MINISTRY OF HIGHER EDUCATION
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ELECTRONIC
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A Multilevel Inverter Based On Space Vector PWM For Solar PV System

A Project

Submitted to the Electronic Department
University of Diyala _ College of Engineering
In Partial Fulfillment of the Requirements for the Degree of Bachelor in Electronic Engineering

By

Huda Aziz

Jumana Jamhure

And

Estabrk Fadul

Supervised by

Dr. Rokan Ali

الإهداء

إلى من كان معي على طول الطريق.............

إلى أهلي إلى والدي والدتي إلى كل صديق.........

إلى كل زملائي في الدراسة و زملائي في طريق العلم ....

إلى كل قريب و إلى كل بعيد........

إلى كل من ساهم في وضعي على طريق العلم..........

إلى كل الذين ساعدوني في كل هذا البحث..........

إلى كل من صبر و إلى كل من طالب علم............

إلى أساتذتي العزاء..............

إلى رئاسة القسم...............

بسم الله الرحمن الرحيم

﴿ اللّهُ لاَ إِلَهَ إِلاَّ هُوَ الْحَيُّ الْقَيُّومُ لاَ تَأْخُذُهُ سِنَةٌ وَلاَ نَوْمٌ لَّهُ
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عِنْدَهُ إِلاَّ بِإِذْنِهِ يَعْلَمُ مَا بَيْنَ أَيْدِيهِمْ وَمَا خَلْفَهُمْ وَلاَ
يُحِيطُونَ بِشَيْءٍ مِّنْ عِلْمِهِ إِلاَّ بِمَا شَاء وَسِعَ كُرْسِيُّهُ
السَّمَاوَاتِ وَالأَرْضَ وَلاَ يَؤُودُهُ حِفْظُهُمَا وَهُوَ الْعَلِيُّ
الْعَظِيمُ ﴾

صدق الله العظيم

سورة البقرة الاية (255)

Supervisors Certification

I *certify that this project entitled (A multilevel Inverter Based On SHEPWM For Photovoltaic Application) was prepared under my supervision at the departments by of electronics engineering, College of engineering by* ***Huda Aziz ,Jumana Jamhure*** *and* ***Estabrk Fadul*** *as partial fulfillment of the requirements for the Degree of Bachelor in Electronics Engineering .*

Signature:

Name: Dr. Rokan Ali

Title: Lecturer (ph. D)

(supervisor) Name: Dr. Mohammed Salman

Date: / / 2016

In view of the available recommendation, I forward this project for debate the examining committee.

Signature:

Title: Lecturer (ph.D)

(Head of The Department)

Date: / / 2016

Certificate of Examination Committee

*We certify that the project entitled(****A multilevel Inverter Based On Space Vector PWM For Solar PV System).*** *And examining committee, examined the student* ***Huda Aziz ,Jumana Jamhure*** *and* ***Estabrk Fadul*** *in contents, and that with our opinion, it meets the standard of a project for the Degree of Bachelor in Electronics Engineering.*

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Title:
(Chairman)
Date: / / 2015
Signature:
Name:
Title:
(Supervisor)
Date: / / 2016

Approved For University of Diyala , College of Engineering and Electronic Department.

Signature:

Name: Mohammed Salman

Title: Lecturer

(Head of Electronic Engineering Department

Abstract

Due to the shortfall of fossil fuels in the near future, development of alternative source of energy is needed. The power electronics device which converts DC power to AC power at required output voltage and frequency level is known as inverter. An inverting system for renewable energy application will be developed using the multilevel inverter technology, which is able to synthesize a desired ac voltage from several levels of dc voltages. Multilevel inverter as compared to single level inverters have advantages like minimum harmonic distortion, reduced EMI/RFI generation and can operate on several voltage levels.

A number of Pulse width modulation (PWM) schemes are used to obtain variable voltage and frequency supply. This project aims at generation of carrier based PWM and space vector scheme applied to the diode clamped e multilevel inverter in order to ensure an efficient voltage utilization and better harmonic spectrum.

Several tests to quantify the performance of the multilevel inverter under the proposed modulation scheme is carried out. Simulation results are obtained using MATLAB/Simulink environment for effectiveness of the study of the different control techniques of the diode clamped multilevel inverter. The results obtained from these tests agree well with theoretical prediction.

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CHAPTER ONE

INTRODUCTION

1-1Background

Power electronic converters, especially dc/ac PWM inverters have been extending their range of use in industry because they provide reduced energy consumption, better system efficiency, improved quality of product, good maintenance, and so on.

For a medium voltage grid, it is trouble some to connect only one power semiconductor switches directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations such as laminators, mills, conveyors, pumps, fans, blowers, compressors, and so on. As a cost effective solution, multilevel converter not only achieves high power ratings, but also enables the use of low power application in renewable energy sources such as photovoltaic, wind, and fuel cells which can be easily interfaced to a multilevel converter system for a high power application.

A multilevel converter can be implemented in many different ways. The simplest techniques involve the parallel or series connection of conventional converters to form the multilevel waveforms. More complex structures effectively insert converters within converters . The voltage or current rating of the multilevel converter becomes a multiple of the individual switches, and so the power rating of the converter can exceed the limit imposed by the individual switching devices.

Objective of Research

Multilevel inverters have been used in power electronic applications for over a decade. Research efforts in this area have contributes toward the development of several PWM schemes suitable for multilevel inverter application. Fundamentally, the choice of the PWM scheme will influence the complexity and performance of the multilevel inverter system. In this work the research will be focused on carrier based pwm and space vector for the diode clamped multilevel inverter.

The main focus will be a simulation study of the diode clamped multilevel inverter using one DC source supply as a photovoltaic cell that will be built using MATLAB simulink. It will be used to investigate and verify the quality of the ac output voltage, harmonic content of the output voltage and effects of different carrier based pwm and space vector modulation

1-3 Thesis Organization

The following thesis is divided into 5 chapters, which are as follows:

In Chapter 1:, the research background and an overview of the study . The outline of the thesis is given at the end of the chapter.

In Chapter 2 a comprehensive introduction about the MLI is presented. The existing MLI basic topologies are presented with discussion about applications of multilevel converters and the advantage and disadvantage aspects of these topologies are also presented.

In Chapter 3, an introduction to some of the most common modulation techniques with multilevel converter topologies used nowadays is made and different types of carrier based pwm and space vector are also presented

In Chapter 4 Simulation results for different carrier based pwm and space vector topology have been discussed. Two control strategies have been used . Some figures of merits of the proposed multilevel inverter system have been shown. Then achievements of the project objectives have been evaluated.

In Chapter 5: the conclusions obtained from the study and provides some suggestion for future studies will be presented in this chapter.

CHAPTER TWO

MULTILEVEL INVERTER

2.1 -1Introduction

The power in the battery is in DC mode and the motor that drives the wheels usually uses AC power, therefore there should be a conversion from DC to AC by a power converter. Inverters can do this conversion. The simplest topology that can be used for this conversion is the two-level inverter that consists of four switches. Each switch needs an anti-parallel diode, so there should be also four anti parallel diodes. There are also other topologies for inverters. A multilevel inverter is a power electronic system that synthesizes a sinusoidal voltage output from several DC sources. These DC sources can be fuel cells, solar cells, ultra capacitors, etc. 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 The THD will be decreased by increasing the number of levels. It is obvious that an output voltage with low THD is desirable, but increasing the number of levels needs more hardware, also the control will be more complicated. It is a tradeoff between price, weight, complexity and a very good output voltage with lower THD

2 .2 Basic topologies of multilevel inverter

.

