taping primary and 0-240V taping secondary. This makes the inverter to provide 230V AC supply from the 12V battery.

So, when single transformer is used for both the charger and inverter operation, then when the transformer is working as inverter, the transformer is used as step-up transformer

When the mains supply is available and transformer is working as charger transformer, then the transformer works as a step-down transformer.

Battery rating

The backup time provided by the inverter battery depends very much on the rating of the battery used with them. Commonly, batteries are available in 6, 12 and 24V ratings. Other than the voltage rating, the Ampere-Hour [AH] rating is used to define the power availability or capability of the battery.

The backup time provided by a battery connected to the inverter depends on the DC bus voltage of the inverter. This depends on their design. It could be 24V, 48V, 72V, 120V and so on. Normally, more than one 6V or 12V battery is used in series for higher voltage requirement.

The components that made up the battery charging units are

I. Voltage regulators

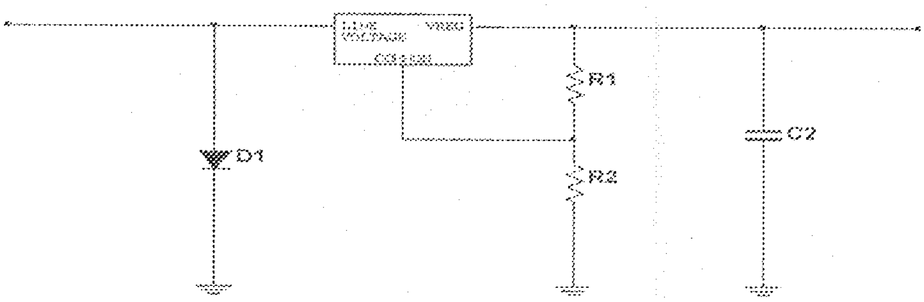

Fig 2.2: circuit configuration of an IC voltage regulator

The DC output is created by rectifying the mains AC supply, so any change in the mains AC supply will also have effect on the value of the output DC supply.

To keep the DC output stable a regulator circuit is added to the DC output. A regulator circuit keeps the output constant even if there is a change in the load, current, input voltage and temperature. The process of maintaining the output DC voltage constant is called ''REGULATION''

This unit takes a d. c voltage and provides a somewhat lower d.c voltage, which remains the same even if the input d.c voltage varies or the output load connected to the d.c voltage changes, examples are 7805, 7812, 7815.

II. Battery

The battery provides a direct current (d.c) input into the inverter. A battery`s capacity is the quantity of electricity which it can give out during a single discharge. It could be defined in terms of ampere hour (Ah).

This is the product of the discharge current and discharge time. It is the power in amps that the battery can deliver over a specified period of time.

A battery charger is an electric device that is used for putting energy into a battery. There are basically three methods of charging batteries,

i. Constant voltage method

ii. Constant current method

iii. Constant voltage constant current method (CVCC).

For this project the constant voltage method was employed. It operates on the principle that as the battery nears its charge, the terminal voltage will increase in opposition to charging current, therefore a balanced potential occurs between the charger and the battery.

2.3.3 INVERTER UNIT

The inverter unit is made up of the switching devices which are power Mosfet (metallic oxide field effect transistors), power transformer, and pulse generators.

CLASSIFICATION OF INVERTERS BASED ON OPERATIONAL MODE

An inverter could be said to be a device that maintains a continuous supply of electric power to connected equipment by supplying power from a separate source when utility power is not available.

This differs from an auxiliary power supply or standby generator which does not provide instant protection from momentary power interruption. Integrated systems that have inverter and generator components are often referred to as "emergency power systems".

Based on its operation, an inverter could be said to be operating in three modes,

I. On-line: An online inverter continuously powers the protected load from its energy reserve stored in a lead-acid battery or flywheel while simultaneously replenishing the reserves from AC power. It provides protection for all common power problems and for this reason, it is also known as a power conditioner.

An online inverter uses "double conversion" method of accepting AC input rectifying to DC passing through the battery then inverting back to AC.

II. Line- interactive : The line interactive inverter is maintain in line and redirecting the battery's DC current path from normal charging mode to supplying current when power is lost. It has a multi-tap variable voltage auto-transformer.

This is a special type of electrical transformer that adds or subtracts powered coils of wire, thereby increasing or decreasing the magnetic field and output voltage of the transformer. This type of inverter is able to tolerate continuous under voltage "brown outs" and over voltage surges without consuming the limited reserve of the battery power.

III. Standby [offline]: The load is powered directly by the input power and the backup circuitry is only invoked when utility power fails. The offline inverter offers only the basic features, providing surge protection and battery back-up.

Usually the standby inverter offers no battery capacity monitoring or self-test capability, making it the least reliable type of inverter since it could fail at any moment without warning.

The components that made up the inverting units are

I. IC-CD4047

It is 14pin low power IC to which a stabilized voltage is supplied through diode (D1) and filtered through a capacitor (C1), the capacitor is between pin 1 & pin 3 and potentiometer Rt between pin 2 & pin 3 are used to set the output frequency of the oscillator. The frequency can be varied by changing the setting of potentiometer. The output from pin 10 and pin 11 are low and out of phase.

