DEVELOPMENT OF A LOAD-BALANCED INVERTER

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ABSTRACT

An inverter is an electrical device that can convert Direct Current (DC) into Alternating Current (AC) by using high frequency switching and power capabilities combined with complex control techniques. Inverter is a useful energy generation technology as it is one of the methods to practice green technology. It also can be used as an alternative energy source for rural area where the cost for grid connection is very expensive because of distance or geographical factor. A DC-AC inverter that is reliable for daily usage must be consistent with load connected and it should have an efficient energy production. This includes all factors such as the pure sine wave output so that it can be used with sensitive electronic equipment. The output need to be steady with increasing load without voltage drop. The design of a load-balance inverter best to have a feedback system which can monitor the output produced as it can calibrate according to the changes on load. The inverter open loop design should be practice before the close loop implementation. A prototype of the DC- AC open loop inverter will be build based on this statement. Battery or solar panel can be use to provide the input DC rail. Filter will be integrated with the design so that it can have a smooth AC signal that reduced in harmonics. The conversion effectiveness and harmonic level of the inverter will be observed at the inverter output. The design of this inverter hopefully can be efficient and reliable enough to provide alternative energy generation for small scale usage in rural area or during mobility demand.

ABSTRAK

Penyongsang merupakan sebuah peralatan elektrik yang boleh menukar Arus Terus (AT) kepada Arus Ulang-alik (AU) dengan menggunakan frekuensi pensuisan dan keupayaan kuasa tinggi yang digabungkan dengan teknik kawalan yang kompleks. Penyongsang adalah teknolog generasi tenaga yang berguna kerana ia adalah satu kaedah untuk mengamalkan teknologi hijau. Ia juga boleh digunakan sebagai sumber tenaga alternatif bagi kawasan luar bandar di mana kos untuk sambungan grid adalah mahal kerana jarak atau faktor geografi. Sebuah penyongsang AT-AU yang boleh dipercayai untuk kegunaan harian mestilah selaras dengan beban yang berkaitan dan ia harus mempunyai pengeluaran tenaga yang cekap. Ini termasuk semua faktor-faktor seperti keluaran gelombang sinus tulen supaya ia boleh digunakan dengan peralatan elektronik yang sensitif. Keluaran penyongsang juga haruslah stabil dengan peningkatan beban tanpa kejatuhan voltan. Reka bentuk penyongsang beban imbangan baik terbaik untuk mempunyai satu sistem maklum balas yang boleh memantau keluaran AU yang dihasilkan kerana ia boleh menentukurkan mengikut perubahan pada beban.Penyongsang gelung terbuka haruslah menjadi amalan sebelum pelaksanaan sistem gelung rapat. Sebuah prototaip penyongsang AT-AU gelung terbuka akan dibina berdasarkan kenyataan ini. Bateri atau panel solar boleh digunakan untuk menjadi input rel AT. Penapis gelombang akan disepadukan dengan reka bentuk supaya ia boleh mempunyai isyarat AU licin yang kurang harmonik.Tahap harmonik penyongsang akan diperhatikan pada keluaran akhir penyongsang. Reka bentuk penyongsang ini diharapkan boleh menjadi cekap dan boleh dipercayai mencukupi bagi menyediakan generasi tenaga alternatif untuk penggunaan berskala kecil di kawasan luar bandar atau semasa permintaan mobiliti.

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LIST OF ABBREVIATIONS

DC	Direct Current
AC	Alternating Current
PWM	Pulse Width Modulation
LC	Inductor Capacitor Circuit
MOSFET	Metal Oxide silicon Field Effect Transistor
FET	Field Effect Transistor
IC	Integrated Circuit
THD	Total Harmonics Distortion
PSpice	Personal Computer Simulation Program with Integrated Circuit Emphasis
PCB	Printed Circuit Board
FFT	Fast Fourier Transform
SMT	Surface Mount Technology

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CHAPTER 1

INTRODUCTION

1.1 Background

Energy utilization has been the main focus for every energy generation method today. This concept of energy utilization is practical for the inverter system. Inverter is a system that can convert Direct Current (DC) to Alternating Current (AC). The conversion of electrical energy from DC to AC can be achieved by high frequency switching of power electronic switches. The efficiency of the inverter can be optimized by developing a load-balance inverter. A load-balance inverter is an inverter system that can produce constant output with increasing load. The advantage of this inverter design is it can be use reliably with few additional loads without voltage drop.

