A STUDY OF THE CASCADED H-BRIDGE MULTILEVEL INVERTER BASED ON SUPERCAPACITOR FOR HARMONIC REDUCTION

MUHAMMAD FADHIL BIN AZWIR

BACHELOR OF ELECTRICAL ENGINEERING

(INDUSTRIAL POWER)

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

I declare that the project report entitled "A Study of Cascaded H-Bridge Multilevel Inverter Based on Super Capacitor for Harmonic Reduction" is the results from my own research except as cited in the references.

Signature: ....

Name : Muhammad Fadhil Bin Azwir

Date : 8 June 2016

I hereby declare that I have read through this report and found that is comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)

Signature : ………..………................................

Name : Prof. Madya. Ir. Dr. Rosli Bin Omar

Date : 8 June 2016

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ABSTRACT

This project present a study of cascaded H-bridge multilevel inverter based on supercapacitor to reduce harmonic for high power applications. Applications of multilevel converters are able to reduce the number of harmonics contained in the system of electrical network. This study deals seven-level cascaded H-Bridge multilevel inverter with sinusoidal pulse width modulation (SPWM) controller and two type of energy storage comprises of supercapacitor and DC supply for reduction of the harmonic in the electrical network. This paper also deals with simulation of seven-level cascaded H-Bridge multilevel inverter in MATLAB/SIMULINK environment.

The proposed system designed using MATLAB/SIMULINK consists of a supercapacitor and DC supply as energy storage. The controller based on sinusoidal pulse width modulation was applied to the inverter. The design to change the modulation index from 0.5 to 1.0 also is used at controller to monitor the supercapacitor performance to reduce the harmonic is also discussed. The various performances of simulation results between super-capacitor and DC supply have been investigated. The Total Harmonic Distortion (THDv) of the inverter output voltage is measured where two types of energy storages (DC supply and super capacitor) are applied to the inverter input. It can be observed that the THD voltage output of the inverter for the super capacitor is considerably lower than the DC supply that is exceed 90% and meet the needs of supercapacitor considered low at 5% as specified by IEEE 519 standard on harmonic distortion level.

ABSTRAK

Projek ini membentangkan kajian penyongsang bertingkat cascaded H-Bridge berdasarkan superkapasitor bagi mengurangkan harmonik untuk aplikasi kuasa tinggi. Aplikasi penyonsang bertingkat dapat mengurangkan bilangan harmonik yang terkandung dalam sistem rangkaian elektrik. Kajian ini membincangkan tujuh peringkat penyongsang bertingkat cascaded H-Bridge dengan pengawal sinusoidal modulasi lebar denyut (SPWM) dan dua jenis penyimpanan tenaga terdiri daripada superkapasitor dan bekalan DC untuk mengurangkan harmonik dalam rangkaian elektrik. Kertas kerja ini juga berkaitan dengan simulasi tujuh peringkat penyongsang bertingkat cascaded H-Bridge dalam persekitaran / SIMULINK MATLAB.

Sistem yang dicadangkan dan direka menggunakan MATLAB / SIMULINK terdiri daripada superkapasitor dan bekalan DC sebagai penyimpanan tenaga. Pengawal berdasarkan sinusoidal lebar denyut modulasi telah digunakan untuk penyongsang. reka bentuk untuk menukar indeks pemodulatan dari 0.5 hingga ke 1.0 juga digunakan pada pengawal untuk memantau prestasi superkapasitor untuk mengurangkan harmonik juga dibincangkan. Pelbagai prestasi dan keputusan simulasi antara superkapasitor dan bekalan DC telah disiasat. Jumlah herotan harmonic (THDv) daripada voltan keluaran penyongsang diukur di mana dua jenis penyimpanan tenaga (DC bekalan dan super kapasitor) digunakan untuk input penyongsang. Ia boleh diperhatikan bahawa keluaran voltan THD daripada penyongsang untuk superkapasitor adalah jauh lebih rendah daripada bekalan DC yang melebihi 90% dan memenuhi keperluan untuk superkapasitor dianggap rendah pada kadar 5% yang ditetapkan oleh IEEE 519 standard pada tahap herotan harmonik.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Multilevel inverter is mainly use in desired single or three phase voltage waveform. The desired output voltage is obtained by combining several direct current (DC) sources. The most common independent sources used are solar cells, fuel cells, batteries and super capacitors. Nowadays, there are three famous of multilevel voltage source inverters exist such as neutral point clamped (NPC), cascaded H-bridge (CHB), and flying capacitors (FCs)[1]. Among this inverter, cascaded multilevel inverter reaches the higher output voltage and power level and the higher reliability due to its performance. The cascaded H-bridge multilevel inverter have been applied where high power and power quality are essential, for example, static synchronous compensators active filter and reactive power compensation applications, photovoltaic power conversion, uninterruptible power supplies, and magnetic resonance imaging. If the number of switches is increase, it will increase voltage. The circuit will become complex if the voltage stresses and switching losses is increase. By using the proposed multilevel inverter, the number of switches will reduce significantly and hence the efficiency will improve. In high power applications, to reach the maximum energy efficiency, the harmonic of the output waveforms has to be reduced as much as possible in order to avoid distortion in the grid [2].

