UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Design and Development of Single Phase 3-Level Cascaded H-Bridge Multilevel Inverter Using Sinusoidal Pulse Width Modulation

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours.

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of **Bachelor's Degree in Electronics Engineering Technology (Industrial Electronics) with Honours**. The member of the supervisory is as follow:

………………………………

(A Shamsul Rahimi Bin A Subki)

ABSTRAK

Inverter multilevel sebagai penyongsang untuk mengubah sumber DC ke sumber AC dengan gangguan rendah harmonik dan kuasa tinggi. Di sesetengah negara yang miskin, rakyat tiada wang yang lebih untuk membeli penyongsang kuasa sandaran. Harga penyongsang kuasa adalah lebih daripada RM100 di pasaran.dalam Malaysia. Matlamat projek ini adalah untuk merekabentuk dan membangunkan single phase 3-level cascaded H-bridge multilevel inverter menggunakan sinusoidal pulse width modulation. Kaedah ini terdiri daripada 6 bahagian, iaitu, schmitt-trigger and low-pass filter with sallen and key topology, precision half-wave rectifier, inverting op-amp amplifier, PWM circuit and H-bridge inverter. Multisim adalah sebagai perisian simulasi untuk menguji setiap bahagian litar dengan memperoleh dan merekodkan bentuk gelombang. Kemudian, breadboard digunakan sebagai alat ujian untuk menguji litar yang dibina oleh multisim. Peralatan oscilloscope digunakan untuk mengutip dan merekodkan bentuk gelombang output. Hasilnya terdiri daripada gelombang sinus, gelombang separuh sinus, membalikkan gelombang setengah sinus, isyarat PWM dan voltan keluaran 3 tingkat. Akhir sekali, bandingkan dan analisa hasil simulasi, hasil papan roti dan hasil prototaip. Kuasa yang dihasilkan oleh jenis inverter H-bridge ini adalah sekitar 250W. Berdasarkan P = VI, semakin tinggi voltan keluaran 3-peringkat, semakin rendah arus keluaran 3 peringkat. Sebagai kesimpulan, isyarat PWM adalah kunci untuk menghasilkan voltan keluaran 3-peringkat dan matlamat projek ini juga dapat dicapai.

ABSTRACT

Multilevel inverter as inverter to transform DC source to AC source with low harmonic distortion and high power. In some impoverished country, the citizen without extra money to buy the backup power inverter. In Malaysia, the price of power inverter is around more than RM100 in market. The aim of this project was to design and development of single phase 3-level cascaded H-bridge multilevel inverter using sinusoidal pulse width modulation. The methods consist of 6 part, that is, schmitt-trigger oscillator and low-pass filter with sallen and key topology, precision half-wave rectifier, inverting op-amp amplifier, PWM circuit and H-bridge inverter. The multisim as simulation software to test each part of circuit and obtained and recorded the waveform. Then, used the breadboard as testing device to test the circuit constructed by multisim. The output waveform was obtained by using the oscilloscope equipment. The result consist of sine wave, half-sine wave, inverting half-sine wave, PWM signal and 3-level output voltage. Lastly, compare and analyse the simulated results, breadboard results and prototype results. The power produced by this type of H-bridge inverter is around 250W. Based on P=VI, the higher the 3-level output voltage, the lower the 3-level output current. As a conclusion, the PWM signal is the key to generate the 3-level output voltage and the objective of this project was also be accomplished.

DEDICATION

This thesis is dedicated to:

My parents,

My sisters and brother,

My supervisor,

And all my friends,

Thanks for yours support and encouragement.

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Lastly, I would also like to express my gratitude towards my friends. Because they willing took their time to helped me and support me.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF FORMULA

Equation 1: $f = \frac{1}{2\pi RC\sqrt{6}}$

Equation 2: $\beta = \frac{1}{29}$

Equation 3: $|A| = g_m R_L$

Equation 4: $R_L = \frac{R_D r_d}{R_D + r_d}$

Equation 5: $f = \frac{1}{2\pi RC} \frac{1}{\sqrt{6 + 4(\frac{R_C}{R})}}$

Equation 6: $f = \frac{1}{2\pi\sqrt{R_1 C_1 R_2 C_2}}$

Equation 7: $f_o = \frac{1}{2\pi RC}$

Equation 8: $\frac{R_3}{R_4} = 2$

Equation 9: $f_o = \frac{R_3}{4R_{1C_1}R_2}$

Equation 10: $m_f = \frac{f_{tri}}{f_{sine}}$

Equation 11: $m_a = \frac{V_{m,sine}}{V_{m,tri}}$

Equation 12: $t_{c(on)} = t_{ri} + t_{fv}$

Equation 13: $W_{c(on)} = \frac{1}{2} V_d I_o t_{c(on)}$

Equation 14: $W_{(on)} = V_{on} I_o t_{(on)}$

Equation 15: $t_{c(off)} = t_{rv} + t_{fi}$

Equation 16: $W_{c(off)} = \frac{1}{2} V_d I_o t_{c(off)}$

Equation 17: $P_s = \frac{1}{2} V_d I_o f_s [t_{c(on)} + t_{c(off)}]$

Equation 18: $P_{on} = V_{on} I_o \frac{t_{on}}{T_s}$

Equation 19: $P_t = P_{on} + 2P_s$

Equation 20: $f_{osc} = \frac{1}{RC}$

Equation 21: $f_{osc} = \frac{1}{2RC}$

Equation 22: $f = \frac{1}{4R_3C}(\frac{R_2}{R_3})$

Equation 23: $c \geq \frac{2[2Q_g + \frac{I_{qbs(\max)}}{f} + Q_{Is} + \frac{I_{Cbs(leak)}}{f}]}{V_{cc} - V_f - V_{LS} - V_{Min}}$