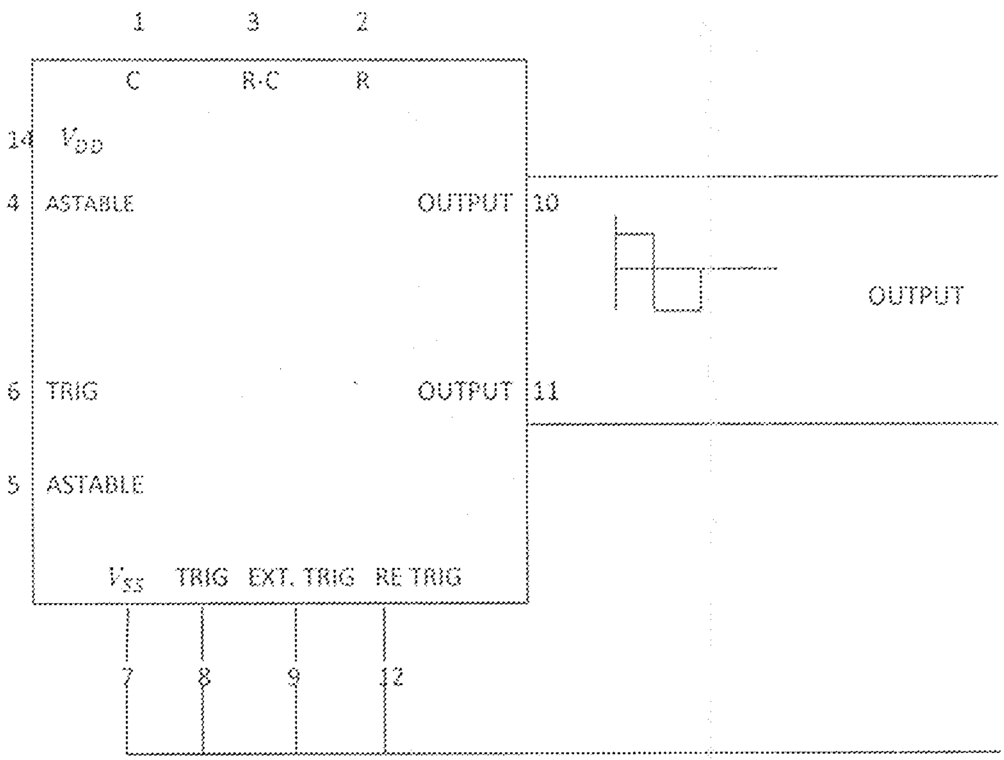

Fig 2.3: schematic diagram of IC-CD4047

II. Power Mosfets

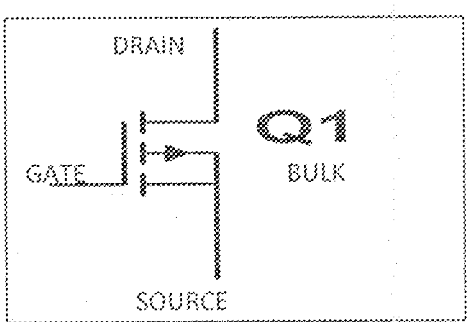

Fig 2.4: circuit symbol of a mosfet

A mosfet is a three terminal device, the three terminals being the gate, source, drain. The charge carries in the device are either electrons or holes not both, in this way it is a unipolar device unlike BJT (Bipolar junction transistor).

Mosfets can be used with both positive and negative gate voltage which can be used to enhance or deplete the channel.

MOSFETS are an intrinsically fast switching device because their operation does not require the injection and removal of excess minority carriers like the BJT. The limiting factors for the MOSFET are stray capacitances that affect the switching transients. In particular, the gate-drain and gate-source parasitic capacitance have a severe effect on switching speed. The equivalent circuit of the MOSFET including these capacitances is shown below:

The MOSFET has to be fixed on the heat sink. The ideal area of the heat sink should be 2 inches width and 3 inches high for each MOSFET

Also, the two windings of the inverter transformers are fixed to the respective heat sink. This ensures electrical contact to each drain of the MOSFETs fixed to the heat sink.

Characteristics of power mosfets

Power mosfets differ bipolar power transistor both in operational principles and performance.

I. It has faster switching time.
II. They are voltage controlled.
III. They have stable gain and response time over a wide temperature range.

2.4 POWER TRANSFER

The device is designed in such a way that it switches automatically between the mains supply and inverter mode supply. When the mains power is on, the battery is disconnected from the inverter unit connected to the charging unit.

When the mains power goes off, the battery powers the inverter unit. This is achieved using a four pins relay.

I. Relays

A relays is a device that is used to perform electrical switching function. It performs the same function as a switch, except that is electrically operated instead of being manually operated.

An electromagnetic relay is basically a switch operated by magnetic force. This magnetic force is generated by flow of current through a coil in the relay. The relay opens or closes a circuit when current through the coil is started or stopped. A circuit using relay normally has two separate circuits. One circuit which contains the relay is called "switching circuit". The circuit drives the relay to switch ON/OFF. Another circuit is known as "switched circuit".

Relays are available in single, double and triple pole configuration. One, two and three pole relay with their internal construction and bottom view of showing the pin configuration.

Since relays are electrically operated, unlike traditional switches, they can be opened or closed from a remote location. Generally, relays are made for voltages 6, 12, 18, 24, 48, 110, 240V AC or DC. Coil resistance is usually given which helps in

Astable mode

This is called a free-running relaxation oscillator. It has no stable state but only two quasi stable (half stable) states between which it keeps oscillating continuously of its own accord without any excitation. In this mode, neither of the transistors reaches stable state. When one is ON the other is OFF and it continuously switch back and forth at a rate depending on the RC time constant in the circuit. It has two energy storing elements, i.e. two capacitor

Bistable mode

It is also called Eccles-Jordan or flip flop multivibrator. It has two stable states. It can remain in either of these states unless an external trigger pulse switches it from one state to the other. Obviously, it does not oscillate. It has no energy storage element, i.e. no capacitor

For this project the CD 4047 IC was used to achieve the mono/astable mode.