1.2 Problem Statement

Based on previous work that has been done, most researchers focus on the harmonic that occur on load and less concerned about the harmonics that occur at the power source. Power sources such as batteries, solar and other sources of DC supply which has a high Total Harmonic Distortion (THD) in term of voltage. Thus, this study is to change the power source from DC supply to supercapacitor and monitor it performance for harmonic reduction in output of cascaded H-Bridge multilevel inverter by using MATLAB/SIMULINK.

1.3 Objectives

The objectives of this project are:

1. To study the concept of cascade H-Bridge multilevel inverter.
2. To compare the output voltage at cascaded H-Bridge multilevel inverter based on DC supply and supercapacitor for harmonic reduction.

1.4 Project Scope

In this study, the main focused of this project is to study of stage level of cascaded H-Bridge multilevel inverter based on supercapacitor for harmonic reduction in electrical system. This project also compares the effectiveness in term of the energy storage between DC supply and supercapacitor for harmonic reduction in term of voltage in electrical network.

1.5 Expected outcome of the project

In this study, this project is to monitor the performance of DC supply and supercapacitor for harmonic mitigation based on cascaded H-Bridge multilevel inverter.

CHAPTER 2

LITERATURE REVIEW

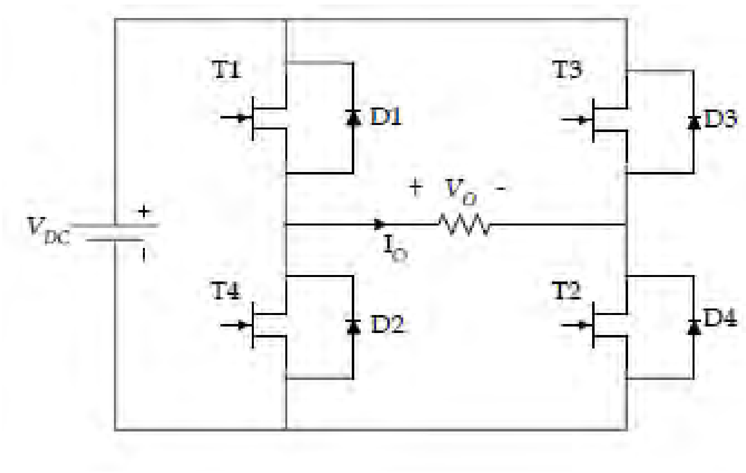
2.1 Theory and basic principle

In this chapter, the main focused is to discuss the related project from previous work that has been done by using cascaded H-Bridge multilevel inverter. From the work that has been done, the previous researchers use several type of direct current (DC) source such as solar cell, DC supply, and batteries. Therefore, to design and monitoring the harmonic reduction in the cascaded H-Bridge multilevel inverter based on previous work, the MATLAB SIMULINK software is used.

2.2 Inverter

Power inverters are devices which can convert electrical energy of DC form into that of AC. They come in all shapes and sizes, from low power functions such as powering a car radio to that of backing up a building in case of power outage. Inverters can come in many different varieties, differing in price, power, efficiency and purpose.

Basic circuit



Equivalent Circuit

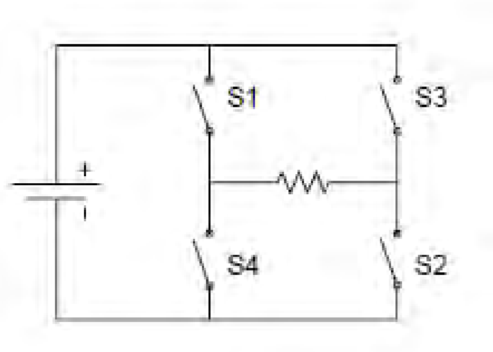


Figure 2.1: Basic circuit and equivalent circuit of inverter

The purpose of a DC/AC power inverter is typically to take DC power supplied by a battery, such as a 12 volt car battery, and transform it into a 120 volt AC power source operating at 60 Hz, emulating the power available at an ordinary household electrical outlet.