Three types of multilevel inverter have been investigated in this thesis

Show blew in figure (2-1)

1. Diode Clamped multilevel inverters
2. Flying Capacitor multilevel inverters
3. Cascaded H-bridge multilevel inverters

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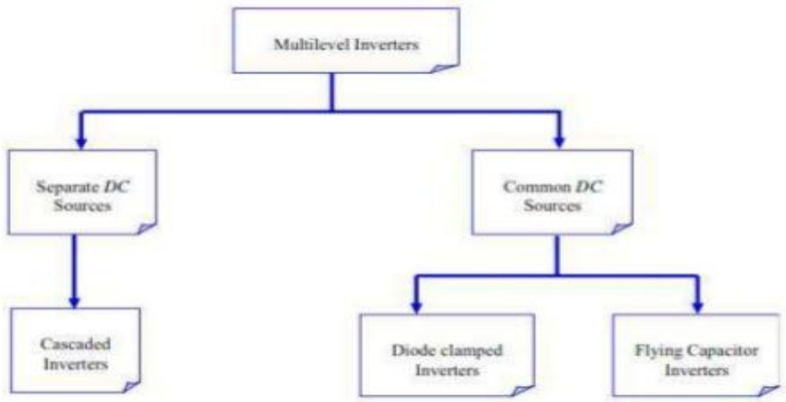

Figure (2-1) *Basic topologies of multilevel inverter*

2-2-1 Diode-Clamped Multilevel Inverter

The most commonly used multilevel topology is the diode clamped inverter, in which the diode is used as the clamping device to clamp the dc bus voltage so as to achieve steps in the output voltage. A three-level diode clamped inverter consists of two pairs of switches and two diodes. Each switch pairs works in complimentary mode and the diodes used to provide access to mid-point voltage. In a three-level inverter each of the three phases of the inverter shares a common dc bus, which has been subdivided by two capacitors into three levels. The DC bus voltage is split into three voltage levels by using two series connections of DC capacitors,C_1 and C_2. The voltage stress across each switching device is limited to V_{dc} through the clamping diodes D_{c1} and D_{c2}. It is assumed that the total dc link voltage is V_{dc} and mid point is regulated at half of the dc link voltage, the voltage across each capacitor is $V_{dc}/2$ ($V_{c1}=V_{c2}=V_{dc}/2$) Show in table (2-1). In a three level diode clamped inverter, there are three different possible switching states which apply the stair case voltage on output voltage relating to DC link capacitor voltage rate. For a three-level inverter, a set of two switches is on at any given time and in a five-level inverter, a set of four switches is on at any given time and so on the diode clamping in figure (2-2)

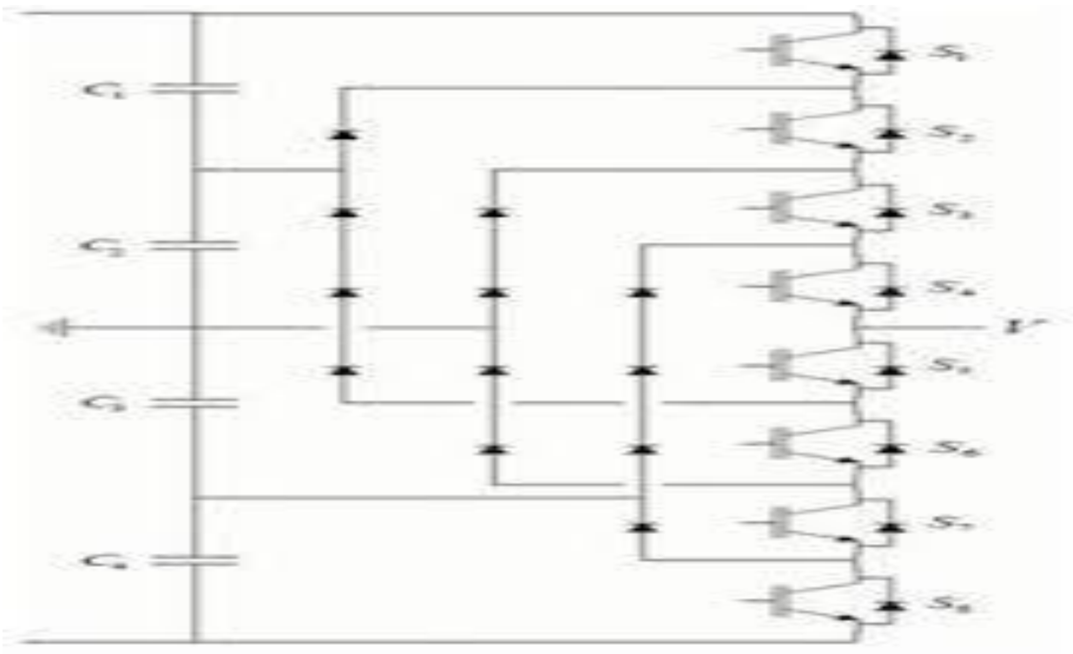

Figure (2-2) One phase of diode-clamped multilevel inverter

Table (2-1) The Switching States of Diode-Clamped Multilevel Inverter

Output Vo	Sa1	Sa2	Sa3	Sa4	S'a1	S'a2	S'a3	S'a4
V5=Vdc	1	1	1	1	0	0	0	0
V4=3Vdc/4	0	1	1	1	1	0	0	0
V3=Vdc/2	0	0	1	1	1	1	0	0
V2=Vdc/4	0	0	0	1	1	1	1	0
V1=0	0	0	0	0	1	1	1	1

2-2-2 Flying Capacitor Structure.

The capacitor clamped inverter alternatively known as flying capacitor was proposed by Meynard and Foch in 1992 [18]. The structure of this inverter is similar to that of the diode-clamped inverter except that instead of using clamping diodes, the inverter uses capacitors in their place. The flying capacitor involves series connection of capacitor clamped switching cells Show in table (2-3). This topology has a ladder structure of dc side capacitors, where the voltage on each capacitor differs from that of the next capacitor. The voltage increment between two adjacent capacitor legs gives the size of the voltage steps in the output waveform.

The circuit of flying capacitor multilevel inverter in figure (2-3)

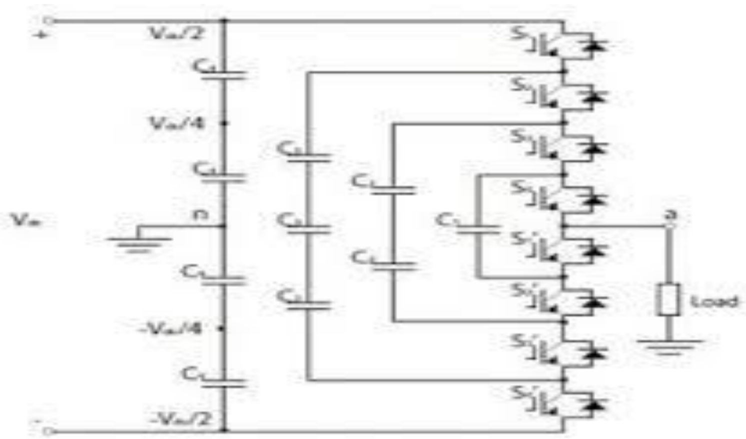

Figure (2-3) Flying Capacitors Multilevel Inverter

2-2-3 Cascaded multilevel inverter

One more alternative for a multilevel inverter is the cascaded multilevel inverter or series H-bridge inverter. Cascaded multilevel inverter was not fully realized until two researchers, Lai and Peng, the CMI has been utilized in a wide range of applications. With its modularity and flexibility, the CMI shows superiority in high-power applications, especially shunt and series connected FACTS controllers. The CMI synthesizes its output nearly sinusoidal voltage waveforms by combining many isolated voltage levels).. A series of single-phase full bridges makes up a phase for the inverter. A three-phase CMI topology is essentially composed of three identical phase legs of the series-chain of H- bridge converters, which can possibly generate different output voltage waveforms and offers the potential for AC system phase-balancing. This feature is impossible in other VSC topologies utilizing a common DC link. Since this topology consists of series power conversion cells, the voltage and power level may be easily scaled. The dc link supply for each full bridge converter is provided separately, and this is typically achieved using diode rectifiers fed from isolated secondary windings of a three-phase transformer. Phase-shifted transformers can supply the cells in medium-voltage systems in order to provide high power quality at the utility connection.