CHAPTER THREE

3. DESIGN AND CONSTRUCTION

Input Voltage = 12V DC

Output Voltage = 230V AC

Power Rating = 2000VA

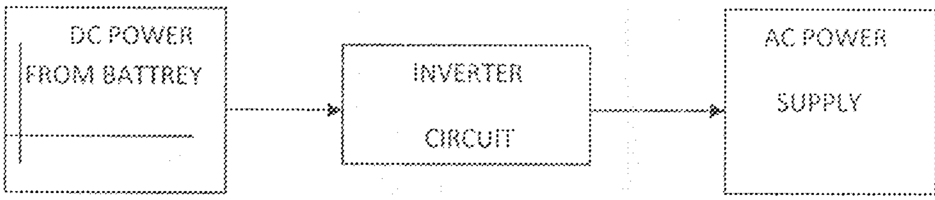

Fig 3.1: block diagram of inverter system

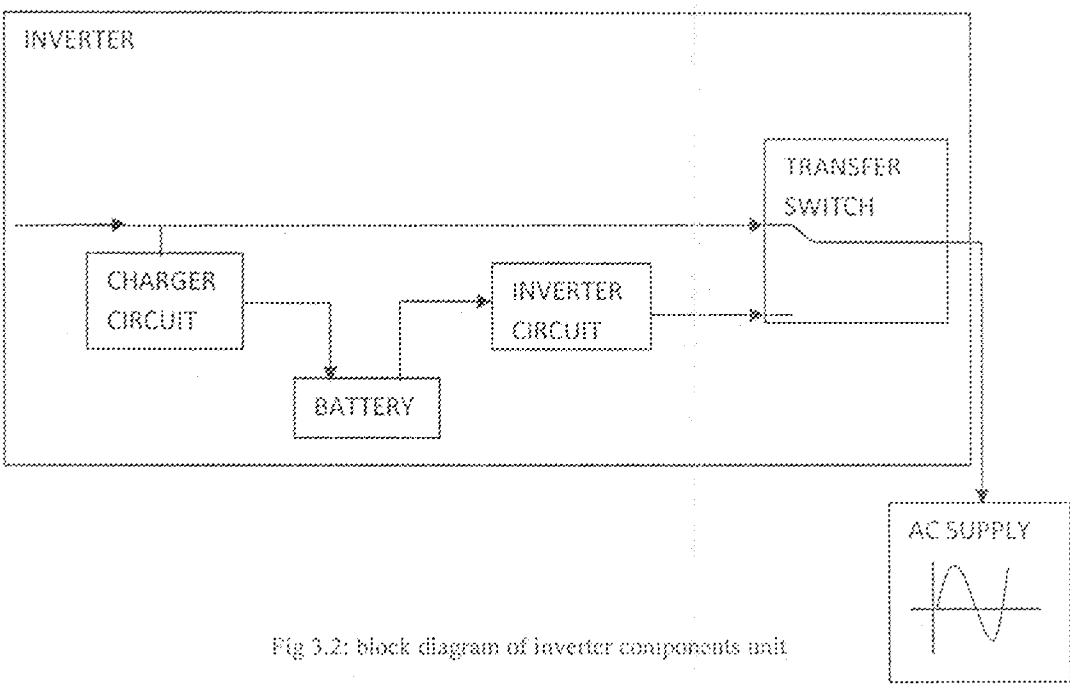

Fig 3.2: block diagram of inverter components unit

The inverter is subdivided into three units

I. Power Supply Unit

II. Battery Charging Unit

III. Inverter Unit

3.1 POWER SUPPLY UNIT

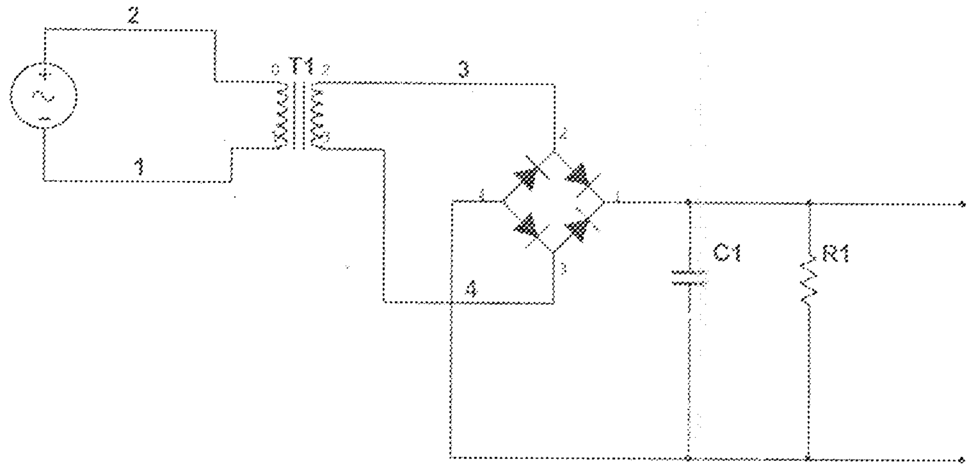

Fig 3.3: circuit diagram of a power supply unit

RECTIFICATION

During the first half-cycle, terminal B is positive and terminal A is negative. Diode D_2 and D_4 become forward biased [ON]. Diodes D_1 and D_3 are reverse biased [OFF]. During the second half cycle, terminal A is positive and terminal B is negative. Diodes D_1 and D_3 are forward biased [ON], while diodes D_2 and D_4 become reversed biased.