1.2 Problem Statement

The open loop inverter design needs to be understood in order to construct its close loop system. The pure sine wave can be the key feature for the close loop inverter design as more equipment is sensitive toward the power quality.

1.3 Objective

The aim of this project is mainly to test the practice of inverter and develop its close loop system.Before the development of the close loop system the open loop inverter operation should be understand first.The main objectives are stated as follow:

i) To develop a prototype of DC-AC inverter
ii) To analyze the performance of the developed prototype

1.4 Project Scope

There have several scopes on achieving the objective mention and covered as the project designs on finding the suitable method to be used. This project involves the study of inverter operating topologies by simulation software and determining the output performance of the inverter system.

1.5 Thesis Outline

This thesis is organized into five chapters:

Chapter 1 consists of the overview of the project, which includes the problem statement, objectives and scope.

Chapter 2 focuses on the literature reviews for the project based on journals and other references.The inverter types, system operation, theory and common design reviewed.

Chapter 3 discusses on the project topologies and circuit design. Details on the project implementation explained later in this chapter.

Chapter 4 presents the result of the project in simulation and prototype. The discussion mainly based on the result of the prototype.

Chapter 5 concludes the overall thesis and provides some recommendation for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the basic operation of inverter will be reviewed. The theory background for the implementation of inverter system will be introduced. The switching scheme, power device and control technique are described.

2.2 Types of Inverters

2.2.1 Square Wave Inverter

This type of inverter could be harmful to some electronic equipment, especially equipment with transformer or motors. The square wave output from the inverter contain high harmonic which can lead to equipment overheating. The square wave inverter was the originator of inverter that is not relevant for modern use. [1]

2.2.2 Modified Square Wave Inverter

Modified square wave inverter is the general type of inverter in the market which available at moderate price range compared to the pure sine wave inverter model. This inverter designed to have better characteristic than square wave inverter unit while being relatively inexpensive. This inverter also does not offer the same perfect output waveform like the pure sine wave inverter. The negative factor of this inverter is the electrical noise which can prevent it from powering certain load properly. For example, many television and stereos cannot eliminate the common mode noise. When these electrical equipments powered with a modified square wave inverter it can cause “grain” or small amount of “snow” on the video or “hum” on the sound system. The appliances with timing devices, light dimmers, battery chargers and variable speed devices may not work well or may not work at all. [1]

2.2.3 Pure Sine Wave Inverter

This type of inverter can produce the electrical output waveform similar to the utility that received from the socket outlets in home or office which is highly reliable and does not produce electrical noise interference like other types of inverter. With the pure sine wave output it can be use to power sensitive loads correctly without interference. Some equipment that require the pure sine wave including computers, digital clock ,battery chargers, light dimmers ,variable speed motors, and audio/ visual equipments. The video presentation, sound system, surveillance video, telecommunications application, calibrated measuring equipment or other sensitive load must use a pure sine wave inverter. [1]

2.3 Pulse Width Modulation (PWM)

2.3.1 2-Level PWM

The most common and popular technique of digital pure-sine wave generation is pulse-width-modulation (PWM). The PWM technique involves generation of a digital waveform, for which the duty-cycle is modulated such that the average voltage of the waveform corresponds to a pure sine wave. The simplest way of producing the PWM signal is through comparison of a low-power reference sine wave with a triangle wave Figure 2.1. Using these two signals as input to a comparator, the output will be a 2-level PWM signal Figure 2.2. This PWM signal can then be used to control switches connected to a high-voltage bus, which will replicate this signal at the appropriate voltage. Put through an LC filter, this PWM signal will clean up into a close approximation of a sine wave Figure 2.3. Though this technique produces a much cleaner source of AC power than either the square or modified sine waves, the frequency analysis shows that the primary harmonic is still truncated, and there is a relatively high amount of higher level harmonics in the signal Figure 2.4.[2]