The output voltage of this inverter has 5 levels like in the previous multilevel inverters. This inverter consists of two H-bridge inverters that are cascaded. For a 5-level cascaded H-bridge multilevel inverter 8 switching devices are needed Show in figure (2-4)

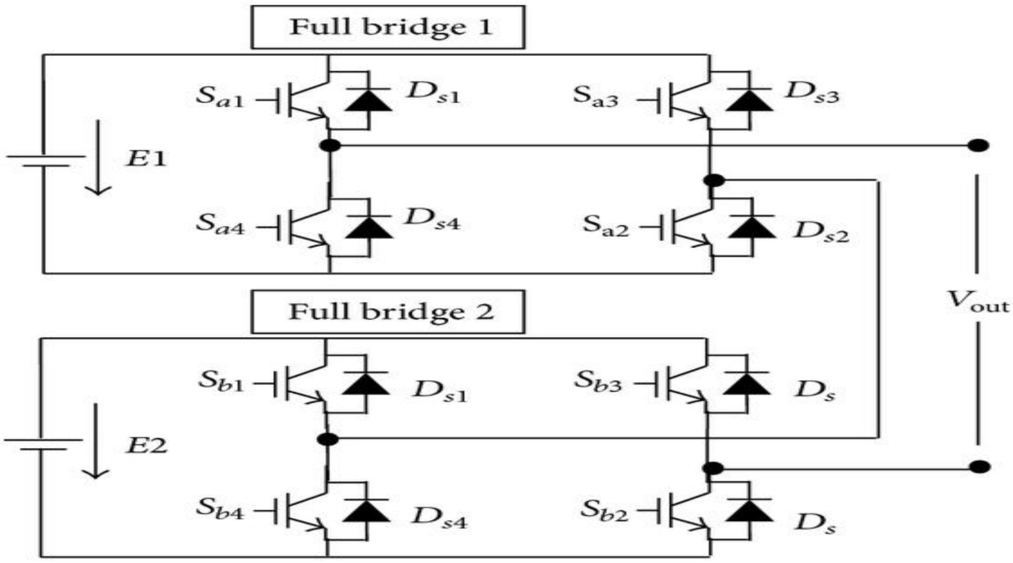

Figure (2-4)

Circuit Cascaded Multilevel Inverter

2-3 Application of multilevel inverter

Multilevel inverters utilize several dc voltages to synthesize a desired ac voltage. For this reason, multilevel inverters can be implemented using distributed energy resources such as photovoltaics and fuel cells. Energy storage devices like ultracapacitors and batteries can also be used with multilevel inverters [2].

Many people feel that distributed energy resources will become increasingly prevalent in the future. As a result, one notable application of multilevel inverters being considered is connecting the aforementioned energy resources with an ac power grid.

Some of the applications of the multilevel converters include compressors, fans, grinding mills, rolling mills, conveyers, blast furnace blowers, mine hoists, reactive power compensations, high voltage direct current (HVDC) transmission, Flexible Alternating Current Transmission System(FACTS), wind energy conversion, electric traction , railway traction , These converters can be easily interfaced with the renewable energy sources like photo voltaic cells, fuel cells, wind energy conversion [2, 4, 7]. Thus, power electronics is contributing toward a greener and cleaner world

If a multilevel converter is made to either draw or supply purely reactive power, then the multilevel converter can be used as a reactive power compensator. For example, a multilevel converter being used as a reactive power compensator might be placed in parallel with a load connected to an ac system. Using a multilevel converter as a reactive power compensator can help to improve the power factor of a load

It was mentioned earlier that it is possible to determine the switching angles of the multilevel converter such that certain higher order harmonics are either minimized or eliminated altogether. The switching angles can also be varied in order to inject certain harmonics into an ac system. For example, consider once again a multilevel converter placed in parallel with a load connected to an ac system. If the load draws a current containing a high amount of harmonic distortion, the multilevel converter can be used to provide some of these harmonics. As a result, the ac system can provide a more sinusoidal current

Another possible application of multilevel converters is their use in Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs). One reason is that multilevel converters, EVs, and HEVs are all ideally suited for utilization of a large number of relatively small-sized energy sources, such as batteries and fuel cells. Hybrid Electric Vehicle. The multilevel converters are not only for high power applications like HVDC etc but also for low power requirements like in renewable energy sources. Also, multilevel converters generally allow for smaller components, thus reducing weight.The most common initial application of multilevel inverter has been in traction, both in locomotives and track-side static converters . More recent applications have been for power system converters for VAR compensation and stability enhancement, high-voltage motor drive, active filtering, high-voltage dc transmission and most recently for medium voltage induction motor variable speed drives.

2-4 Advantage of multilevel inverter

One additional advantage of multilevel converters concerns switch ratings. Since multilevel converters usually utilize a large number of dc sources, switches are required to block smaller voltages. Since switch stresses are reduced, required switch ratings are lowered. As a result, cost is reduced

Another advantage of multilevel converters concerns the idea of reliability. If a component fails on a multilevel converter, most of the time the converter will still be usable, albeit at a reduced power level. Furthermore, multilevel converters tend to have switching redundancies. In other words, there might be more than one way to produce the desired voltage.

. These large components are expensive, bulky, and generally not reliable [1]. However, multilevel converters allow for the utilization of smaller, more reliable components. Another advantage of multilevel converters concerns application practicality. As an example, consider designing an inverter for a large HEV.

2-5 Disadvantage of Multilevel Inverter

One disadvantage of multilevel converters is that they require more devices on than many traditional converters. The system cost will increase (although this increased cost might be offset by the fact switches with lower ratings are being used). The idea of using more devices also means the probability of a device failure will increase.

Another disadvantage of multilevel converters concerns the idea of controlling the switches. The increased number of switches will result in more complicated control one disadvantage of using the multilevel fundamental switching scheme is that the created harmonics occur at much lower levels. However, determining the appropriate switching angles can result in eliminating some of these harmonics. The other harmonics can then be filtered.

CHAPTER THREE

MODULATION TECHNIQUE FOR MULTILEVEL CONVERTER

3-1 Introduction

Modulation: Process by which a property or a parameter of a signal is varied in proportion to a second signal.

Mainly the power electronic converters are operated in the "switched mode". Which means the switches within the converter are always in either one of the two states - turned off (no current flows), or turned on (saturated with only a small voltage drop across the switch). Any operation in the linear region, other than for the unavoidable transition from conducting to non-conducting, incurs an undesirable loss of efficiency and an unbearable rise in switch power dissipation. To control the flow of power in the converter, the switches alternate between these two states (i.e. on and off). This happens rapidly enough that the inductors and capacitors at the input and output nodes of the converter average or filter the switched signal. The switched component is attenuated and the desired DC or low frequency AC component is retained. This process is called Pulse Width Modulation (PWM), since the desired average value is controlled by modulating the width of the pulses.

The low pulse numbers place the greatest demands on effective modulation to reduce the distortion as much as possible. In these circumstances, multi-level converters can reduce the distortion substantially, by staggering the switching instants of the multiple switches and increasing the apparent pulse number of the overall converter.

3-2 Type OF Modulation

Three type of modulation have been investigated in thesis

1-Single pulse Width Modulation

2-Multiple Pulse Width Modulation

3-Sinusodal Pulse Width Modulation

3-2-1-Single pulse Width Modulation

In this there is only one pulse in each half cycle the width of the pulse is varied to control the inverter output voltage the instantaneons output voltage is

$Vo=Vs\ (g_1-g_4)$ (3-1)

the ration of Ar to Ac is the control variable and defined as amplitude modulation index show in figure(3-1)

$Vo = Vs\sqrt{S/}\pi$ (3-2)

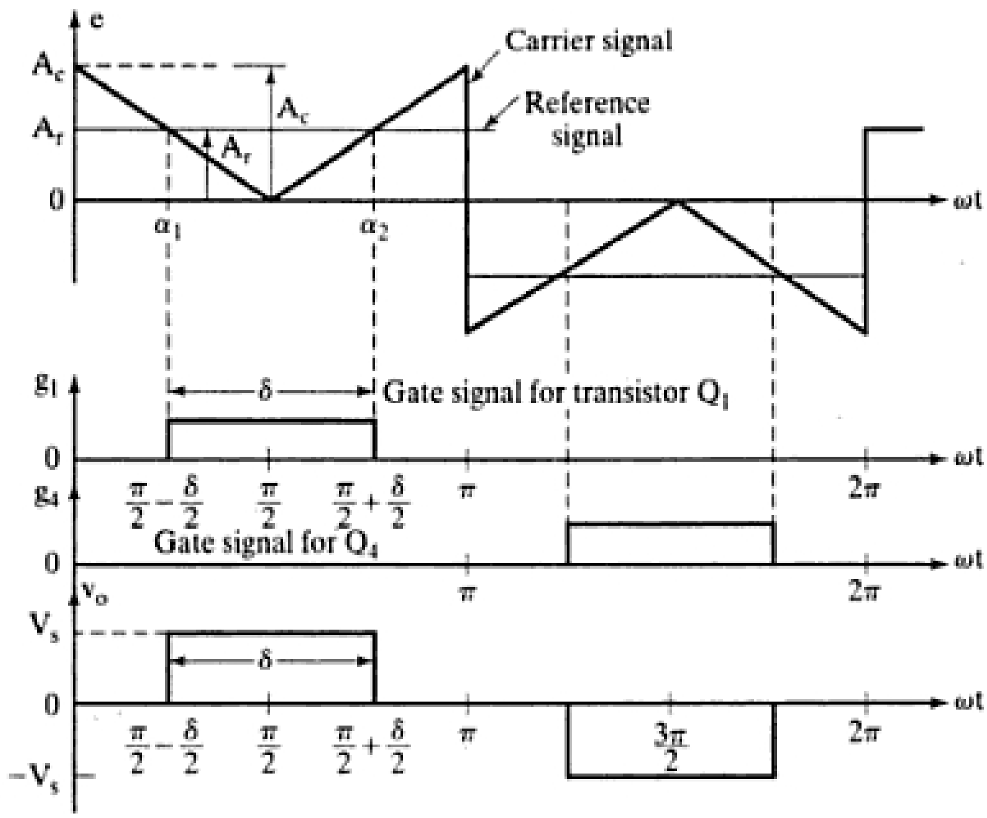

Figure (3-1) Single pulse width modulation

3-2-2-Multiple Pulse Width Modulation

The harmonic control can be reduced by using pulse in each half cycle output voltage the number of pulse per half cycle