Equation 24: $\Delta T = T_{max} - T_{min}$

Equation 25: $f = \frac{1}{\Delta T}$

Equation 26: $V_+ = \left(\frac{R_2}{R_1+R_2} \mathrm{x} V_{in}\right) + \left(\frac{R_1}{R_1+R_2} \mathrm{x} V_s\right)$

Equation 27: $V = \frac{R_2}{R_1+R_2} x V_{in}$

Equation 28: $\tau = RC$

Equation 29: $V_t = V_o e^{-\frac{t}{\tau}}$

Equation 30: $T = 2t$

Equation 31: $tan\emptyset = \sqrt{\frac{C_3}{C_2} - 1}$

Equation 32: $f = \frac{1}{2\pi R\sqrt{C_3 x C_2}}$

Equation 33: $V_p = \frac{V_{p-p}}{2}$

Equation 34: $V_o = -\frac{R_f}{R_1} V_{in}$

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AC	-	Alternating Current
DC	-	Direct Current
PWM	-	Pulse Width Modulation
SPWM	-	Sinusoidal Pulse Width Modulation
SVPWM	-	Space Vector Pulse Width Modulation
MOSFET	-	Metal-Oxide-Semiconductor Filed-Effect Transistor
IGBT	-	Insulated-Gate Bipolar Transistor
BJT	-	Bipolar-Junction Transistor
FET	-	Field-Effect Transistor
THD	-	Total Harmonic Distortion
RMS	-	Root Mean Square
RL Filter	-	Resistor-Inductor Filter
RC Filter	-	Resistor-Capacitor Filter
RLC Filter	-	Resistor-Inductor-Capacitor Filter
Hz	-	Hertz
||	-	Parallel
PCB	-	Printed Circuit Board
k	-	x1,000
M	-	x1,000,000
IC	-	Integrated Circuit
FFT	-	Fast Fourier Transform
°C	-	Celcius
Vcc	-	Collector Supply Voltage

CHAPTER 1

INTRODUCTION

1.0 Introduction

The power semiconductor devices is very important in the power electronics field. It will form of a matrix of on or off switches and help to convert the power from one to another one such as AC to DC, DC to AC, DC to DC and AC to AC.

The inverter is the one type of the basic conversion which will transform a low DC power to a high voltage AC power. The inverters are always make use of renewable energy source such as wind, fuel cell and so on. These environmentally friendly energy source can be convert into AC source and used in many application. Besides, the inverters are widely used industrial applications such as variable speed AC motor, induction heating and so on. The output AC source is depends on the input DC source. For example, the output AC will very low if the input DC is very small. Hence, one of the method to generate a high AC source is boost a low DC source to the high DC source using the DC to DC boost converter. After that, transform the high DC source to high AC source using the PWM. Another method is convert the low DC source to low AC source and then use the transformer to boost the AC source.

The multilevel inverter is the improvement of the inverter which will transform a high AC source power. There are three type of the multilevel inverter, that is, diode clamped multilevel inverter, flying capacitor multilevel inverter and cascaded H-bridge multilevel inverter. This project focuses on cascaded H-bridge multilevel inverter which connect all the H-bridge in the series form to obtain a high AC source power.

The switching control method is very important to control the power semiconductor devices. The switching control method will reduce the harmonic contents in the output AC. Besides, the multilevel inverter will increase the components of the power semiconductor devices and cause to increase the switches stress. The multilevel carrier based on PWM, selective harmonic elimination and multilevel SVPWM are the switching control methods and always used in industrial applications and power electronics. The multilevel carrier based on PWM method is the most popular method due to easily implemented. This method can be categories into SPWM and SVPWM. The SPWM is comparing the references wave and the carrier wave to produce the pulse. The carrier based on PWM scheme are classified into phase shifted multicarrier modulation and level shifted multicarrier modulation. The SVPWM have the constant switching time calculations for each state and can easily be changed to higher level (C.Gomathi.et.al, 2013). This project focusses the SPWM as the switching control method.

1.1 Problem Statement

In some impoverished country, there are poor and lack of money and technology to build production facilities or transmission lines in all area. For example, 80% of Africa's population without electricity. To build a production facilities or transmission line, a government needs to spend a lot of money and hire worker with knowledge. But most of the government focus on their capital, so, some of the village can't get high power from transmission line. So, the local facilities such as clinic in the village can't provide a high quality of medical instrument because a high quality of medical instrument requires a high power to activate it. Besides, they are also limit electricity in their living, so, they can't use electronic devices with high power such as air-conditional, heater and others in their living. Then, they need to spend extra money to buy backup power inverter. But a high quality and efficiency of the power inverter is very expensive in the market, so, they can't afford to buy it.

The function of power inverter is convert a low DC voltage to a high AC voltage with 50Hz - 60Hz frequency. The low DC voltage source can be obtained from recycled battery or solar panel. The output is depending on the load, if the load is very sensitive, the output definitely will be in pure sine wave. The pure sine wave can be produced by filtering the modified square wave. The modified square wave is easier than pure sine wave because the cut-off frequency of the filter isn't so easy to calculate.