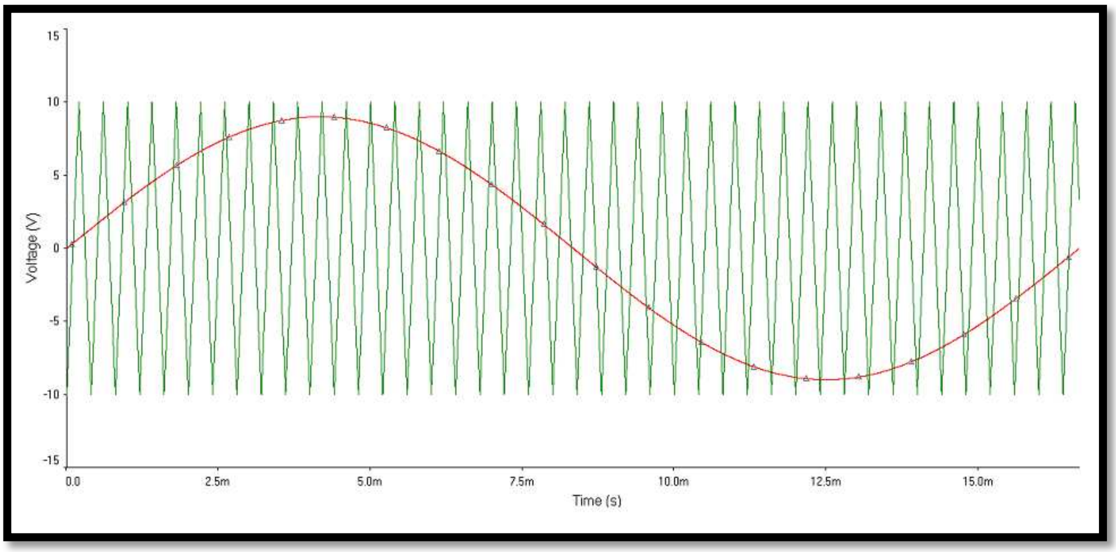

Figure 2.1 2-level PWM comparison signals [2]

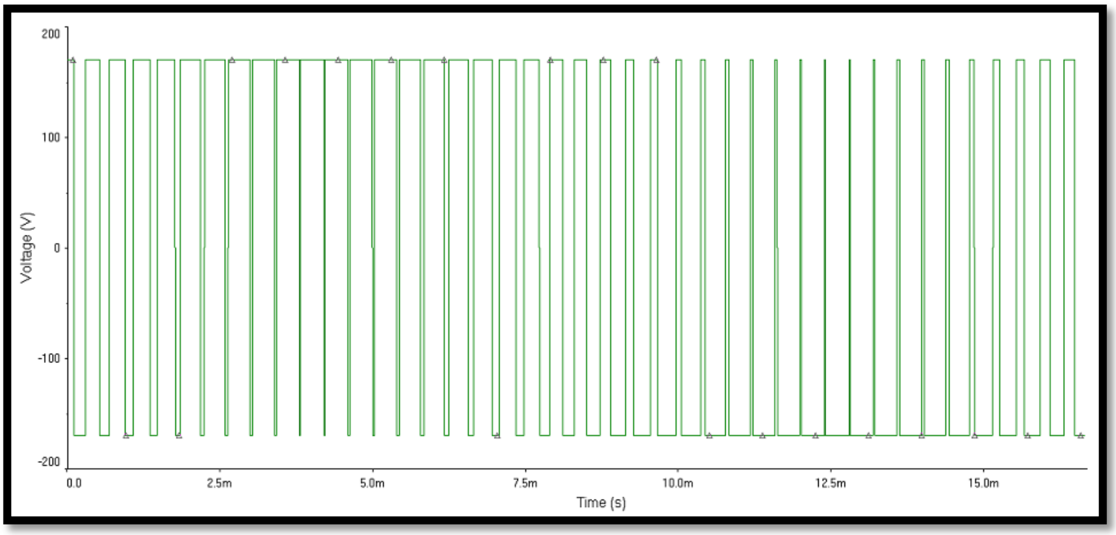

Figure 2.2 2-level PWM output (unfiltered) [2]