P=mf/2 3-2

Mf =Fc/F 3-4

P =Number of pulse

Where Mf is define as frequency modulation ration the variation of modulation index M (0) to (1) varies the pulse width from 0 to and the output voltage from 0 to V_s show in figure (3-2)

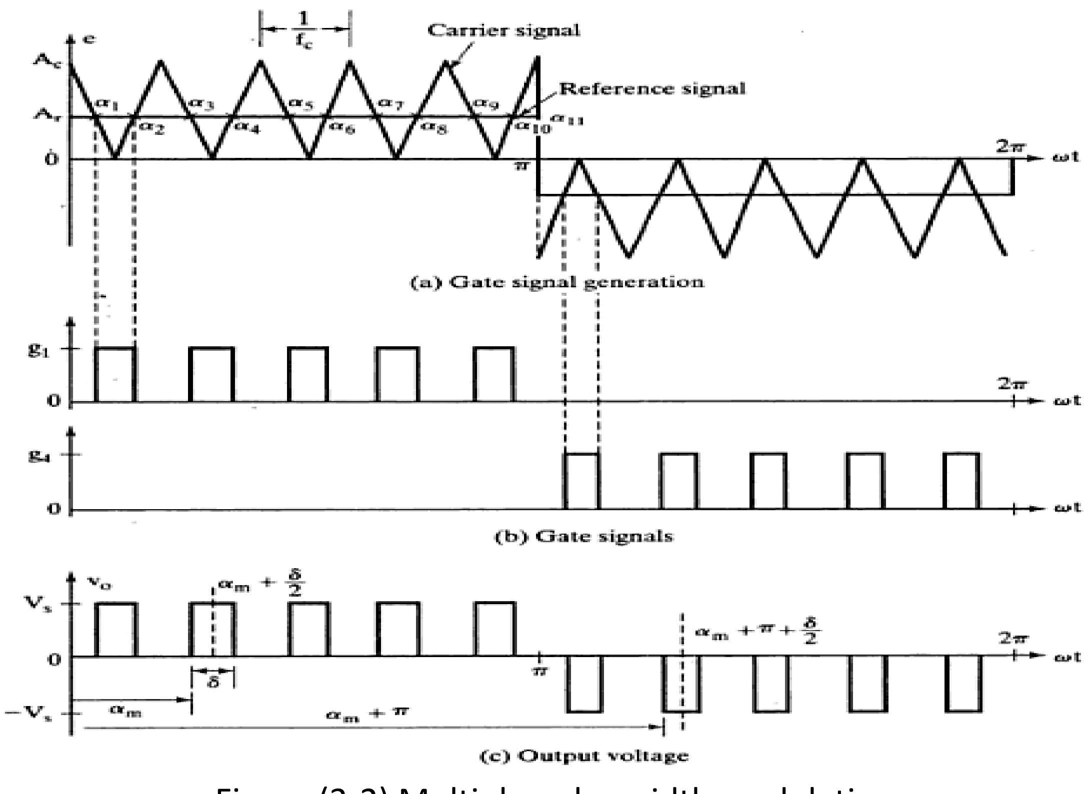

Figure (3-2) Multiple pulse width modulation

3-2-3-Sinusodal Pulse Width Modulation

Instead of maintaining the width of all pulse the same as in the case of multiple pulse modulation the width of each pulse is varied in proportion to the amplitude of a sine wave evaluated at the center of the same pulse if is the width of mth pulse can be extended to find show in figure (3-3). A sinusoidal reference signal and a high frequency carrier signal (triangular signal) are compared to give two states (high or low). The amplitude of the fundamental component of the output voltage of the inverter can be controlled by varying Modulation Index (MI). Modulation Index is defined as the ratio of the magnitude of the reference signal (V_r) to that of the magnitude of the carrier signal (V_c). Thus, by keeping V_c constant and varying V_r, the modulation index can be varied

V0=Vs $(\sum_{M=1}^{P} Sm/\pi)$^1/2 3-5

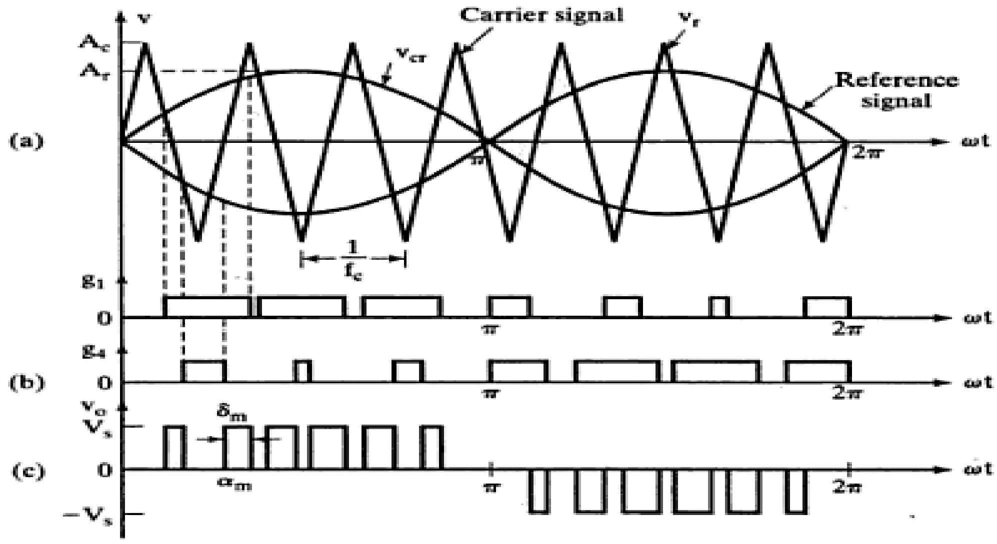

Figure (3-3) Sinusoidal pulse width modulation

3-3 Multicarrier Pulse Width Modulation Techniques

The carrier based PWM techniques for cascaded multilevel inverter can be broadly classified into : phase shifted modulation and level shifted modulation [13]. In both the techniques, for an m level inverter, (m-1) triangular carrier waves are required. And all the carrier waves should have the same frequency and the same peak to peak magnitude

3-3-1 Phase Shifted Multicarrier Modulation

In phase shifted PWM (PS-PWM) as shown in figure (3-4), there is a phase shift of between the adjacent carrier signals. The phase shift is give for a three phase inverter, the modulating signals should also be three phase sinusoidal signals with adjustable magnitude and frequency. For this modulation scheme, the frequency modulation index and the amplitude modulation index is given by n by

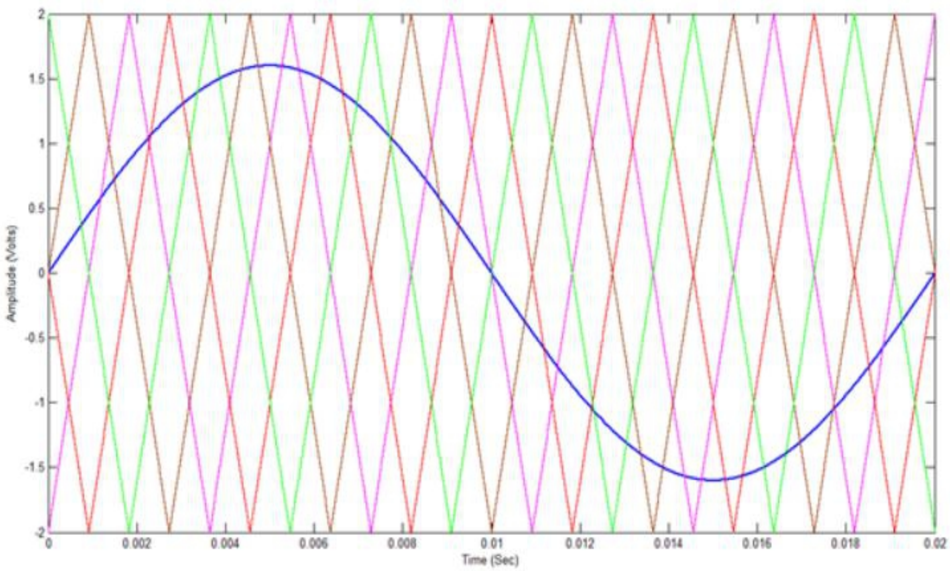

Figure (3-4) Phase Shift Multicarrier Modulation

3-3-2 Level Shifted Multicarrier Modulation

In Level Shifted PWM (LS –PWM), the triangular waves are vertically displaced such that the bands occupy are contiguous. The frequency modulation is given by and amplitude modulation index is