On the market today are two different types of power inverters, modified sine wave and pure sine wave generators. These inverters differ in their outputs, providing varying levels of efficiency and distortion that can affect electronic devices in different ways.

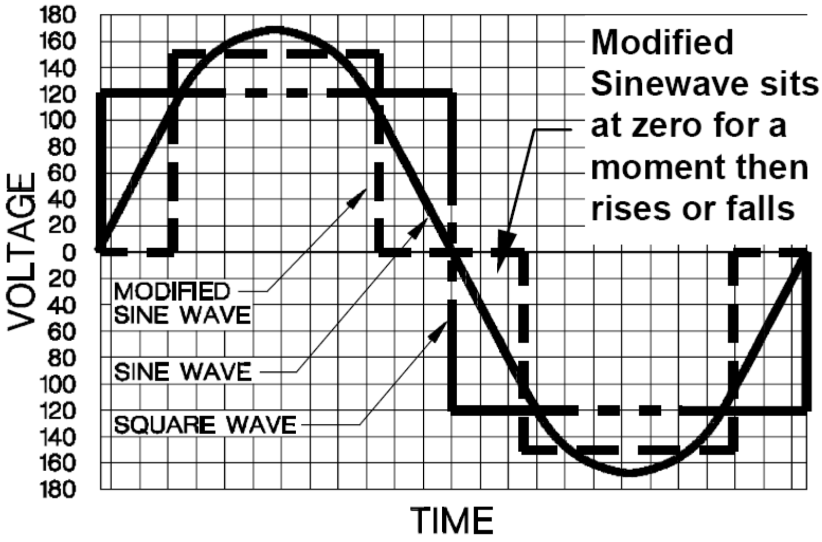


Figure 2.2: Square, Modified and Pure Sine wave

A modified sine wave is similar to a square wave but instead has a “stepping” look to it that relates more in shape to a sine wave. This can be seen in Figure 2.2, which displays how a modified sine wave tries to emulate the sine wave itself. The waveform is easy to produce because it is just the product of switching between three values at set frequencies, thereby leaving out the more complicated circuitry needed for a pure sine wave.

The modified sine wave inverter provides a cheap and easy solution to powering devices that need AC power. It does have some drawbacks as not all devices work properly on a modified sine wave, products such as computers and medical equipment are not resistant to the distortion of the signal and must be run off of a pure sine wave power source.

Pure sine wave inverters are able to simulate precisely the AC power that is delivered by a wall outlet. Usually sine wave inverters are more expensive then modified sine wave generators due to the added circuitry. This cost, however, is made up for in its ability to provide power to all AC electronic devices, allow inductive loads to run faster and quieter, and reduce the audible and electric noise in audio equipment, TV’s and fluorescent lights.

2.2.1 How Does It Work?

Figure 2.3 show the component involves which is four Insulated Gate Bipolar Transistor (IGBT) to operate this H-Bridge inverter.

