DESIGN OF 240V SQUARE WAVE INVERTER

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“I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drives).”

Signature : ………………………………………………

Supervisor’s Name : ……………………………………………….

Date : ……………………………………………….

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references.."

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Name : …………………………………..
Date : …………………………………..

Dedicated to my beloved parents …

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ABSTRACT

A dc-ac converter is a circuit that converts the dc voltage supply to an ac voltage output and this converter also known as inverter. Inverter is used in many types of industrial and commercial applications especially in dc–ac conversion, ac motor drives, system controls and *Uninterruptible Power Supply* (*UPS*). This project combines the knowledge of electrical and electronic. The objective of this project is to design *Quasi Square Wave Inverter* that supply 240 Vac which controlled by four switches of MOSFET (*Metal Oxide Semiconductor Field Effect Transistor*). The MOSFETs also are controlled by gate drive circuits. The project is started with simulation of inverter circuit by using OrCad software to get the waveform of output and switching of MOSFET. The hardware circuit is then constructed and the output waveforms are shown by oscilloscope. This project will include operation, analysis, control strategy and experimental result based on the software and hardware implementation.

ABSTRAK

Penukar a.t-a.u (penukar arus terus kepada arus ulang-alik) atau *dc-ac converter* adalah suatu litar yang menukarkan bekalan voltan arus terus kepada suatu voltan keluaran arus ulang-alik pada beban dan secara umumnya ia dikenali sebagai *inverter*. Inverter banyak digunakan di dalam aplikasi industri dan komersil terutamanya di dalam penukaran a.t-a.u, pemacuan motor arus ulang alik, sistem kawalan dan *Uninterruptible Power Supply* (*UPS*). Projek ini menggabungkan pengetahuan elektrik dan elektronik. Objektif projek ini adalah membangunkan *Quasi Square Wave Inverter* yang dapat membekalkan 240 Va.t dengan kawalan 4 suis MOSFET (*Metal Oxide Semiconductor Field Effect Transistor*). MOSFET tersebut juga dikawal oleh litar *gate drive*. Projek dimulakan dengan simulasi litar *inverter* menggunakan perisian OrCad untuk mendapatkan bentuk gelombang bagi keluran dan pensuisan bagi MOSFET. Litar perkakasan (*hardware circuit*) kemudian dibina dan bentuk gelombang keluaran ditunjukkan oleh osiloskop. Projek ini mengandungi operasi, analisis, strategi kawalan dan keputusan eksperimen berdasarkan pelaksanaan bagi perisian dan perkakasan projek

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ATTACHMENTS

CHAPTER 1

INTRODUCTION

1.1 Introduction

Inverter is a dc-to-ac converter. The function of an inverter is to change a dc input voltage to a symmetric ac output voltage of desired magnitude and frequency like the general block diagram shown at figure 1.1 below. Depending on the input dc voltage range in comparison to the output ac voltage, inverters also can be buck inverters, boost inverters, or buck-boost inverters. The applications of the inverter are power conversion from variable dc voltage into fixed ac voltage for stand-alone applications or ac current output following the grid voltage and frequency for grid-connected applications.

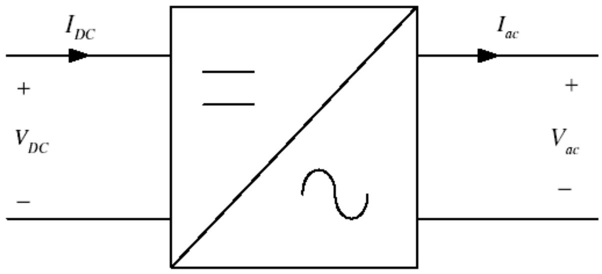

Figure1.1 General Block diagram of Inverter

Figure 1.2 below show the ac output voltage is obtained by alternatively closing of switch pairs S_1-S_2 and S_3-S_4

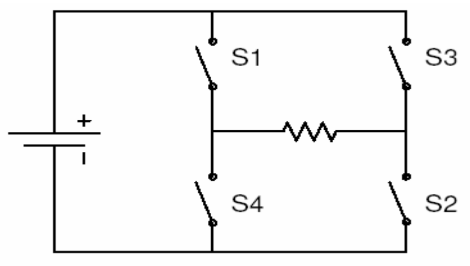

Figure1.2 Equivalent circuit

Inverters are widely used in industrial applications such as:

a. variable-speed ac motor drives
b. induction heating
c. traction
d. standby power supplies
e. uninterruptible power supplies