, where fm and fcr are the frequencies of the modulating and carrier waves and VmA and Vcr are the peak amplitudes of modulating and carrier waves respectively. The amplitude modulation lies in the range of 0 to 1. Depending upon the disposition of the carrier waves, level shifted PWM can be In Phase Disposition PWM (IPD – PWM), Phase Opposition Disposition PWM (POD – PWM) and Alternate Phase Opposition Disposition PWM (APOD –PWM) as shown in figure (3-5)

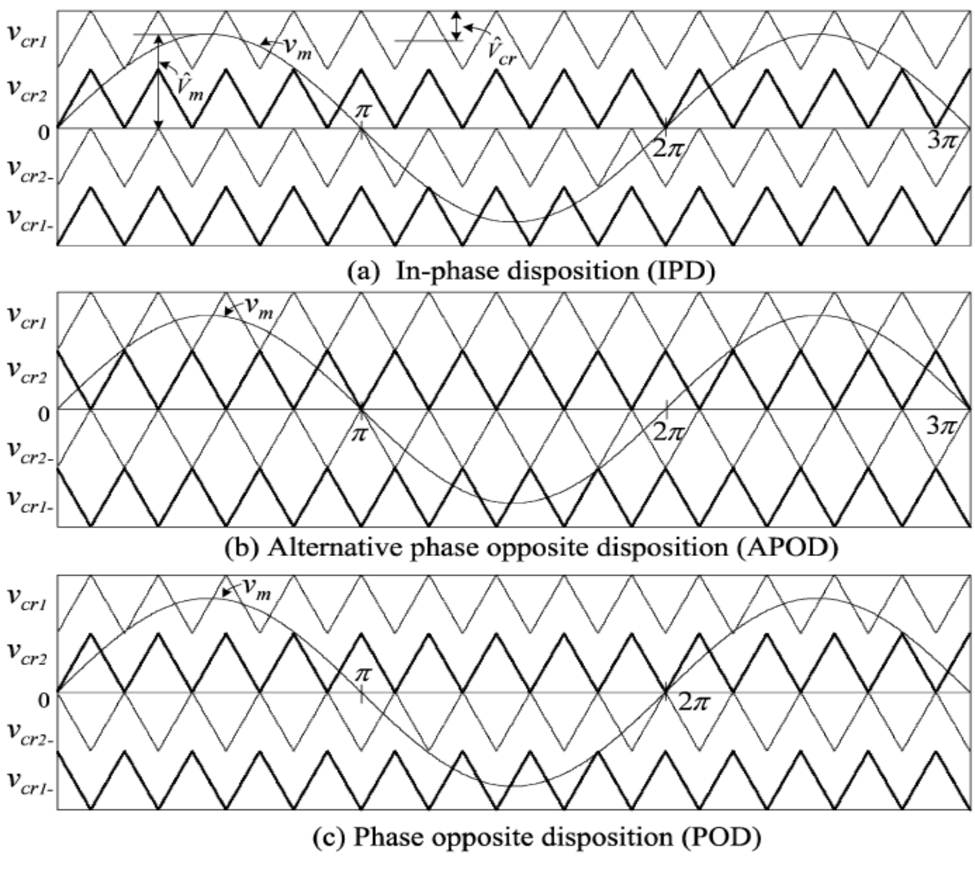

Figure (3-5) Level-shifted multicarrier modulation for five-level inverters.

3-4 Space vector PWM (SVPWM)

Space vector representation of the three-phase inverter output can be explained by using the Clark‟s Transformation theory and for that the reference vector should be represented in a αβ plane. This is a two-dimensional plane which is transformed from a three-dimensional plane and contains the vectors of the three phases. The αβ planeis shown in figure (3-6) consists of the horizontal α axis and the vertical β axis which is the imaginary axis. The reference voltage V_{ref} makes an angle Θ with the horizontal axis. Two level inverters switching states

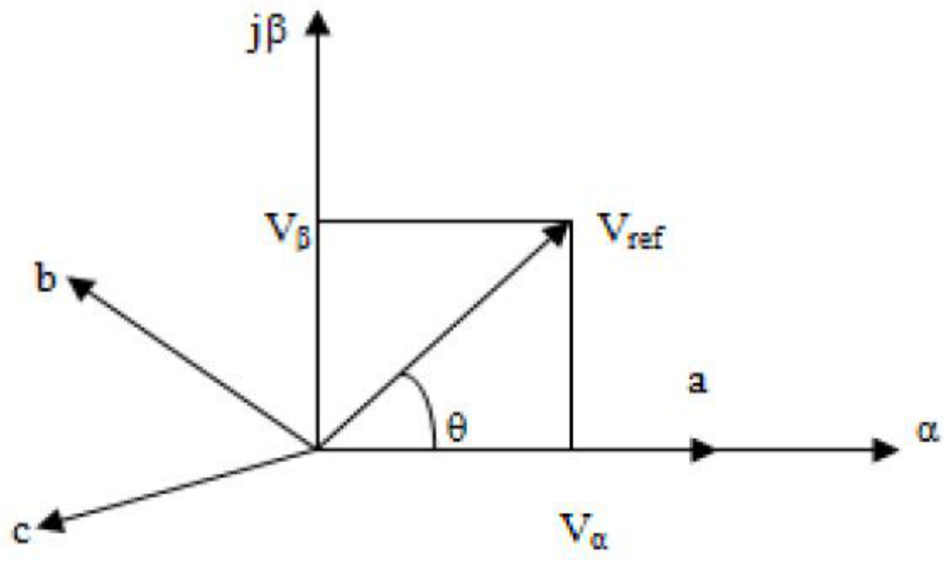

Figure (3-6) The reference vector in the two and three dimensional Plane

Two level inverters switching states are shown in Fig. 3.7

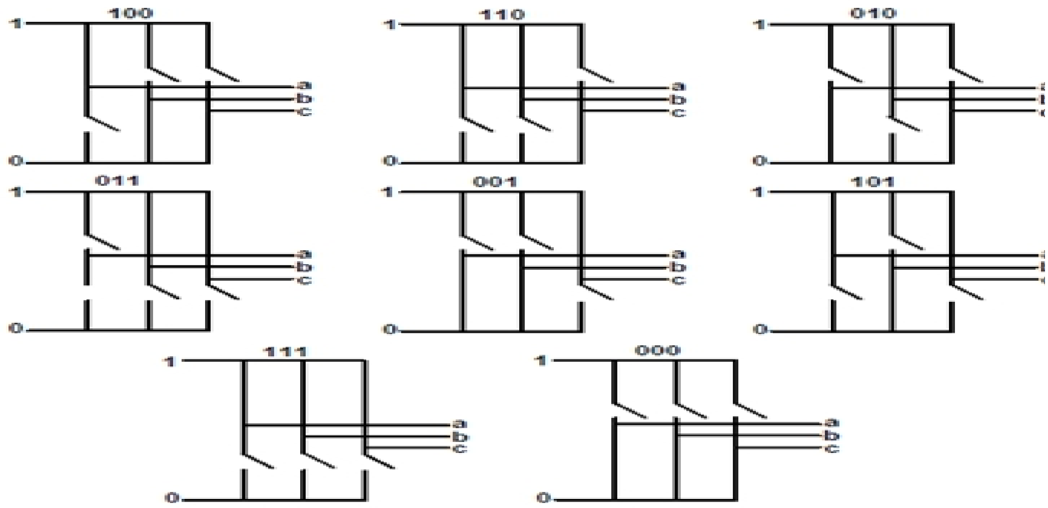

Figure (3-7) Switching State Of two Level

In two level inverters, there are 23= 8 possible states [10]. Two of them are (000 and 111) zero voltage vectors and others are active voltage vectors. "1" switching state represents +VDC/2 and "0" switching state represents- VDC/2 [11].