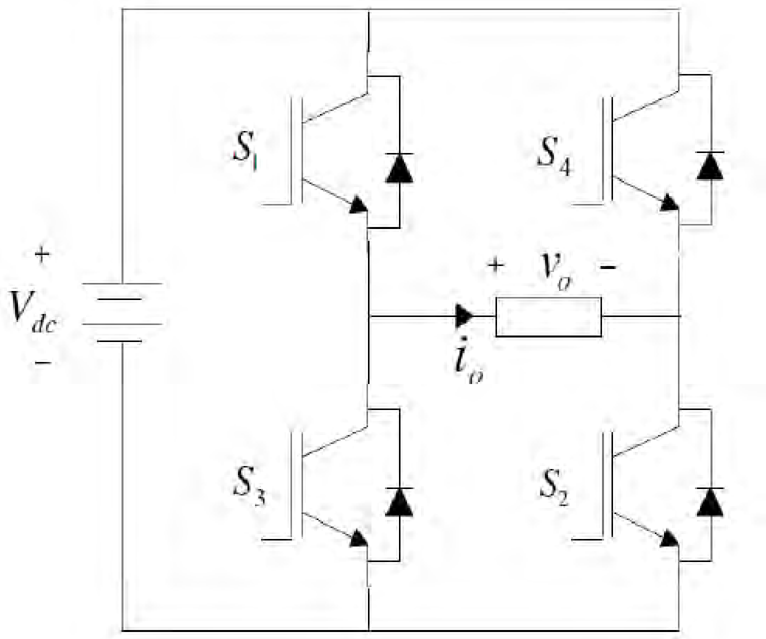


Figure 2.3 Schematic Diagram of basic H-Bridge inverter

The above topology are analyzed under the assumption of ideal circuit conditions. Accordingly, it is assumed that the input dc voltage (Vdc) is constant and the switches are lossless. In full bridge topology has two such legs. Each leg of the inverter consists of two series connected electronic switches shown within dotted lines in the figures. Each of these switches consists of an IGBT type controlled switch across which an uncontrolled diode is put in anti-parallel manner. These switches are capable of conducting bi-directional current but they need to block only one polarity of voltage. The junction point of the switches in each leg of the inverter serves as one output point for the load.

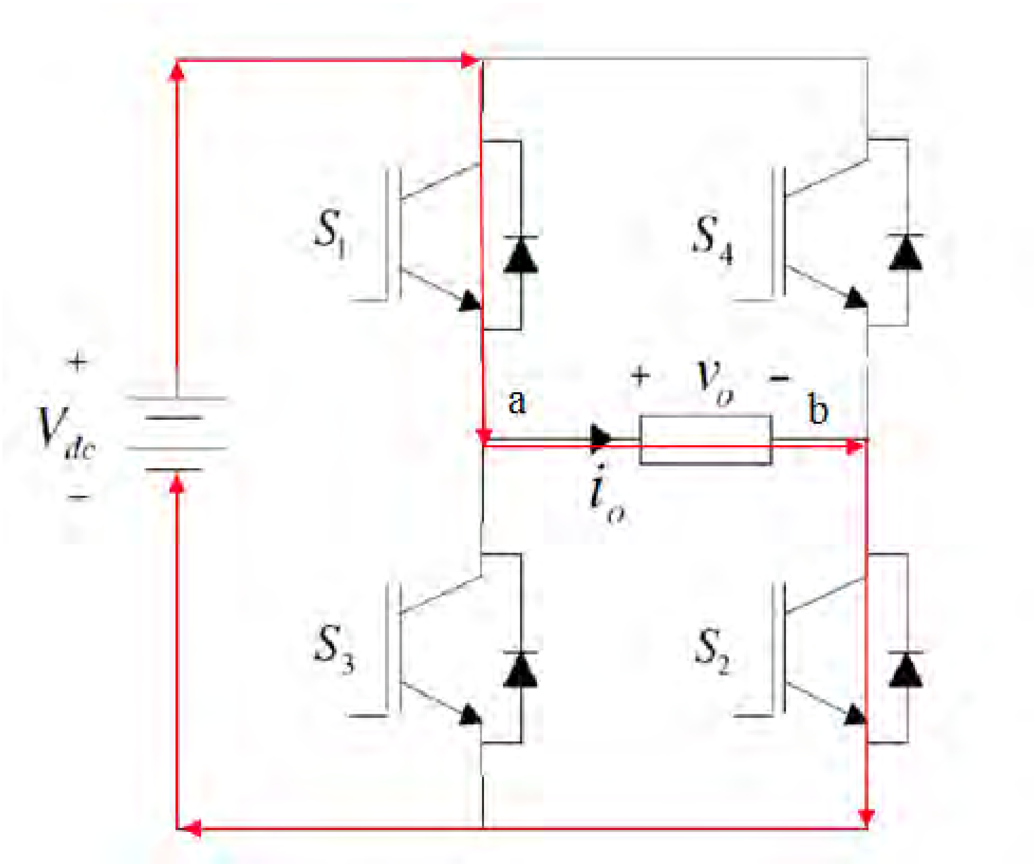


Figure 2.4: Positive cycle of basic H-Bridge inverter

Figure 2.4 show that the operation of basic H-Bridge inverter in posotive cycle.When the switches S1 and S2 are turned on simultaneously $0 \leq t \leq T1$, the the input voltage Vin appears across the load and the current flows from point a to b. S1– S2 ON, S3 – S4 OFF ==> v o = + Vs.