The input may be a battery, fuel cell, solar cell or other dc source. Inverters can be broadly classified into two types;

a. single phase inverters
b. three phase inverters

Each type can be controlled by turn-on and turn-off devices such as:

a. MOSFET (metal oxide semiconductor field-effect transistors)
b. IGBT (insulated-gate bipolar transistors)
c. BJT (bipolar junction transistor)
d. MCT (metal-oxide semiconductor-controlled thyristor)
e. SIT (static induction transistor)
f. GTO (gate-turn-off thyristor)

The output voltage waveforms of ideal inverters should be sinusoidal. However, the waveform of practical inverters are non sinusoidal and contain certain harmonics. With the availability of high-speed power semiconductor devices, the harmonic contents of output voltage can be minimized or reduced significantly by switching techniques.

There are three major waveforms of inverter which are square-wave, modified sine-wave (quasi sine wave) and true sine-wave. **Square wave inverters** are largely outdated, as the waveform shape is not well suited for running most modern appliances, and prices have come down considerably for the superior modified sine wave and true sine wave types running some type of electrical tools and motors and incandescent lights.

Modified Sine Wave Inverters is designed to have characteristics similar to the sine wave shape of utility power. A waveform of this type is suitable for most AC loads, including linear and switching power supplies used in electronic equipment, transformers, and motors. This waveform is much better to the square wave produced by many other dc to ac inverters. The least expensive type of modern inverter produces modified sine wave power. The waveform looks like a stair-step, where the power rises straight from zero to upper peak voltage, straight back to zero, and straight to lower peak voltage, resting at each point for a moment.

Modified sine wave inverters will run many household appliances such a televisions, radios, washers, dryers and microwaves (or some that use electronic timing for cycling) with occasional minor electrical "noise" present. The quasi square wave inverter is inherently smaller, simpler and more reliable and efficient than the sine wave inverter. The only apparent disadvantage is a 3 to 5 percent loss in motor efficiency and the performance degradation. Variations in induction motor performance may occur when a motor is driven from a quasi square wave inverter rather than a sine wave source. It will use about 20% more power with a modified sine wave than with a true sine wave. The performance difference may be a change in speed, maximum torque or maximum power capability depending on the motor power factor and inverter configuration.

Sensitive equipment like battery chargers, tools with variable speed motors, laser printers and certain heating controllers will run erratically or not at all with modified sine wave power. For a remote cabin with only the "basics" running on the electrical system, a modified sine wave inverter is an economical choice. Most computers, TV's and similar items will have no problem.

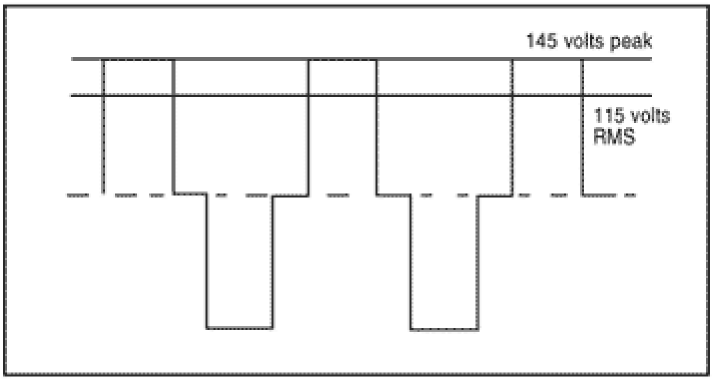

Figure 1.3: Modified Sine Wave

The power supplied by utility companies and engine generators is a **true sine wave** form. This is the most reliable waveform for household use. True sine wave power passes from the upper and lower peak voltages in a smooth curved wave, rather than the stair-step of the modified sine wave. All appliances and electronic equipment will run as intended when using sine wave power. True sine wave inverters will produce AC power as good as or better than utility power, ensuring that even the most sensitive equipment will run properly. While sine wave inverters are more expensive than modified sine wave models which shown as figure 1.3 above, the quality of their waveform can be a definite advantage.

For office buildings considering a backup power inverter, a true sine wave model will allow proper function of all electronic office equipment and fluorescent lighting. For residential power, anyone using battery chargers, electric drills, digital clock radios or other sensitive electronics should consider a true sine wave inverter to ensure proper function of all household appliances. Figure 1.4 below, show modified sine wave and true sine wave.