The principle of SVPWM method is that the command voltage vector is approximately calculated by using three adjacent vectors. The duration of each voltage vectors obtained by vector calculations [12];

$$T_1.V_1 + T_2.V_2 + T_0.V_0 = T_s.V_{ref} \quad (3-6)$$

$$T_1 + T_2 + T_0 = T_s \quad (3-7)$$

where V_1, V_2, and V_0 are vectors that define the triangle region in which V_{ref} is located. T_1, T_2 and T_0 are the corresponding vector durations and

TS is the sampling time. In a two-level inverter, space vector diagram is divided into 6 sectors (A-…-F). A typical space vector diagram of two-level inverter has been shown in Fig.(3-7). SVPWM for two-level inverters can be implemented by considering the following steps;

- Sector identification,
- Calculate the switching times, T_1, T_2, T_0
- Find the switching states.

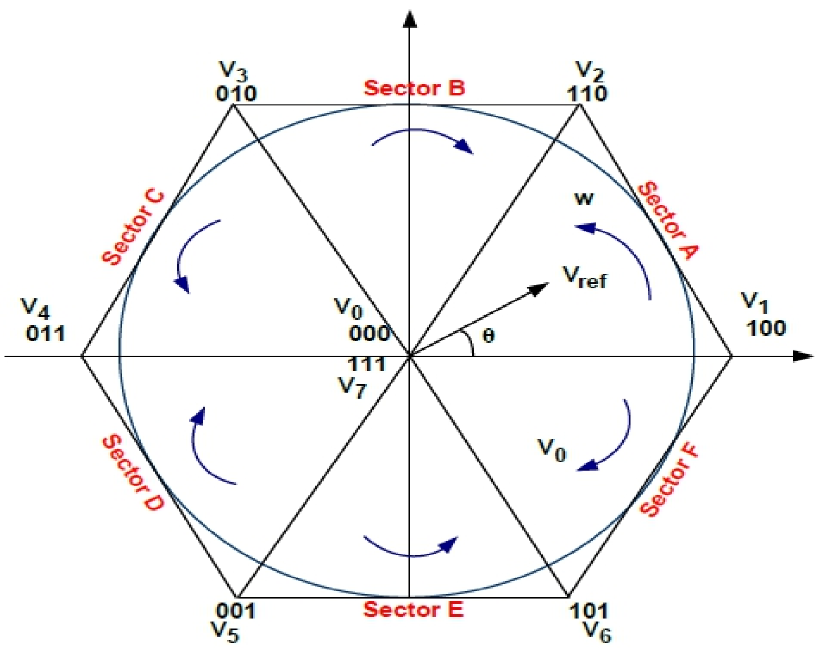

Figure (3-8) space vector diagram of two- level inverter

Orthogonal coordinates to represent the 3- phase voltage in the phasor diagram. A three-phase-voltage vector can be expressed as;

$$V_{ref} = V_d + V_q = \frac{2}{3}\left(V_{an} + V_{bn}e^{j\frac{2\pi}{3}} + V_{cn}e^{-j\frac{2\pi}{3}}\right) \qquad (3\text{-}8)$$

and θ angle is calculated by;

$$\theta = \arctan(\frac{V_q}{V_d}) \qquad (3\text{-}9)$$

where, Van, Vbn and Vcn are three phase voltages and Vref (reference voltage vector) rotates at angular speed of w = 2.π.f.

3.4.1. Sector Identification

Sector determination according to θ angle has been shown in Table 1.

Table I. Sector Determination

Angle (θ)	Sector where V_{ref} is placed
$0° \leq \theta < 60°$	Sector A
$60° \leq \theta < 120°$	Sector B
$120° \leq \theta < 180°$	Sector C
$180° \leq \theta < 240°$	Sector D
$240° \leq \theta < 300°$	Sector E
$300° \leq \theta < 360°$	Sector F

3.4.2 Calculating the Switching Times

V_{ref} is calculated by using two active voltage vector and one zero voltage vector. If Vref is located in Sector A, Vref is synthesized by V_1, V_2 and

V_0. According to this approach T_1, T_2 and T_0 can be calculated as;

$$T_1 = \frac{\sqrt{3}V_{ref}}{V_{DC}}.T_s.\sin\left(\frac{\pi}{3}-\theta\right) \qquad (3\text{-}10)$$

$$T_2 = \frac{\sqrt{3}V_{ref}}{V_{DC}}.T_s.\sin\left(\frac{\pi}{3}\right) \qquad (3\text{-}11)$$

$$T_0 = T_S - T_1 - T_2 \qquad (3\text{-}12)$$

If T_1, T_2 and T_0 switching times for all sector can be generalized, they can be calculated by;

$$T_k = \frac{\sqrt{3}.\frac{T_S}{2}V_{ref}}{V_{DC}}.(\sin(\frac{\pi}{3}-\theta+\frac{k-1}{3}\pi)) \qquad (3\text{-}13)$$

$$T_{k+1} = \frac{\sqrt{3}.\frac{T_S}{2}V_{ref}}{V_{DC}}.(\sin(\theta-\frac{k-1}{3}\pi)) \qquad (3\text{-}14)$$

$$T_0 = T_S - T_1 - T_2 \qquad (3\text{-}15)$$

where k = 1-..-6 (Sector A-..-Sector F) and $0 \le \theta \le 60°$

.

3.4.3. Finding Switching States

Switching states for Sector A has been shown in Figure 5.

All switching states has been given in Table 2.

Table II. Switching states for Two level inverter

Sectors	Switching States
Sector A	$V_0\ V_1\ V_2\ V_7\ V_7\ V_2\ V_1\ V_0$
Sector B	$V_0\ V_3\ V_2\ V_7\ V_7\ V_2\ V_3\ V_0$
Sector C	$V_0\ V_3\ V_4\ V_7\ V_7\ V_4\ V_3\ V_0$
Sector D	$V_0\ V_5\ V_4\ V_7\ V_7\ V_4\ V_5\ V_0$
Sector E	$V_0\ V_5\ V_6\ V_7\ V_7\ V_6\ V_5\ V_0$
Sector F	$V_0\ V_1\ V_6\ V_7\ V_7\ V_6\ V_1\ V_0$

CHAPTER FOUR

SIMULATION RESULTS

4.1 Introduction

It is fact that harmonic components in load current closely affect the performance of the inverter. So harmonic components are tried to be reduced and load current is brought in a quality sinusoidal form. To analyze the harmonic performance of the two techniques for purpose of comparison, several harmonic measures are possible. The total harmonic distortion (THD) is one of these measures, which evaluates the quantity of harmonic contents in the output waveform. For this purpose, the simulation studies are carried out for two different cases.

The first case is the ordinary diode clamed multilevel inverter by using CBPWM. This case is studied to examine the characteristics of the output voltage and output current.

The second case is ordinary diode clamed multilevel inverter by using space vector modulation. It is studied to examine the characteristics of the output voltage and output current to compare with other methods.

4.2. Simulation results for Diode-Clamped MLI Topology

To ensure its feasibility, three phase dioed clamed   in Fig. 4.1 was simulated in Matlab Simulink power block set software. Table 4.1 shows the ON switches lookup table.