Where, V_s= Secondary winding voltage = 12V

V_d = voltage drop across each diode = 0.85V

Considering the diode voltage drops

$V_{out} = V_s - 2V_d$

= 12 - 2[0.85] V

V_{out} = **10.3V**

Peak inverse Voltage [V_{PI}] for each diode used is

$V_{PI} = V_{out} - V_d$

= 10.6 + 0.85

P_{IV} =**11.15V**

Peak Secondary Voltage [V_{SP}]

$V_{SP} = \sqrt{2}$ Vs

V_{SP} = **16. 968V**

The peak full rectified voltage at the filter input [V_{PFR}]

$V_{PFR} = V_{SP} - 2V_d$

= 16.968 – 2[0.85]

=**15.268V**

Given that,

R_1 = Value of resistance

C_1 = Value of capacitance

Filtered D.C output voltage

$V_{dc} = 1 - [\frac{0.00417}{R_1 C_1}] V_{PPR(in)}$

Given that,

V_r= r.m.s ripple factor

$V_r = [\frac{0.0024}{R_1 C_1}] V_{PPR(in)}$

Given,

R_1 = 220Ω and C_1 = 63μF

Filtered d.c output voltage [V_{dc}]

$= 1 - [\frac{0.00417}{63 \times 220 \times 10^{-6}}]$

= 13.55V

R.m.s ripple [V_r]

$V_r = \frac{0.0024}{R_1 C_1}$

$V_r = [\frac{0.0024}{63 \times 220 \times 10^{-6}}]$

$$= 5.1 \times 10^{-3} V$$

Ripple factor, $r = \frac{V_r}{V_{d.c}}$

$$r = \frac{5.1 \times 10^{-3}}{13.55}$$

$$r = 3.77 \times 10^{-4}$$

Rated voltage of capacitor is given as

$$= \sqrt{2} \times V_{out}$$

$$= 1.414 \times V_{out}$$

$$= 1.414 \times 10.6 \text{ V}$$

$$= \mathbf{14.99 \text{ V}}$$

Approximately = **15 V**

3.3 BATTERY CHARGING UNIT

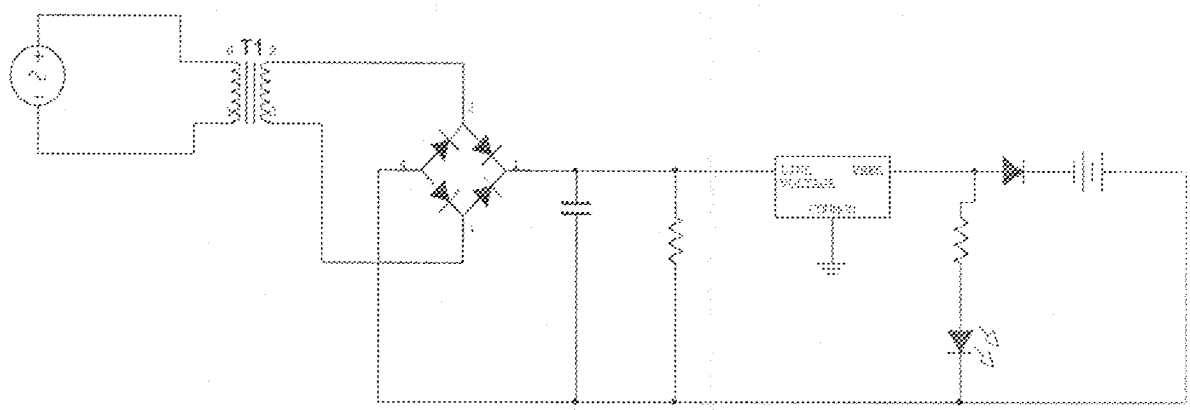

Fig 3.4: circuit diagram of the battery charging unit

3.3.1 DESIGN SPECIFICATION

Battery rating = 120Ah

Voltage rating= 12V

Given that the filtered d.c output voltage of the rectifier $V_{d.c}$ is 15V

The voltage regulator regulate the voltage to 5V, hence it

Cut off = 15 – 5

= **10 V**

Vout of the regulator is 5V

Considering the diode D_5 which stops the flow of current in the opposite direction from the battery, V_d is voltage drop across the diode D_5

