UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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A COMPARATIVE STUDY OF DIODE-CLAMPED AND CASCADED H-BRIDGE IN MULTILEVEL INVERTER FOR HARMONIC REDUCTION

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A COMPARATIVE STUDY OF DIODE-CLAMPED AND CASCADED H-BRIDGE IN MULTILEVEL INVERTER FOR HARMONIC REDUCTION

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DECLARATION

I declare that this dissertation entitled "Comparative Study Of Diode-Clamped and Cascaded H-Bridge Multilevel Inverter for Harmonic Reduction" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature :

Name : Mohammed Rasheed Jubair

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APPROVAL

I hereby declare that I have read this dissertation and in my opinion, this dissertation is a sufficient term of the scope and quality of the award of master of electrical engineering (Industrial Power).

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ABSTRACT

This dissertation presents a comparative study of two types of multilevel inverters that comprise of diode clamped and cascaded H-Bridge multilevel inverter for reduction of harmonics in the multilevel inverter output. The proposed system is designed using MATLAB/SIMULINK and it consists of diode clamped and cascaded H-Bridge multilevel inverters. The controller is based on the pulse width modulation (PWM) technique which is applied to the purposed three phase multilevel inverters. The various performances of simulation results of the diode clamped and cascaded H-Bridge multilevel inverters were investigated. The Total harmonic distortion (THDv) of the output voltage was measured for the two types of multilevel inverters. Based on varying simulation results, it has been found that the THD voltage of the H-Bridge multilevel inverter is considerably lower than the diode clamped multilevel inverter.

ABSTRAK

Disertasi ini membentangkan satu kajian perbandingan dua jenis penyongsang pelbagai peringkat, terdiri daripada diod diapit dan disebarkan H-Bridge penyongsang bertingkat untuk mengurangkan harmonik dalam output penyongsang pelbagai peringkat. Sistem yang dicadangkan ini direka menggunakan MATLAB / SIMULINK dan ia terdiri daripada diod diapit dan disebarkan H-Bridge penyongsang pelbagai peringkat. Pengawal ini adalah berdasarkan modulasi lebar denyut (PWM) teknik yang digunakan untuk berniatlah tiga fasa penyongsang pelbagai peringkat. Pelbagai persembahan daripada keputusan simulasi diod diapit dan disebarkan H-Bridge penyongsang bertingkat telah disiasat. Jumlah herotan harmonik (THDv) voltan keluaran diukur untuk kedua-dua jenis penyongsang pelbagai peringkat. Berdasarkan berbeza keputusan simulasi, didapati bahawa voltan THD daripada H-Bridge penyongsang bertingkat adalah jauh lebih rendah daripada diod diapit penyongsang pelbagai peringkat.

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DEDICATION

I dedicate this message to my father and my mother particularly cherished. Without their support and most of all love, the completion of the hard work \ was not possible.

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LIST OF ABREVIATIONS

AC	-	Alternating Current
DC	-	Direct Current
THD	-	Total Harmonic Distortion
THDv	-	Voltage Total Harmonic Distortion
IGBT	-	Insulated Gate Bipolar Transistor
GTO	-	Gate turn-off
PDM	-	Pulse-Duration Modulation
PWM	-	Pulse Width Modulation
SPWM	-	Sinusoidal Pulse Width Modulation
MI	-	Modulation Index
Vdc	-	Voltage Direct Current
IEEE STD	-	Institute of Electrical and Electronic Engineer
MLI	-	Multilevel Inverter
NPCMLI	-	Neutral-Point Clamped Multilevel Inverter
CCMLI	-	Flying Capacitor Multilevel Inverter
CHBMLI	-	Cascaded H- Bridge Multilevel Inverter
CC	-	Clamped Capacitors
VCHB	-	Voltage Cascaded H- Bridge
PD	-	Phase Disposition
POD	-	Phase Opposition Disposition
RMS	-	Root Mean Square

LIST OF SYMBOLS

b	-	Bias
f	-	Frequency
F	-	Force
F_f	-	Friction force
F_{rms}	-	Root mean square of force
$F_{initial}$	-	Initial force
N	-	Normal fares
Ra	-	Arithmetic average roughness
Rt	-	Roughness total
Rz	-	Ten-point mean roughness
T	-	Periods
t	-	Time
w	-	Weight
x	-	Horizontal Cartesian coordinates
y	-	Vertical Cartesian coordinates
μ_k	-	Coefficient of kinetic friction
μ_s	-	Coefficient of static friction
μ_0	-	Population mean
$\bar{x}$	-	Mean of data
$\sum$	-	Summation
π	-	Phi (3,14)
ω	-	Rotational speed
σ	-	Standard deviation
θ	-	Threshold
φ	-	Activation function
α	-	Significance level