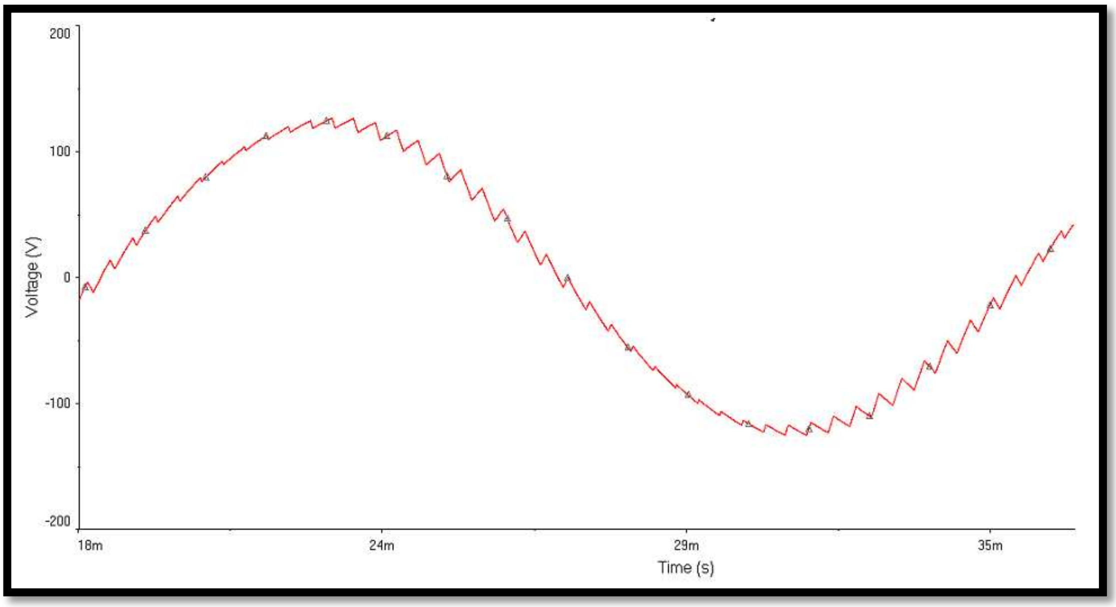

Figure 2.3 2-level PWM output (filtered) [2]