V_d = 0.85 V

Given that,

V_c = battery charging voltage

V_{out} = output voltage = 4.15 V

V_r = rated voltage of the battery = 12 V

Hence, battery charging voltage

$V_c = V_{out} - V_r$

$V_c = 12 - 4.15$

Charging voltage, V_c is 7.85 V

3.4 INVERTER UNIT

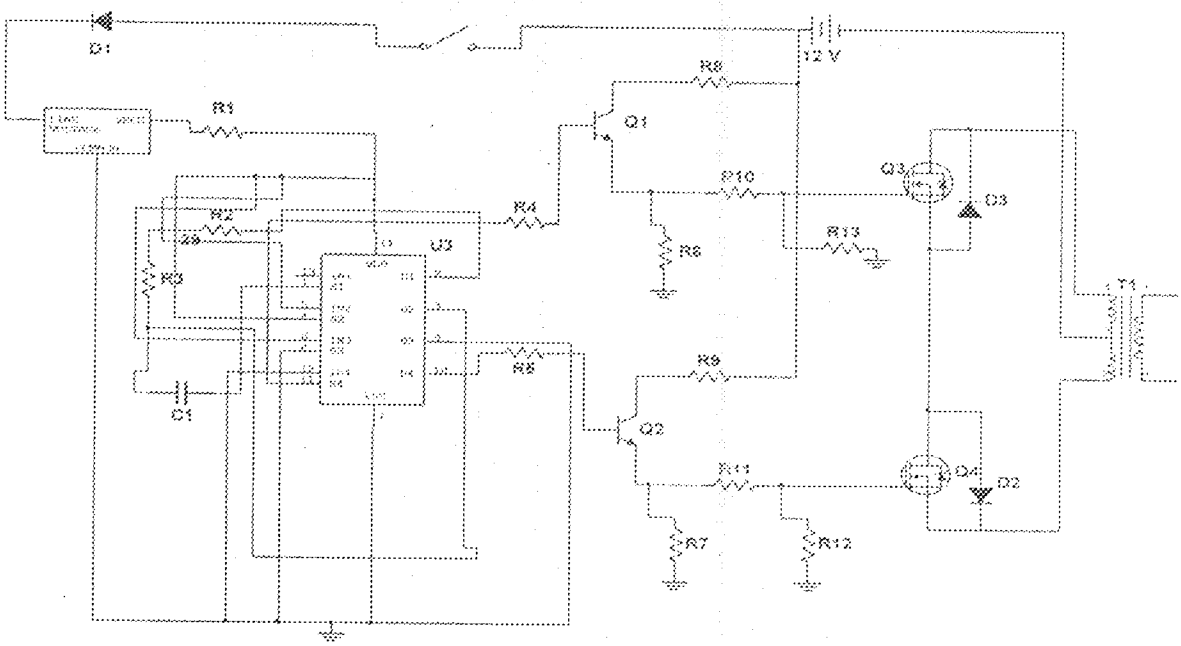

Fig 3.5: circuit diagram of inverting unit

3.4.1 DESIGN SPECIFICATION

Input voltage = 12V D.C [battery]

Output voltage = 240V A.C

Frequency = 50Hz

This unit consists of an IC-CD4047 was configured in the mono/astable mode, 4 (70N06) power mosfets were used as switches.

Calculation of input power [P_{in}]

Inverter rating = $2KVA$

Output power = $2000VA$

V_{out}[Output voltage] = $230V_{a.c}$

$V_{d.c}$ = 12V

$Using, P_{in} = I_{in}V_{in}cos\,\varphi$

Where, $I = \frac{P}{V}$

$I_{in} = [\frac{P_{in}}{V_{in}}]cos\varphi$.

Let input power = output power

$V_{d.c}$ is the voltage of the 12V battery, due to the internal resistance in the cells of the battery; we assume a voltage drop of 0.3V

$V_{d.c} = 12 - 0.3$

$= \mathbf{11.7V}$

$I_{in} = \frac{P_{in}}{V_{in}}$

Where

P_{in}= 2000VA and $V_{in} = V_{d.c}$= 11.7 V

$I_{in} = \frac{2000}{11.7}$

$I_{in} = 170.9A$

Current through the Mosfets at full load

$= \frac{170.9}{4}$

=42.74A

3.5 INVERTER / OUTPUT TRANSFORMER

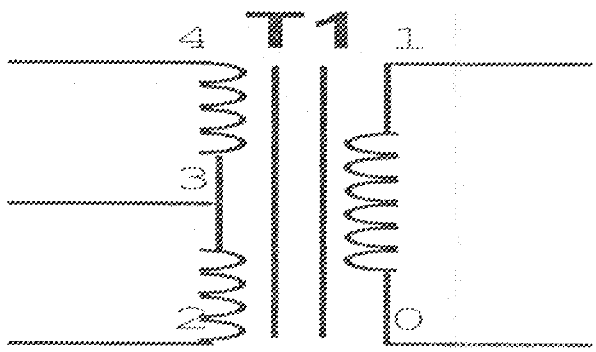

Fig 3.6: circuit symbol of center-tap inverter/output transformer

This is a center-tap transformer that steps up the 12V d.c from the output of the battery to the desired 230Va.c

3.5.1 CONSTRUCTIONAL DETAILS

At the start of designing, the primary voltage, secondary voltage and secondary current must be specified;

Let, primary voltage = 230V

Secondary voltage = 12V

Secondary current = 20A

The cross section area of the core is given by

$$\text{Core area} = 1.152 \times \sqrt{[output\ voltage \times output\ current]}$$

$$= 1.152 \times \sqrt{[12 \times 20]}$$

$$= 17.847\, sq.cm$$

For deciding the number of windings in primary and secondary, we calculate the turns per volt, which is given by

$$\text{Turn per volt} = \frac{1}{[4.44 \times 10^{-4} \times freq \times core\ area \times flux\ desity]}$$

Given frequency = 50Hz and flux density = 1.0Wb/sq.m

$$\text{Turn per volt} = \frac{1}{4.44 \times 10^{-4} \times 50 \times 17.845 \times 1.0}$$

= 2.52

The primary current is calculated by,

$$\text{Primary current} = \frac{[output voltage \times output amperes]}{[primary volt \times efficiency]}$$

$$= \frac{[12 \times 20]}{[230 \times 0.85]}$$

= 1.23A

The wire diameter depends on the current to be supplied and the allowable current density of wire, thus