LIST OF PUBLICATIONS

Published

- *Rosli Omar, **Mohammed Rasheed**, Ahmed Al-janad, Marizan Sulaiman* "Fundamental Studies of a Three Phase Cascaded H-Bridge and Diode Clamped Multilevel Inverters Using Matlab/Simulink"Vol. 6, N.5 Sep 2013 (I.RE.A.CO.) Available at *http://www.praiseworthyprize.com/IREACO-latest/IREACO_vol_6_n_5.html*

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, multilevel inverters have become more attractive for their initial usage in high-voltage and high-power applications. Multilevel converters (or inverters) have been used for AC to DC, AC to DC to AC, DC to AC, and DC to DC power conversions in high power applications such as utility and large motor drive applications (Peng, 2001). Multilevel inverters provide more than two voltage levels. The generalized multilevel inverter topology can balance each voltage level by itself regardless of the inverter control and load characteristics. The concept of multilevel converters has been introduced since 1975 (Karuppanan, 2011). The usage of these applications has become more diverse and affects a wide field of electrical engineering from a few watts to several hundred megawatts. Converting static structures that comprise mainly applications of power electronics is becoming increasingly powerful, and the technology has had to adapt to the growth of the power to convert. This growth has been possible to the development of technologies of semiconductor components. Changing templates voltage and current, as well as improved performance of these components, has to use more power electronics performance for applications of greater power (Colak, 2010). However, the performance of current components do not allow for an optimum conversion of electrical energy. Indeed, the increase in tension is often used to improve yields. However, the use of components with templates in high voltage does not improve the overall efficiency of the plant, or even worse, because these components are generally underperform components templates voltage lower, and thus, produce more losses (Axelrod, 2005). Hence, to solve this problem, more efficient components are used and new structures have been developed. These structures are known as multilevel inverters, and they have more than two output levels of voltages. They were created at the first time to be able both to be several switches in series, and ensure properly withstand voltage across them later, as these inverters showed an interesting property on the output waveforms. The rotary electric actuators play a very important role in the industry and particularly in electric traction. The performance required for these actuators is high, both in terms of the dynamics of the speed and the precision of torque delivered (Xu et al, 2004). The DC machine has been used to make the most of these actuators given the simplicity the order. However, the current machine has several drawbacks associated with its mechanical commutators. In contrast, AC machines (synchronous and asynchronous) possess many advantages. The absence of collector allows them to have a smaller footprint, increased reliability, and high operating speed. Indeed, the permanent magnet synchronous machine is distinguished by its excellent performance and its large mass couple is allowed to prevail in applications that require very high static and dynamic performance, particularly in areas of applications such as flexible manufacturing systems, robotics, aeronautics, and space (Babaei, 2013). The emergence and development of new components for controllable powers opening and closing as the GTO (gate turn-off Thyristor) and IGBT (insulated gate bipolar transistors) allow the design of new converters to be reliable, fast, and powerful. Thus, all drives (static machine converter current AC) costs are reduced considerably. Progress in the field of the microcomputer (fast and powerful microcontrollers) allows the synchronized control algorithms of these sets to be more efficient converter machine and robust (Chen, 2004). The Pulse Width Modulation (PWM) is a technique to control static converters for interfacing between a load (electrical machine) and supply means (three-phase inverter). It is a technique used for energy conversion, having its base in the field of telecommunications (signal processing). It can possibly name as Pulse Width Modulation (PWM) or Pulse-Duration Modulation (PDM). Far from being an accessory element in the chain of variable speed (inverter power associated with an electric machine), the PWM stage plays an important role with impact on the performance of all system performance driving, loss in the inverter or the machine, the acoustic noise, electromagnetic noise, even the destruction of the system, e.g. due to over voltages which occur during the use of long cables (Du et al, 2007).