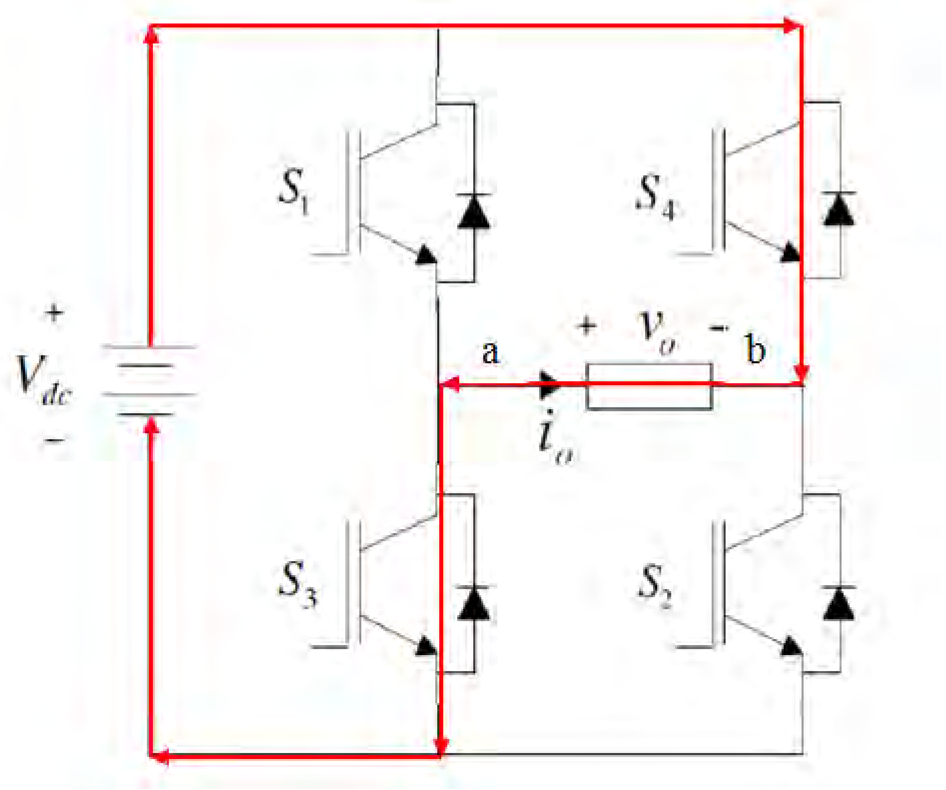


Figure 2.5: Negative cycle of basic H-Bridge inverter

Figure 2.5 shows that the operation basic H-Bridge inverter in negative cycle. If the switches S3 and S4 turned on duration T1 ≤ t ≤ T2, the voltage across the load the load is reversed and the current through the load flows from point b to a.

S1 – S2 OFF, S3 – S4 ON ==> v o = -Vs

Table 2.1 Table of switching scheme of basic H-Bridge inverter

Switching State	S_1	S_2	S_3	S_4	v_{out}
1	On	On	Off	Off	$+V_{dc}$
0	On	Off	Off	On	0
1	Off	Off	On	On	$-V_{dc}$

2.2.2 Output Waveforms

An inverter can produce square wave, modified sine wave, pulsed sine wave, or sine wave depending on circuit design. There are two basic designs for producing household plug-in voltage from a lower-voltage DC source, the first of which uses a switching boost converter to produce a higher-voltage DC and then converts to AC. The second method converts DC to AC at battery level and uses a line-frequency transformer to create the output voltage