Let input power = output power

$$E_s = e.m.f\ of\ secondary\ side\ of\ transformer = 230V$$

$$E_p = e.m.f\ of\ primary\ side\ of\ transformer = 12V$$

$$N_s = number\ of\ turns\ in\ secondary\ side\ of\ transformer = 25\ turns$$

$$N_s = number\ of\ turns\ in\ primary\ side\ of\ the\ transformer$$

$$\mathrm{K} = transformormation\ ratio$$

$$Gauge\ size = \frac{E_s}{E_p} = \frac{N_s}{N_p} = K$$

To find the number of primary turns, N_p

$$\frac{E_s}{E_p} = \frac{N_s}{N_p}$$

$$N_p = \frac{E_s}{E_p} \times N_s$$

$$= \frac{230}{12} \times 25$$

= 480 turns

Number of turns in primary side of the transformer = 480 turns

Primary window area

$$= \frac{primary\ turns}{turn\ per\ sq.cm}$$

$$= \frac{480}{286}$$

= 1.68 sq.cm

While the secondary window area

$$= \frac{secondary\ turns}{turn\ per\ sq.cm}$$

$$= \frac{25}{215}$$

= 1.16 sq.cm

Some insulation area is required for the former and the insulation between the windings this extra area is considered to be 30%. The space for insulation is:

Space for insulation = 30% of [primary winding area + secondary winding area]

= 0.3 × [1.68 + 1.16]

= 0.852

The total window area is given by

Total window area = primary window area + secondary winding area +space for insulation

= 1.68 + 1.16 + 0.852

= 3.692 sq.cm

The gross core area = $\frac{core\ area}{core\ stacking\ factor}$

$$= \frac{17.845}{0.9}$$

= 19.83 sq.cm

Usually the core of E and I shape are preferred and the tongue width is given by

Tongue width $= \sqrt{[gross\ core\ area]}$

$$= \sqrt{19.83}$$

= 4.45 cm

The stack height of the core is given by;

Stack height $= \frac{gross\ core\ area}{actual\ tongue\ width}$

$$= \frac{19.8277}{4.4582}$$

= 4.45 cm

For the transformer having input of **230V**, output of **12V** and secondary current of **20A**.

The number of turns in the primary winding is **450 of 24 SWG**

The number of turn in secondary winding is **25 of 14 SWG**

The numbers of lamination core used is **89**

3.6 METHODOLOGY

The following methodology was used to achieved the project.

I. The project was first simulated on a workbench to confirm its efficiency

II. The project was divided into three units namely

- Power supply unit,
- Inverting unit and
- Charging unit

III. The mains power supply was rectified and its output is also used to charge the battery when there is no power supply in the mains.

IV. The inverting unit comprises of the oscillating and switching unit. The oscillating unit comprises of the pulse generator which switches on and off a set of power mosfets connected in parallel, powered by a 12V battery. The output of the inverting unit is fed into a centre-tapped power transformer that amplifies the 12Vd.c to the required 230V and was tested okay.