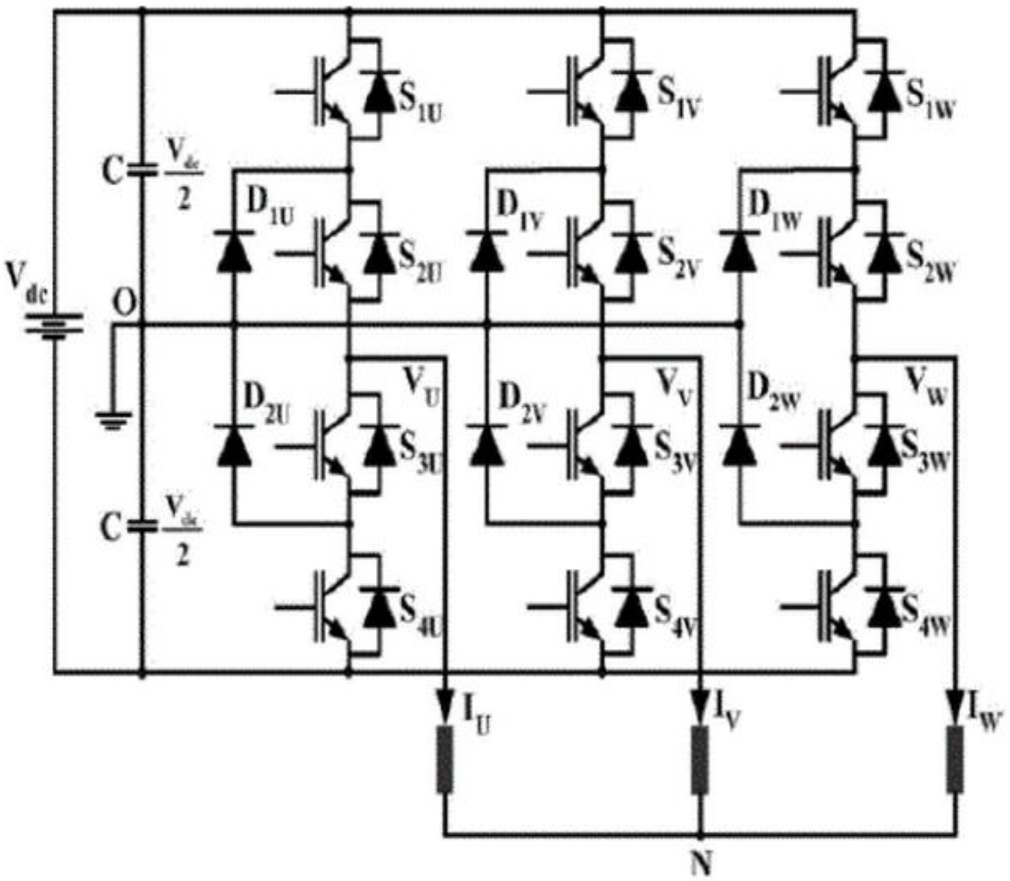

Fig4. 1 Power circuit of a three level diode clamped MLI

Table 4.1 Switching states for different values of Vo for three level diode clamped MLI

V_{an}	S_{1W}	S_{2W}	S_{3W}	S_{4W}
Vdc/2	1	1	0	0
Vdc/2-	0	0	1	1
0	0	1	0	1

4.3 Simulation of In-Phase Disposition (IPD) modulation

Specific control strategy was applied to bring the load voltage waveform close to the reference signal with 50 Hz. Staircase modulation, which was mentioned in Chapter 2, was the chosen technique,. Figure 4.2 shows the switching pulses of this topology. Figures 4.5 show the wave-shape output voltage in the time domain. Figure 4.4 shows the output voltage waveform with its corresponding FFT spectrum.

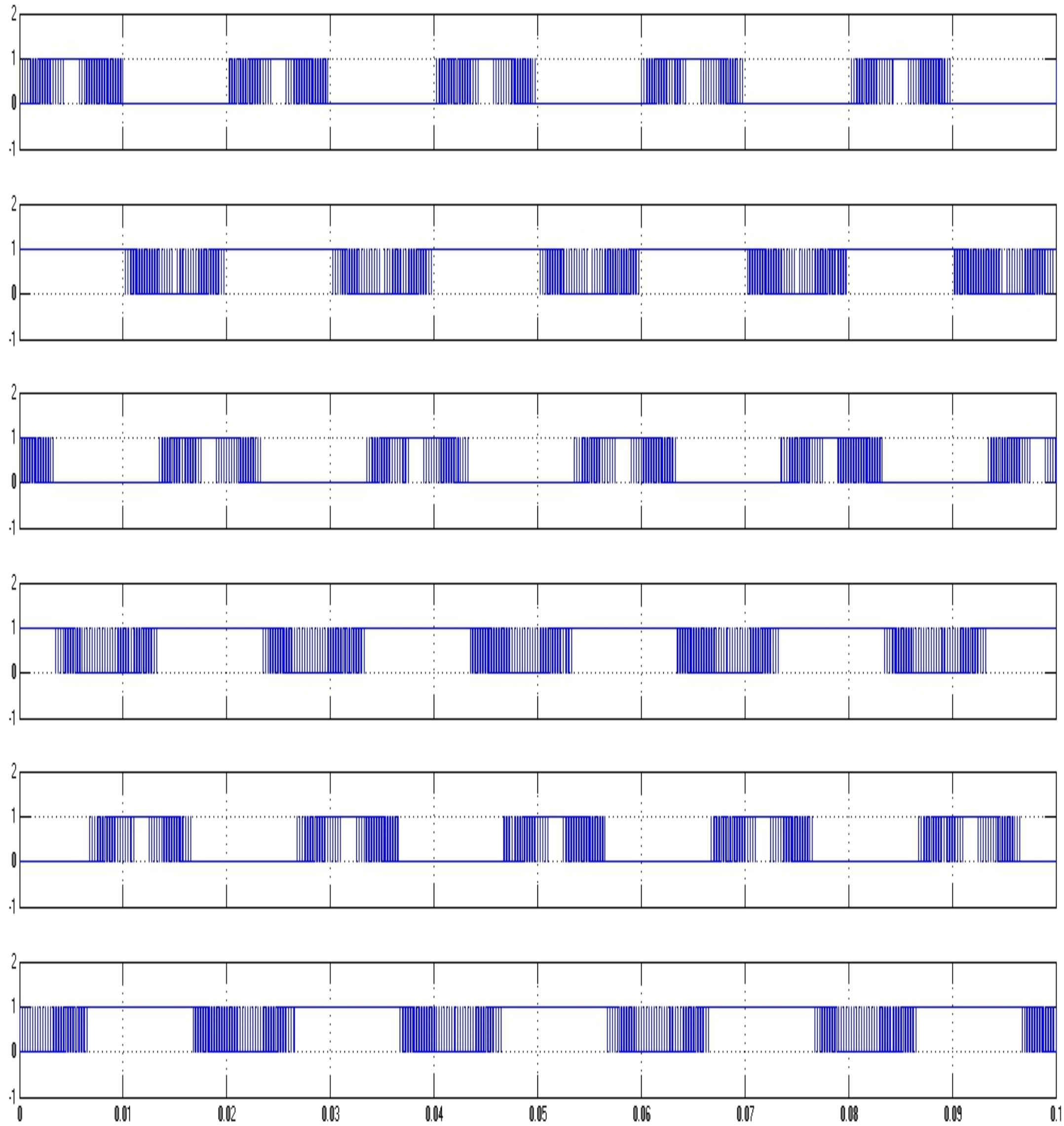

Fig 4. 2 Switching pulse for three level diode clamped MLI by using In-Phase Disposition (IPD) modulation.