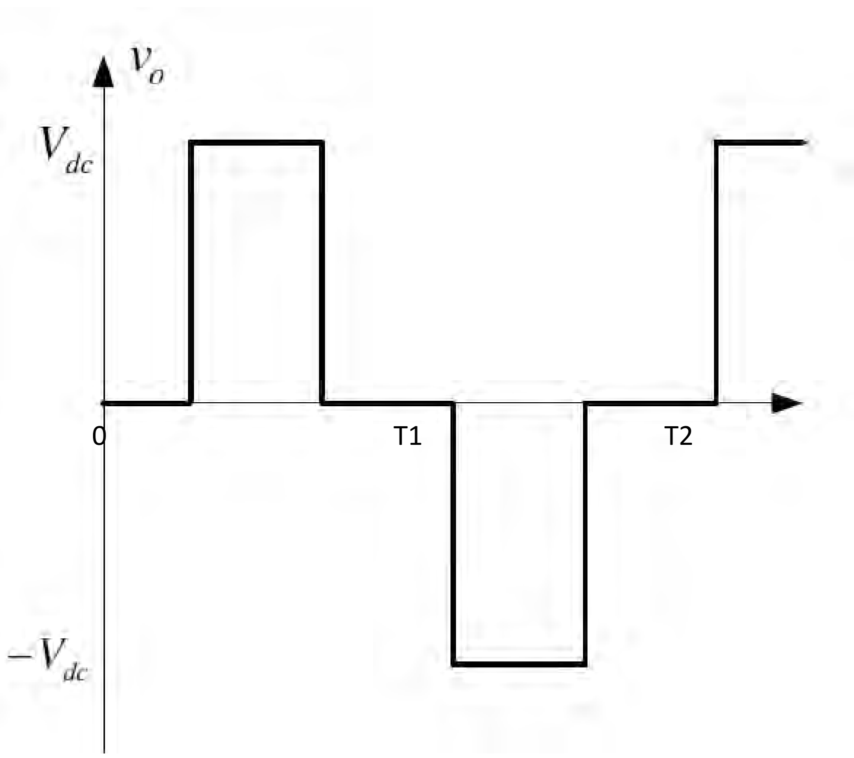


Figure 2.6: Output waveform of basic H-Bridge inverter

Based on Figure 2.6, single-phase square wave type voltage source inverter produces square shaped output voltage for a single-phase load. Such inverters have very simple control logic and the power switches need to operate at much lower frequencies compared to switches in some other types of inverters.

The first generation inverters, using thyristor switches, were almost invariably square wave inverters because thyristor switches could be switched on and off only a few hundred times in a second. In contrast, the present day switches like IGBTs are much faster and used at switching frequencies of several kilohertz. Single-phase inverters mostly use half bridge or full bridge topologies.

2.3 Multilevel Inverter

The concept of multilevel inverters (MLI) does not depend on just two, three or five levels of voltage to create an AC signal. Instead several voltage levels are added to each other to create a smoother stepped waveform, see Figure 2.7, with lower $\frac{dy}{dt}$ and lower harmonic distortions. With more voltage levels in the inverter the waveform it creates becomes smoother, but with many levels the design becomes more complicated, with more components and a more complicated controller for the inverter is needed. To better understand multilevel inverters the more conventional three-level inverter, shown in Figure 2.8, can be investigated. It is called a three-level inverter since every phase-leg can create the three voltages $\frac{V_{dc}}{2}$, 0, - $\frac{V_{dc}}{2}$ as can be seen in the first part of Figure 2.7. A three-level inverter design is similar to that of a conventional two-level inverter but there are twice as many valves in each phase-leg. In between the upper and lower two valves there are diodes, called clamping diodes [3], [4]

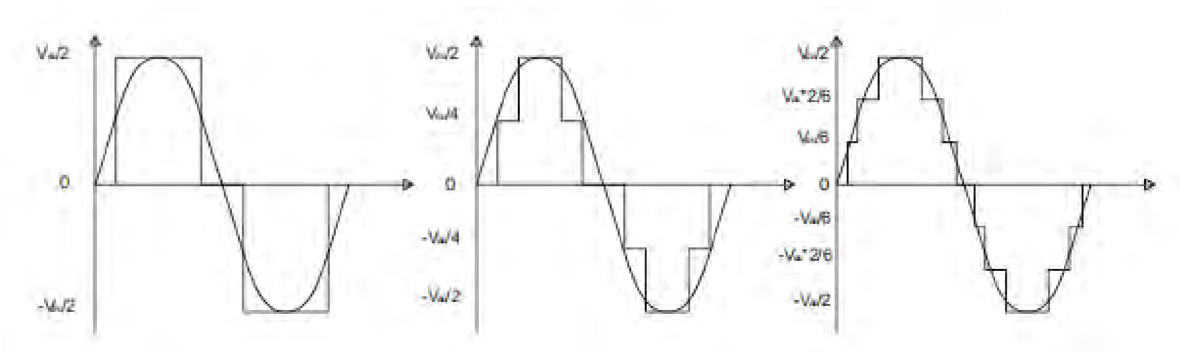


Figure 2.7: A three-level waveform, a five-level waveform and a seven-level multilevel waveform, switched at fundamental frequency.[4]