V. The project was finally packed after tested okay

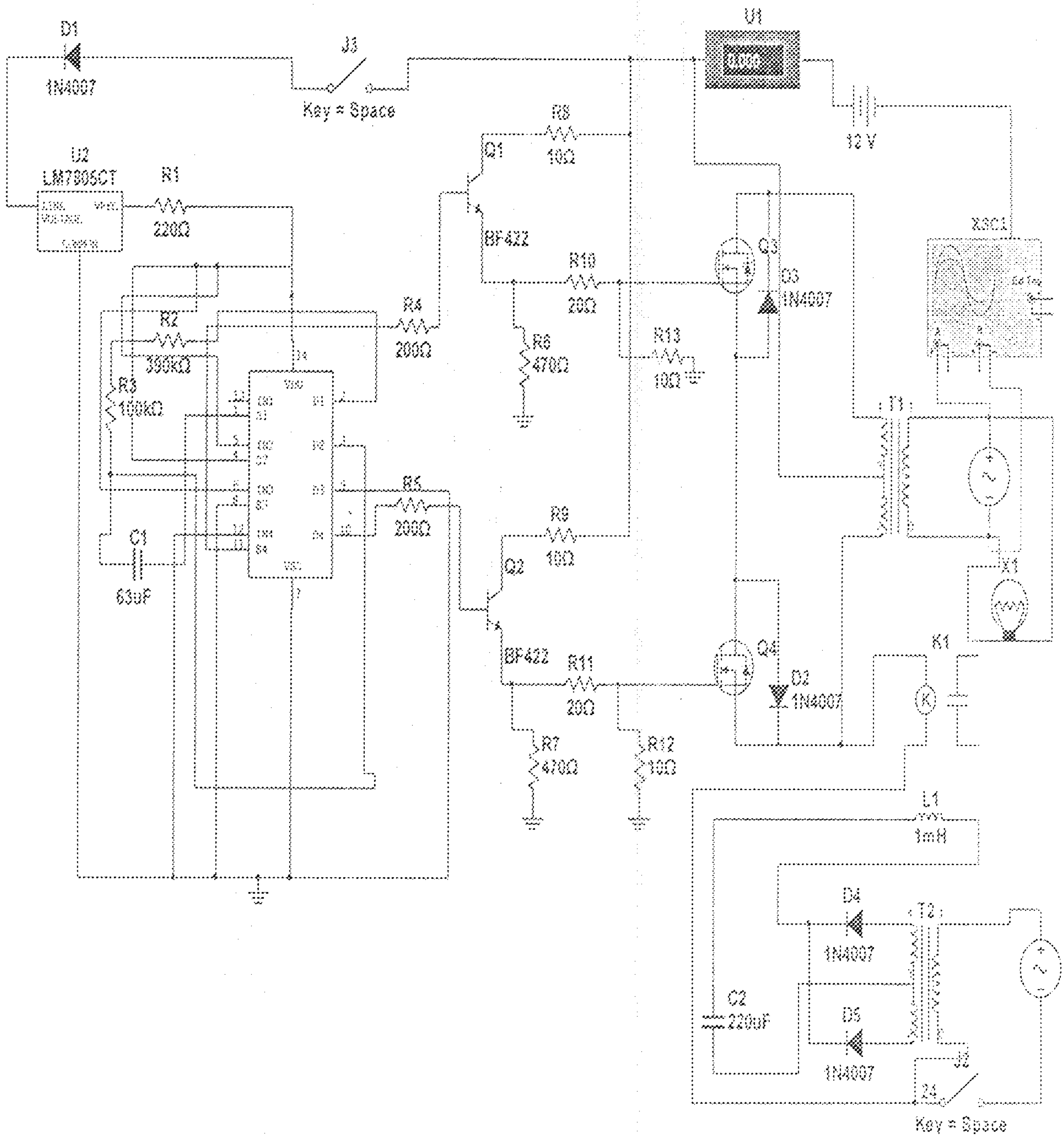

Fig 3.7: complete circuit diagram of the inverter system

CHAPTER FOUR

4.1 CONSTRUCTION PROCEDURE

The circuit components were first simulated on the computer according to the circuit diagram and the output voltage was tested.

The power mosfets were mounted on aluminium heat sinks as a result of heat dissipated by the power mosfets is high..

Having ensured proper connection of all the components, the inverter was connected to a 12V- 120Ah car battery.

4.2 TESTING

The output waveform of the inverter was tested; also the output waveform of the inverter was tested. It is a square wave.

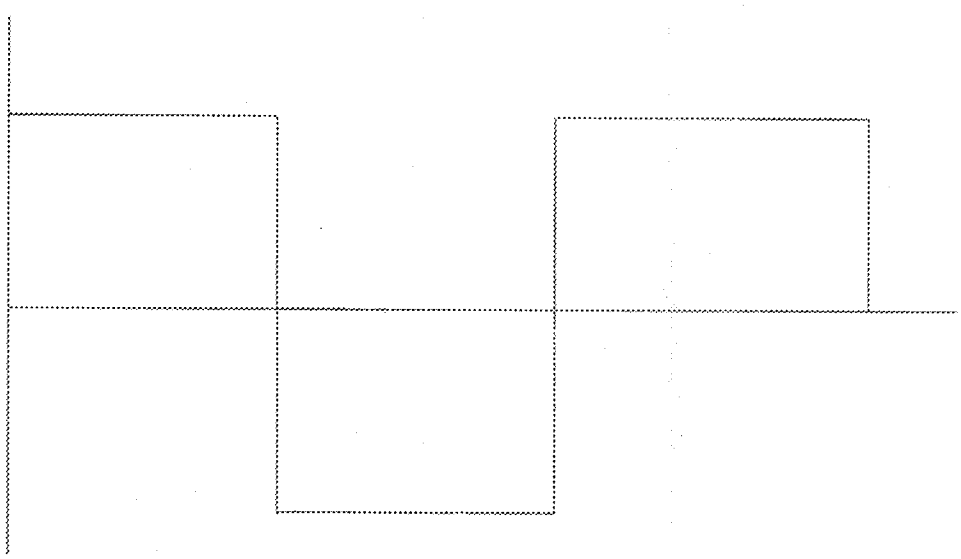

Fig 4.1: output waveform of the inverter

4.3 RESULT

Given below are the various loads applied to the output of the inverter,

APPLIANCE	POWER CONSUMPTION	
	[WATTS]	[VA]
21" Colour Television	60	48
DVD Player	40	32
Incandescent bulbs	60	48
Fluorescent tube 61cms	20	16
Fan	60	48
Personal Computer	200	160
Radio	15	12
Mosquito repellent	5	4
Fluorescent tube 122cms	40	32

Table 4.2: Power rating of some appliances

4.3.1 POWER CONSUMPTION BY SOME APPLIANCES FOR THE PERIOD OF SOME HOURS.

Given that, I= current;

P= power rating of appliance

V= voltage output = 230V

Car battery rating of 120Ah

In a room, where we have the following electrical and electronic appliances.

i.A computer system of power rating of 160VA

ii.A coloured television set of power rating of 48VA

iii.A DVD player of power rating of 32VA

iv.A fan of power rating of 48VA

v. A fluorescent tube, 61cm of power rating of 16VA

Power consumption for the whole room will be,

$$I = \frac{P}{V}$$

P = total power rating of all appliance = 304VA

V = voltage output = 230V

Therefore, current $I = \frac{304\ VA}{230\ V}$

$= 1.322A$

Using two 12V-60Ah battery connected in series that will generate a current of 120Ah to achieve longer time,