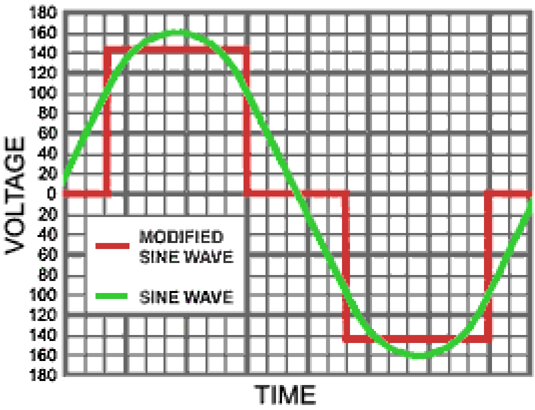

Figure 1.4: Modified sine wave and true sine wave

A dc-ac converter is a circuit that converts the dc voltage supply to an ac voltage output and this converter also known as inverter. The function of an inverter is to change a dc input voltage to a symmetric ac output voltage of desired magnitude and frequency.

This project is to design *Quasi Square Wave Inverter* that supply 240 Vac which controlled by four switches of MOSFET (*Metal Oxide Semiconductor Field Effect Transistor*). The MOSFETs also are controlled by gate drive circuits.

Inverter is used in many types of industrial and commercial applications especially in dc–ac conversion, ac motor drives, system controls and *Uninterruptible Power Supply* (*UPS*).

This project will include operation, analysis, control strategy and experimental result based on the software and hardware implementation.

1.2 Problem statement

This project can be upgraded by designing a fly back converter circuit that will be a supply to this quasi square wave inverter. The converter circuit can implement a high frequency transformer that is small in size and weight rather than low frequency transformer since the size and weight for high frequency transformer is approximately half than a low frequency transformer. Therefore, it can replace the 240 V DC power supplies that had being used in this project which is larger in size and weight.

There should be a feedback controller for this inverter circuit. It is very useful in practical because in real situation, the power output will always changing with the change of load. When the load is changing then the output voltage will also change. Therefore this feedback controller circuit will regulate the dc input voltage to the inverter in order to fix it at the required voltage.

The quasi square wave output waveform has to be changed with the sine wave because in most application a pure sine wave output is required. Therefore the switching scheme at the inverter drive circuit has to be changed with the PWM (Pulse Width Modulating) switching scheme.

Quasi square waveform is inherently generated in a three-phase inverter bridge by switching the transistors on and off at the proper intervals therefore, the resulting inverter is smaller, lighter weight, and simpler, implying greater reliability and lower cost. These advantages invite a closer look at inverter-motor systems, particularly for space flight. The only apparent disadvantage is a 3 to 5 percent loss in motor efficiency and the performance degradation discussed later. Methods to eliminate the performance degradation, which depends somewhat on the switching drive to the bridge transistors, are discussed, and test results are presented.

Variations in induction motor performance may occur when a motor is driven from a quasi square wave inverter rather than a sine wave source. The performance difference may be a change in speed, maximum torque, or maximum power capability depending on the motor power factor and inverter configuration. Motor operation is normally changed very little at loads less than rated for the motors tested (most induction motors are rated at less than 70 percent peak torque). Motors with power factors greater than 0.7 show a marked decrease in peak torque and power output as a direct result of fundamental voltage drops caused by waveform variations in 120 degree drive inverters.

1.3 Objective

The objectives of this project are:

a) Develop a quasi square wave inverter and analysis the circuit.
b) Build in small size and weight.
c) Upgrade the present hardware of a quasi square wave inverter by using dead time circuit, gate drive circuit and (MOSFET).
d) Calculate the theoretical values of inverter and compare it with simulation result.
e) Simulate the circuit using OrCad software and develop the hardware circuit.

1.4 Scope

The construction of this project will use full bridge inverter which is converting input voltage of 24Vdc to output voltage of 240Vac. The inverter designed will consists of dc power supplies circuit, dead time circuit, step up transformer, and gate drive circuit. Analyses of quasi square wave inverter performance and characteristic.

1.5 Expected Output

At the end of this project, overall size of the circuit in this project is quite small while the gate drive circuit diodes are connected in anti-parallel with the switches a distinction must be mode between the on states versus the conducting state of the switch.