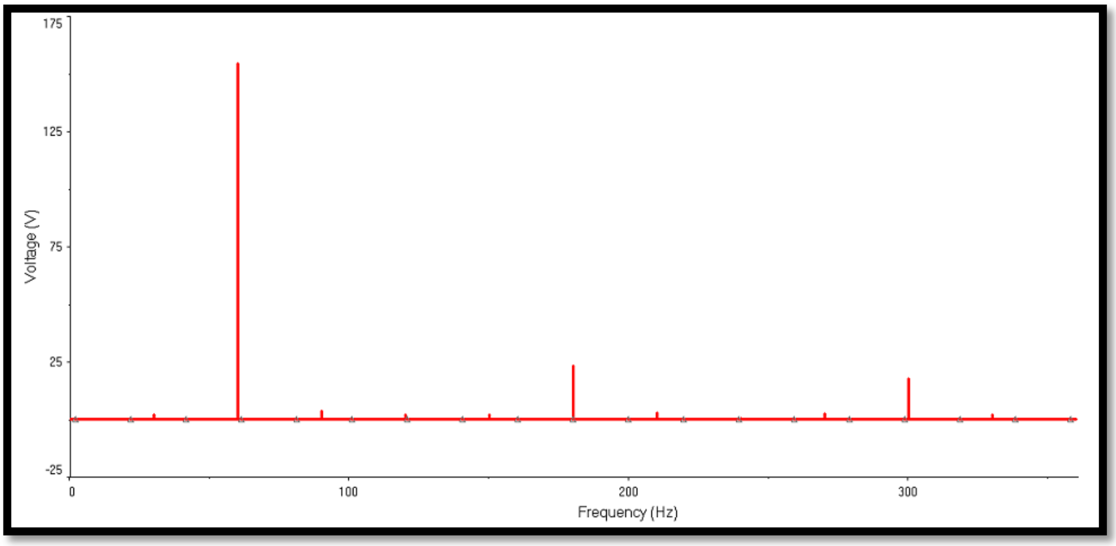

Figure 2.4 2-level PWM harmonic analysis [2]

2.3.2 3-Level PWM

In order to create a signal which is closer to a true sine wave, a 3-level PWM signal can be generated with high, low, and zero voltage levels. For the resulting 3-level PWM signal to correspond to a sine wave, the signal comparison stage must also be 3-level Figure 2.5. A triangle wave is used as it is in the 2-level PWM comparison, but it half the amplitude and summed with a square wave to compare one half of the sine reference signal at a time. The resulting PWM signal is used to control one half of an H-Bridge Figure 2.6, which controls how long the bus voltage is allowed through to the load. The other half of the H-Bridge controls the polarity of the voltage across the load, and is controlled by a simple square wave of the same frequency and in phase with the sine signal. Generally, this square wave can simply be created in a stage of the sine wave generation circuit. A virtual example of such a 3-level circuit simulated is shown in Figure 2.6. The resulting 3-level high-voltage PWM signal Figure 2.7 can be filtered into a very close approximation of the desired sine wave. The harmonic level can be noticed in Figure 2.8 as the output sine wave can be seen in Figure 2.9.It should be noted that the simulations for this technique utilized a very low switching frequency for the triangle wave, so the PWM switching frequency is also low. This was done so that the waveforms would be easy to view and understand. In reality, a switching frequency above 20 kHz would be used to keep inductance ringing outside the range of human hearing. [2]

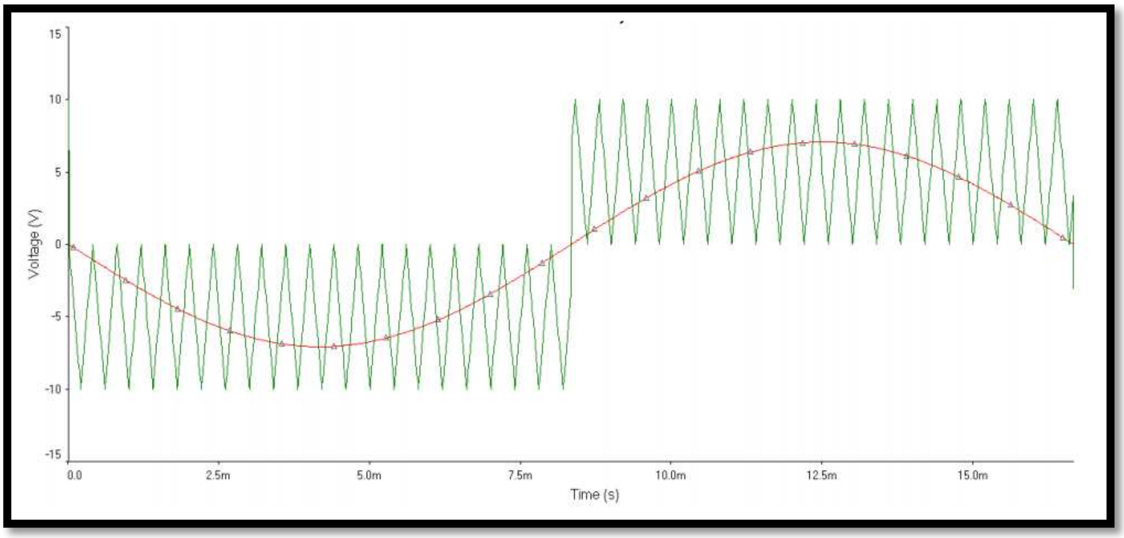

Figure 2.5 3-level PWM comparison control signals [2]