For 1hr 30minutes, power supply will consumed

$1.322 \times 90 = 119Ah$

Calculating, the power consumption for individual appliances

I. For a 21" Colour Television [48VA]

$$I = \frac{P}{V}$$

$$I = \frac{48}{230} = 0.209A$$

For 9hrs, power supply will consumed

0.209 × 540 = 113Ah

II. For a DVD set [32VA]

$$I = \frac{P}{V}$$

$$I = \frac{32}{230} = 0.139A$$

For 12hrs, power supply will consumed

$0.139 \times 720 = 101Ah$

III. For a personal computer [160VA]

$$I = \frac{P}{V}$$

$$I = \frac{160}{230} = 0.696A$$

For 2hrs 30minutes, power supply will consumed,

$0.696 \times 150 = 105Ah$

IV. For a fan [48VA]

$I = \frac{P}{V}$

$I = \frac{48}{230} = 0.209A$

For 9hrs, power supply will consumed

$0.209 \times 540 = 113Ah$

V. For a radio [12VA]

$I = \frac{P}{V}$

$I = \frac{12}{230} = 0.052A$

For 24hrs, power supply will consumed

$0.052 \times 1,140 = 75Ah$

V. For incandescent bulb [48VA]

$I = \frac{P}{V}$

$I = \frac{48}{230} = 0.209A$

For 9hrs, power supply will consumed

$0.209 \times 540 = 113Ah$

VII. For fluorescents [32VA]

$$I = \frac{P}{V}$$

$$I = \frac{32}{230} = 0.139A$$

For 12hrs, power supply will consumed

$0.139 \times 720 = 101Ah$

The table below shows the power consumption of individual appliance tested

APPLIANCE	POWER CONSUMPTION [VA]	APPLIANCE RUNTIME [HOURS]	AMPERE HOUR RATING OF BATTERY
21" Colour Television	48	9	113
DVD Player	32	12	101
Incandescent bulbs	48	9	113
Fluorescent tube 61cms	16	24	100
Fan	48	9	113
Personal Computer	160	2.5	105
Radio	12	24	76
Mosquito repellent	4	96	102
Fluorescent tube 122cms	32	12	101

Table 4.2 Appliance runtime of various appliances tested

4.4 DISCUSSION OF RESULT

From the result obtained from the above, it could be inferred that the inverter is an efficient source of electrical power generation. It was also observed that the inverter has a number of advantages over the generator such as,

I. Automatic change over, hence no delay

II. It is noiseless

III. It doesn't emit fumes

The inverter can power various load depending on the ratting of the load. To achieve a longer time, the inverter should be powered by high capacity batteries, strings of batteries connected in parallel, or a battery bank

CHAPTER FIVE

5.1 CONCLUSIONS AND DISCUSSION

Clearly, despite the type of the outcome of a research and development project of this kind, conclusions can be drawn that will aid further research into the area. This project provides considerable ground for additional research – in a number of areas – and also brings to light some lessons to be learned in switch-mode power supply design.

This project was aimed at providing an alternative to the mains power supply. It was also aimed to provide a solution to the erratic nature of power supply in the country.

The inverter can supply power to most household appliances for a period of time that is directly proportional to the ampere hour rating of the battery. To achieve a longer time of power supply, battery banks are required. The inverter has proved to be cheap alternative to generators

This project was clearly not as successful on the surface as was originally hoped. Despite this, many conclusions can be drawn that place the results of this project in a more 'successful' light.

In conclusion, this thesis needed to be more thoughtfully planned from inception – and would benefit greatly from the attention of more than one student in future years.

5.2 PROJECT SUMMARY

This project work has covered the research, development and testing of an inverter system capable of producing 230VAC from a 12V DC source.

The literature review covered recent literature concerning power inverters, their control and some of the recent advances in circuit and component design that can be used to increase the inverters performance and reliability.

The literature review chapter was followed by a detailed design explanation – that covered each stage in detail and outlined the major design decisions that were made. This thesis then covered the results obtained from the inverter system – and highlighted the areas success and failure of each stage. The appendices contain complete circuit schematics, block diagram, tables and figures

5.3 LIMITATIONS

During the course of writing this project work, the following problems were encountered,

I. Sometimes, some of the components obtained operate below the specified ratings; hence they are destroyed as soon as they are powered

II. Difficulties in obtaining the required ratings

III. Inconsistencies between theoretical calculations and practical values

5.5 FUTURE WORK

The future work of most interest of this type depends on what the following students see as the ultimate aim of a power inverter – for example, a power inter system with Microcontroller application, UPS applications or remote power supply applications.

At the conclusion of this project, I see the most valuable path being the pursuit of a Microcontroller application. This provides significant ground for future work – as most Microcontroller systems are very intelligent control systems.

Despite this, there is great potential for an inverter of this type, in this new era of 'clean' electricity – the demand for intelligent and efficient inverters of this type will be growing rapidly.

5.6 RECOMMENDATIONS

For further advancement, the following are recommended

I. The use of pulse-width modulation for inversion. it is a better method for DC to AC conversion

II. The use of battery banks is encourage to achieve a longer period of power supply

III. The charging unit should be designed to be able to deliver a high charging current so that battery banks could be charged on time.

TROUBLE-SHOOTING OF 2KVA INVERTER SYSTEM

I. If inverter is dead

Check the transformer T1, IC-CD4047 terminals, relay RL1& RL2, transistor R6, R7, R12, and R13

II. The output voltage is not stable

Check the Voltage Regulator, diode D1, resistor R1, capacitor C1, Mosfets

III. Change Over does not work

Check relay RL1& RL2, transformer T1& T2, transistor R4, R5, R8, R9, R10, R11

IV. Battery charging not functioning

Check transformer T1, diode D2- D5, VR1, IC-CD 4047, Mosfet Q1- Q4

V. Inverter fails to shut down when mains AC returns

Check VR1, IC-CD4047, relay R1& R2, capacitor C1, transistor R4- R12

VI. Strange noise when inverter in working

Check transformer T1, diode D2& D3, Mosfets Q1- Q4

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