1.2 IEEE Standard 519

The IEEE Standard 519 was introduced in 1981 and most-recently has been revised in 1992. It is intended to provide direction on dealing with harmonics introduced by nonlinear loads. The standard recognizes the responsibility of an electricity user not to distort the voltage of the utility by drawing heavy nonlinear or distorted currents. It also recognizes the responsibility of the utility to provide the users with a near-sine-wave voltage. Table 1.1 shows the distortion limits for both current and voltage are defined in order to minimize interference between electrical equipment, in Figure 1.1 definition of notch depth and notch area. It is presented as a guideline for power system design when nonlinear loads are presented. IEEE STD 519 establishes harmonic limits on voltage as 5% for total harmonic distortion and 3% of the fundamental voltage for any single harmonic (Almarghani, 2009).

Table 1.1: Harmonic voltage distortion limits

	Special Applications*	General system	Dedicated System
Notch Depth	10%	20%	50%
THD (voltage)	3%	5%	10%
Notch Area	16,400	22,800	36,500

It is considered from Table 1.1 that A_N value for other than 480-volt systems should be multiplied by V/480, and its unit is represented in microsecond*volts.

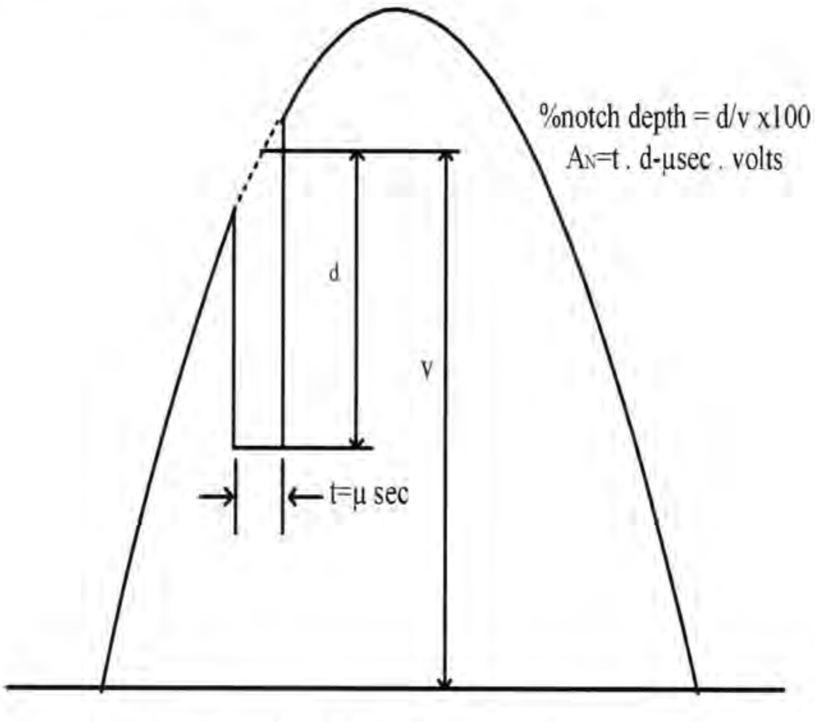

Figure 1.1: Definition of Notch Depth and Notch Area (Handbook, 2000)

1.3 Problem Statement

One of the major problems with electric power quality is the harmonic contents. There are several methods of indicating the quantity of harmonic contents. The main focus is measuring the total harmonic distortion (THD). In electrical systems, the inverters are used to convert DC voltage to AC voltage, but it has been noticed that the voltage from the inverter does not produce smooth waveform, but rather a discrete waveform. As a result, it is more likely that the output waveform consists of harmonics, which are not usually desirable since they deteriorate the performance of the load. There are also other topologies for inverters such as multilevel inverters. The main idea of multilevel inverters is to have a better sinusoidal voltage and current in the output by using switches in series. Since many switches are put in series, the switching angles are important in the multilevel inverters because all of the switches should be switched in such a way that the output voltage and current have low harmonic distortion.

There are 3 types of multilevel inverters which are diode clamped multilevel inverters, flying capacitor multilevel inverters, and cascaded H-bridge multilevel inverter. In this dissertation, two types of multilevel inverters; diode clamped multilevel inverters and cascaded H-bridge multilevel inverter, were constructed and ensuring the approach of less switches and acquired low harmonic distortion.

1.4 Motivation of Research

With the development of power electronics and the proliferation of non-linear loads in the applications of industrial power, the issue of harmonic contents and their effects on power quality are important topics to be studied. Proper strategy should be implemented to minimize harmonic problems to avoid the system to become worse. In recent years, there is an increase in interest of multilevel power conversation. Recent researches have introduced novel converter topologies and unique modulation strategies, and because of its diverse applications, the multilevel inverter has become the most-used and analysed topology in the power