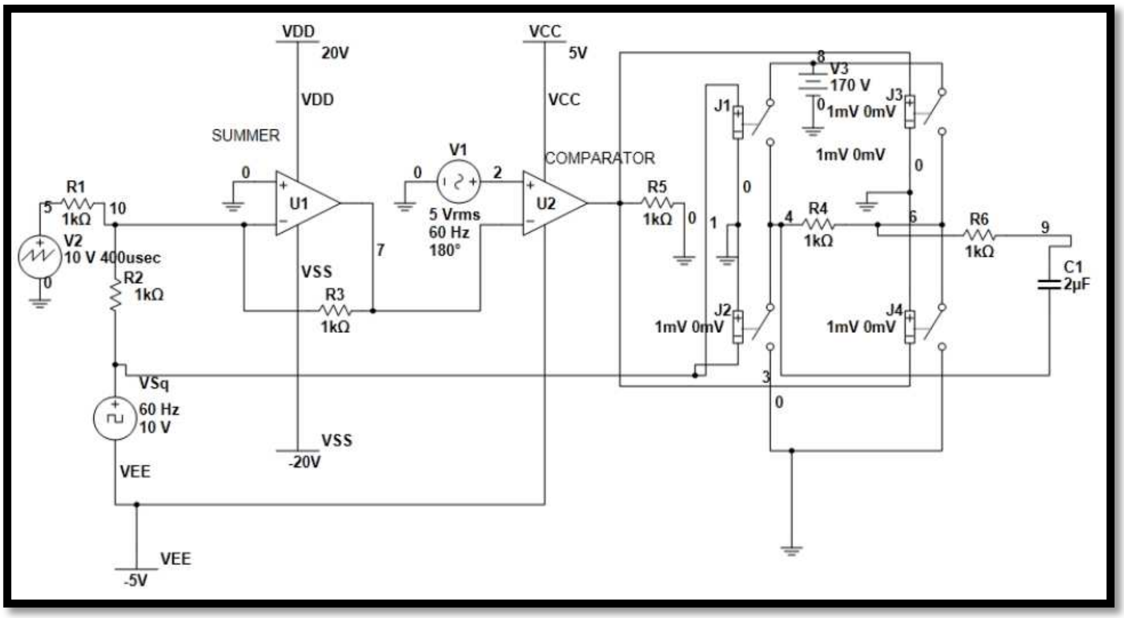

Figure 2.6 3-level PWM simulation circuit [2]