The project will construct new circuit that present a quasi square wave by using gate drive circuit. In addition, the simulation of inverter circuit shows the result as precise as the theory. Moreover, the hardware circuits also can show the waveform like the simulation result.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The chapter describes about literature review. A literature review is an evaluate report information found in the literature research to the related area of study. The literature review part will describe domain related with the project and existing system that related to the project. Figure 2.1 and figure 2.2 below shows basic diagram for whole operation and block diagram of inverter.

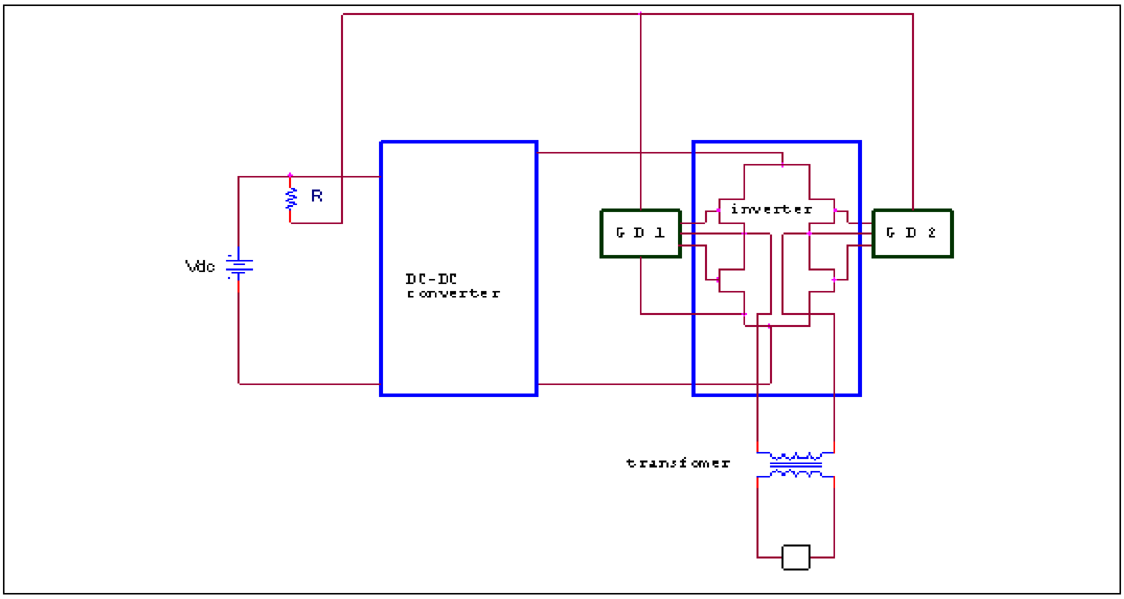

Figure 2.1: Basic diagram of the whole operation

BLOCK DIAGRAM

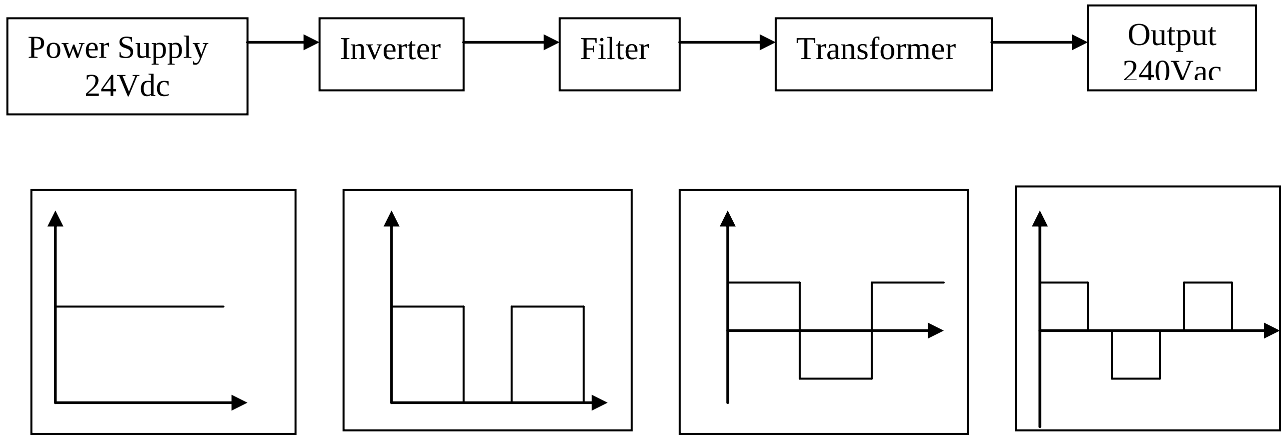

Figure 2.2: Block diagram of inverter

2.2 Introduction to Inverter

The output voltage could be fixed or variable at a fixed or variable frequency. A variable output voltage can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant. If the dc input voltage is fixed and it is not controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse-width modulation (PWM) control within the inverter. The inverter gain may be defined as the ratio of the ac output voltage to the dc input voltage.

There are three inverter types:

1. *Voltage Source Inverter (VSI)* – creates an ac voltage and current from a dc voltage source
2. *Current Source Inverter (CSI)* – creates an ac voltage and current from a dc current source
3. *Resonant Inverter* – the load is involved in a series resonant circuit in order to produce a high frequency sine wave ac voltage

If the output voltage or current of the inverter is forced to pass through zero by creating an *LC* resonant circuit, this type of inverter is called *resonant-pulse inverter* and it has wide applications in power electronics.

The Voltage Source Inverter (VSI) is divided into three general categories:

1. *Pulse-width-modulated inverter*

The input dc voltage is essentially constant in magnitude. A diode rectifier is used to rectify the line voltage. Therefore the inverter must control the magnitude and frequency of the ac output voltages. This is achieves by PWM of the inverter switches and hence such inverters are called PWM inverters. PWM provides a way to decrease the Total Harmonic Distortion (THD) of load current. This method generally meet THD requirement more easily than the square wave switching scheme. The unfiltered PWM output will have relatively high THD but the harmonics will be at much higher frequencies than for a square wave, making filtering easier. In PWM, the amplitudes of the output voltage can be controlled with the modulating waveforms. Control of the switches for PWM output requires:

a. a reference / modulating / control signal
b. carrier signal (triangular wave that controls the switching frequency)

The advantages of PWM are:

a. reduction in filter requirements to decrease harmonics
b. easier to control the output voltage amplitude

The disadvantages of PWM are:

a. complex control circuit for the switches
b. losses increase due to more frequent switching

2. Square-wave inverters

The dc input voltage is controlled in order to control the magnitude of the output ac voltage. Therefore the inverter has to control only the frequency of the output voltage. The output ac voltage has a waveform similar to a square wave so these inverters are called square-wave inverters.

3. *Single-phase inverters with voltage cancellation*

In case of inverters with single-phase output, it is possible to control the magnitude and the frequency of the inverter output voltage, even though the output to the inverter is a constant dc voltage and the inverter switches are not pulse-width modulated (and hence the output voltage wave shape is like a square wave). Therefore this inverter combines the characteristics of the previous two inverters. The voltage cancellation technique works only with single-phase inverters and not with three-phase inverters. Mainly three Voltage Source Inverter circuit topologies are used:

1. *Full Bridge Inverter* - most powerful circuit. The voltage across the transistor is equal to supply voltage. The load could be ac supplied via transformer
2. *Half Bridge Inverter* - circuit uses the half of dc supply voltage. Hence, its output voltage and power are twice less than compared to other circuits

Push Pull Inverter - allows easy transistor driving but requires a transformer and transistor voltage is twice higher. The output voltage depends on transformer ratio

2.2.1 Dc-Dc Converter

In many industrial applications, it is required to convert a fixed-voltage dc source into a variable-voltage dc source. A dc-dc converter converts directly from dc to dc and is simply known as a dc converter. Dc converters are widely used for traction motor control in electric automobiles, trolley cars, marine hoists, forklift trucks and mine haulers. They provide smooth acceleration control, high efficiency and fast dynamic response. Dc converters are used in dc voltage regulators and also are used in conjunction with an inductor to generate a dc current source especially for the current source inverter.

Dc converters can be used as switching-mode regulators to convert a dc voltage, normally unregulated to a regulated dc output voltage. The regulation is normally achieved by PWM at a fixed frequency and the switching device is normally BJT, MOSFET or IGBT. But the output of dc converters with resistive load is discontinuous and contains harmonics. The ripple content is normally reduced by an *LC* filter.