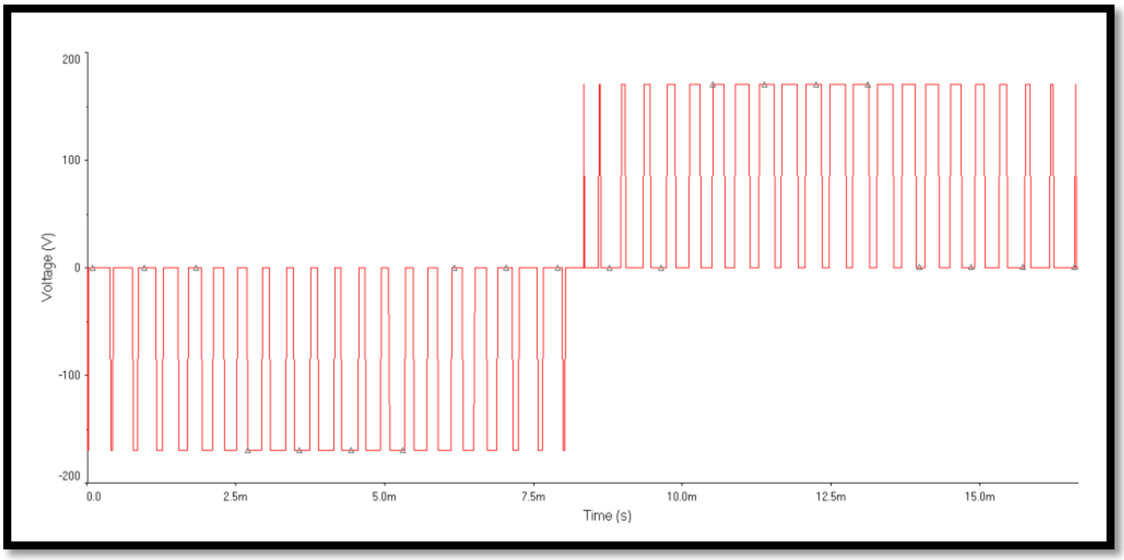

Figure 2.7 Simulated 3- level PWM output (unfiltered) [2]

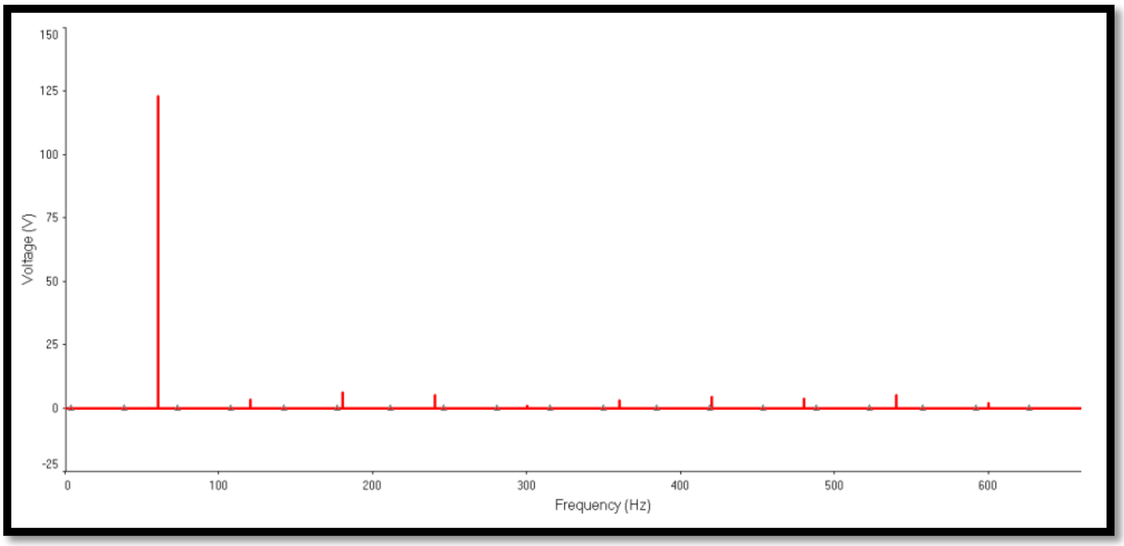

Figure 2.8 Simulated 3- level PWM harmonic analysis [2]

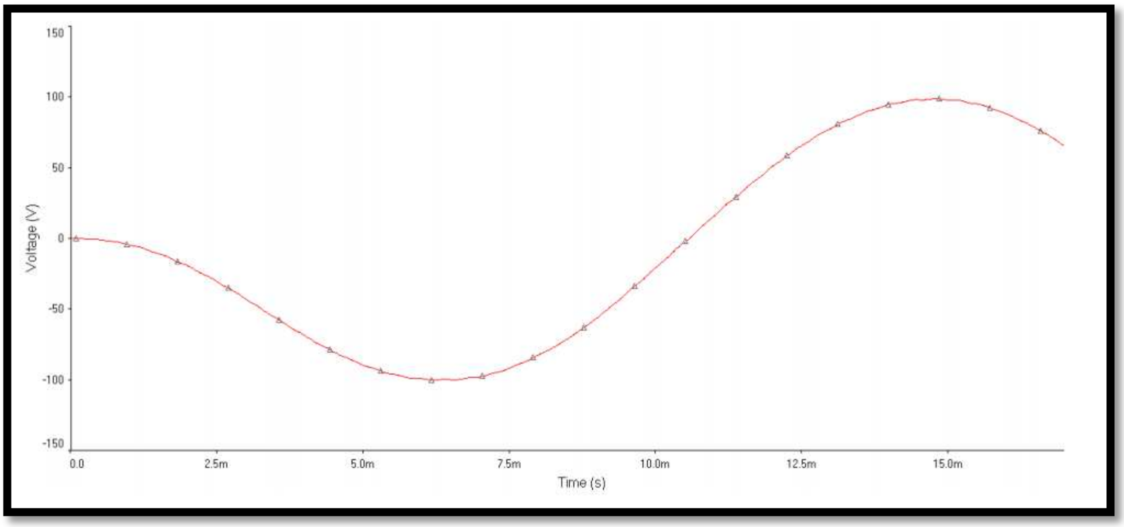

Figure 2.9 Simulated 3- level PWM output (filtered) [2]

The 3-Level PWM frequency plot shown in Figure 2.8 markedly improved. The primary frequency of 60Hz is the dominant, but the magnitude of the harmonic frequencies is much reduced in 3-Level PWM, and the primary is of larger magnitude. When compared to the 2-level PWM, however, a couple things are noticed. First, the harmonics plot shows no higher level harmonics of significant magnitude. This represents the 3-Level signal that follow much closely to the desired sine wave. However, the primary frequency has a much lower voltage magnitude than that of the 2-Level design. The reason for this is the presence of other frequencies which are not harmonics of the 60Hz signal, which caused by the switching of the signal from one polarity to the other, and vice versa. [2]

2.4 MOSFET

The latest and greatest switching technology is the Metal Oxide Semiconducting Field Effect Transistor (MOSFET) or Field Effect Transistor (FET). In some ways the FET is the answer to all problems encountered with inverter designs. A FET is essentially a variable resistor. The “on” resistance is very low, and FET’s are easy to drive (easy to connect in circuit). They are low cost, and handle high currents well (60-100 amps). Probably one of the few shortcoming of a FET is they do not operate well at high voltages, and still cannot handle the extreme currents that an SCR is capable of. However, FET's lend themselves well to parallel connection, which allows not only more current carrying ability, but also lower on resistance. FETs are ideal for medium power applications and due to their ruggedness, the FET has proven to be an outstanding switch for inverters, whether high or low frequency. [3]

2.5 H-Bridge Configuration

An H-Bridge or full bridge converter is a switching configuration composed of four switches in an arrangement that resembles an H. By controlling different switches in the bridge, a positive, negative, or zero potential voltage can be placed across a load. When this load is a motor, these states correspond to forward, reverse, and off. The use of an H-Bridge configuration to drive a motor is shown in Figure 2.10. [4]

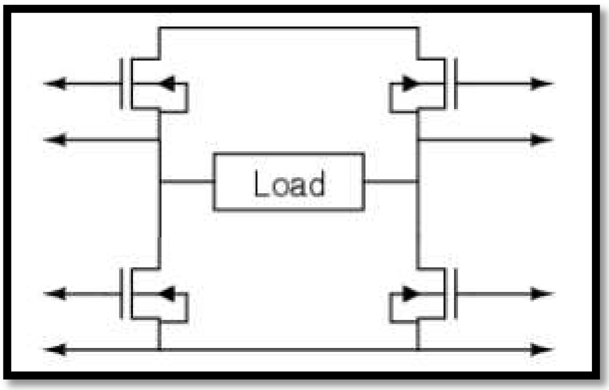

Figure 2.10 H-Bridge configuration using N-Channel MOSFETs [4]

As shown in Figure 2.10, the H-Bridge circuit consists of four switches corresponding to high side left, high side right, low side left and low side right. There are four possible switch positions that can be used to obtain voltages across the load. These positions are outlined in Table 2.1. Note that all other possibilities are omitted,