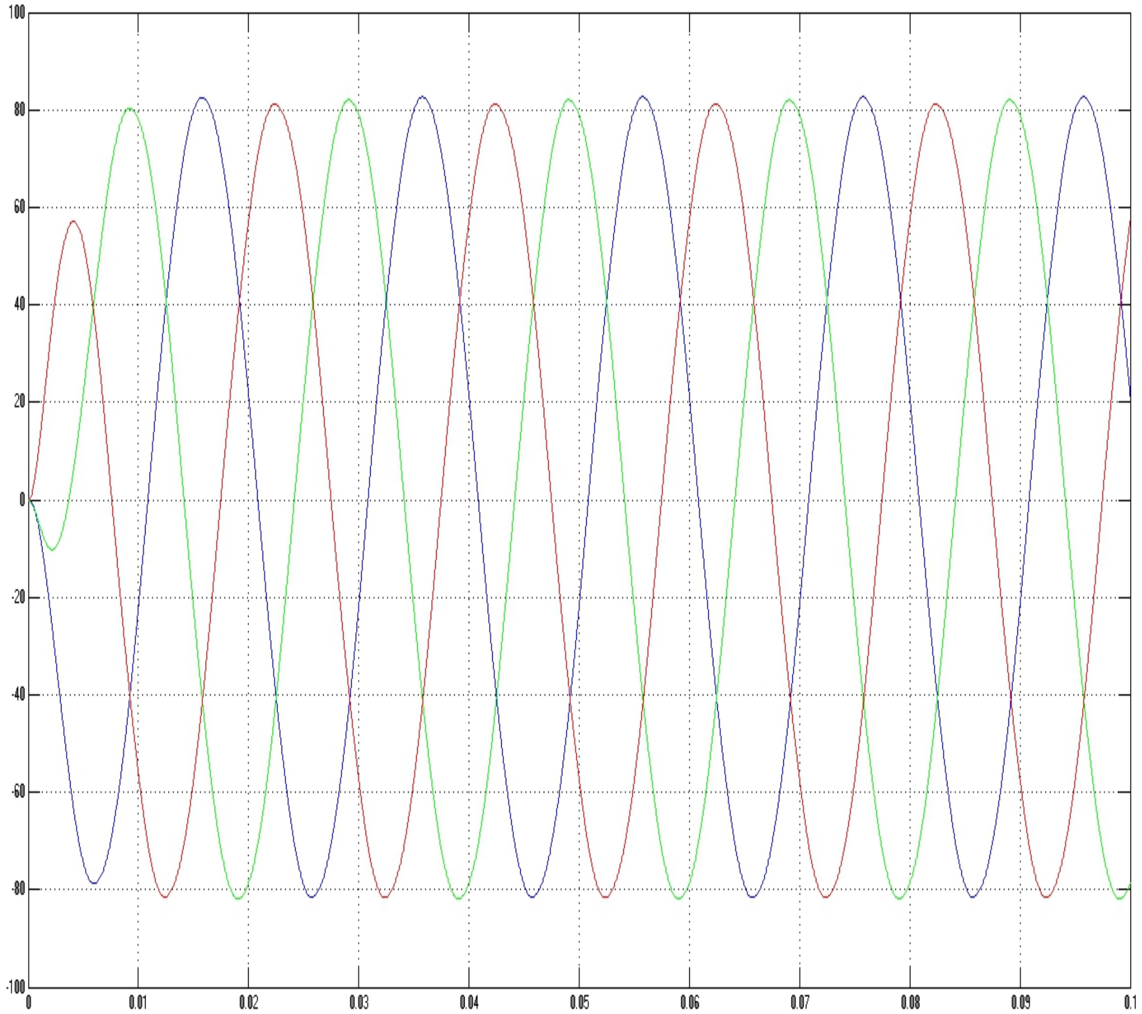

Fig 4.3 Simulated output voltage for three level diode clamped MLI by using In-Phase Disposition (IPD) modulation

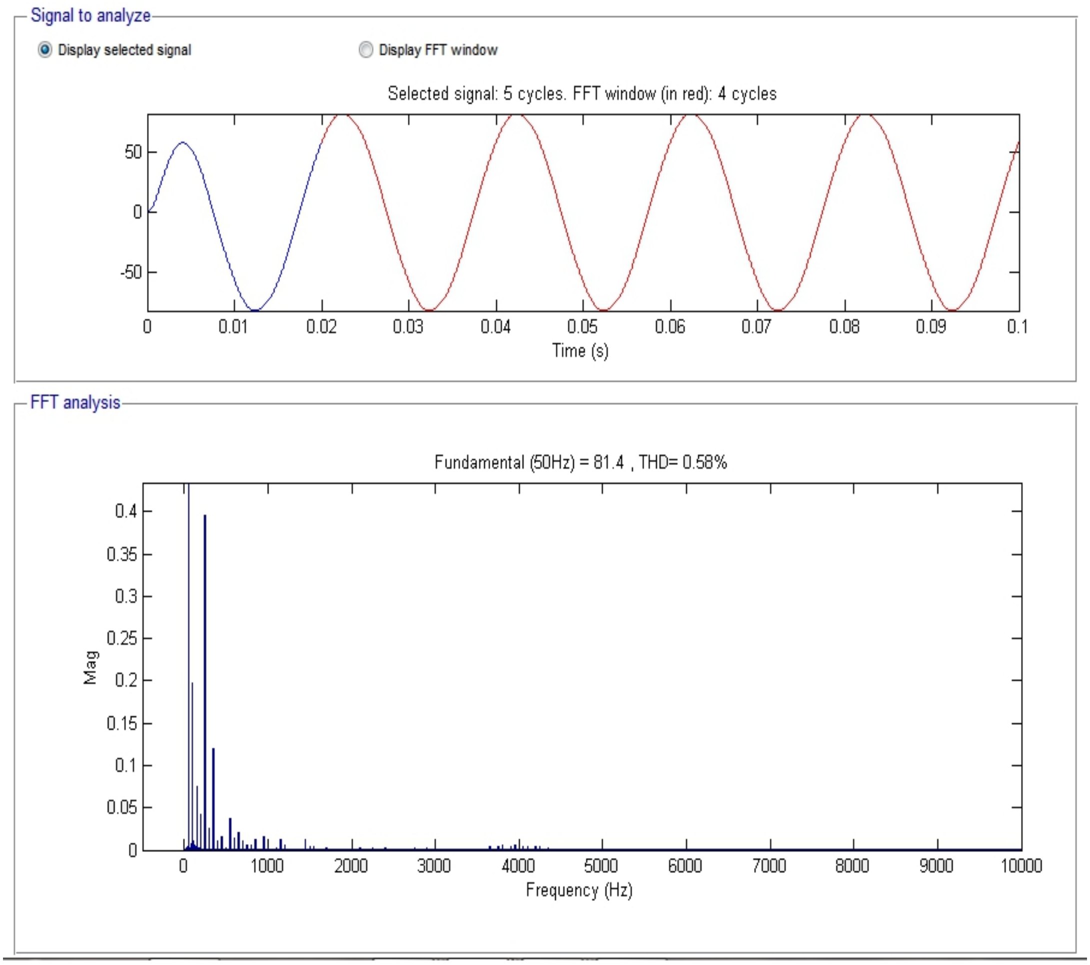

Fig 4.4 Output voltage with corresponding Fourier spectrum of three level diode clamped MLI

4.4 Simulation of SVPWM

The results of the three-phase diode clamped MLI with the same test but by using space vector modulation to make load voltage waveform close to the reference signal. Space vector modulation has taken place as modulation technique as explained below

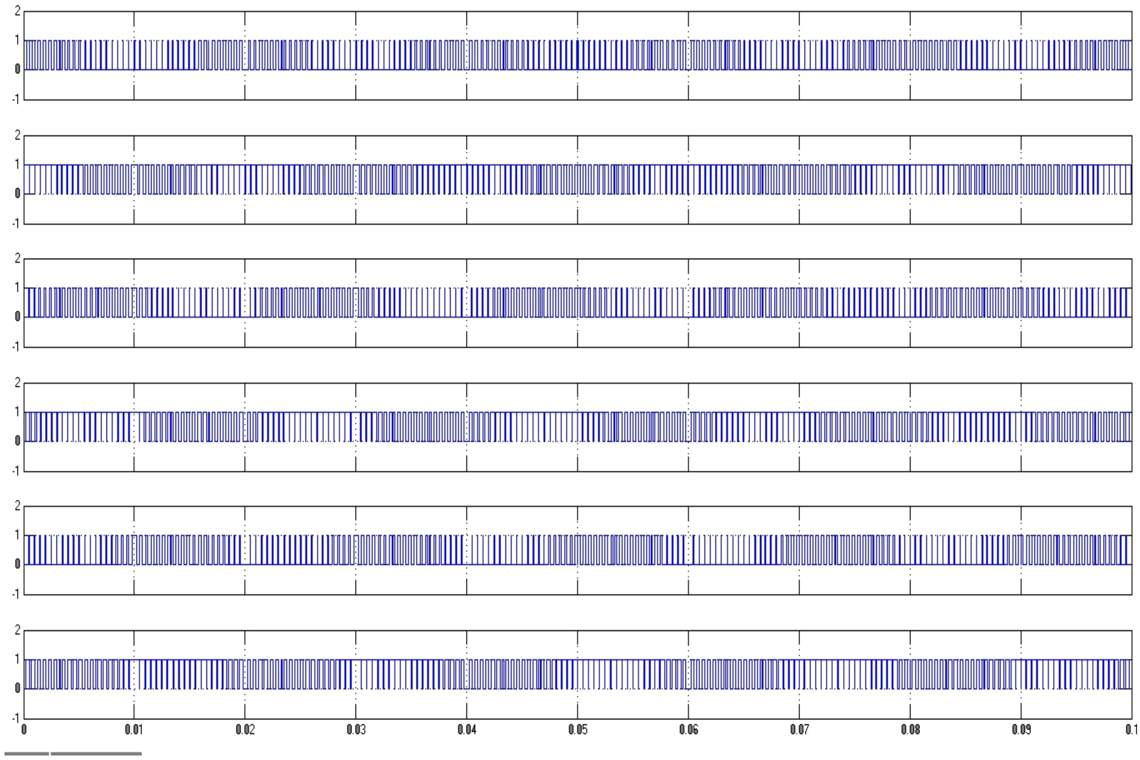

Figure (4.5).
Switching pulses for three level diode clamped MLI by using SVPW

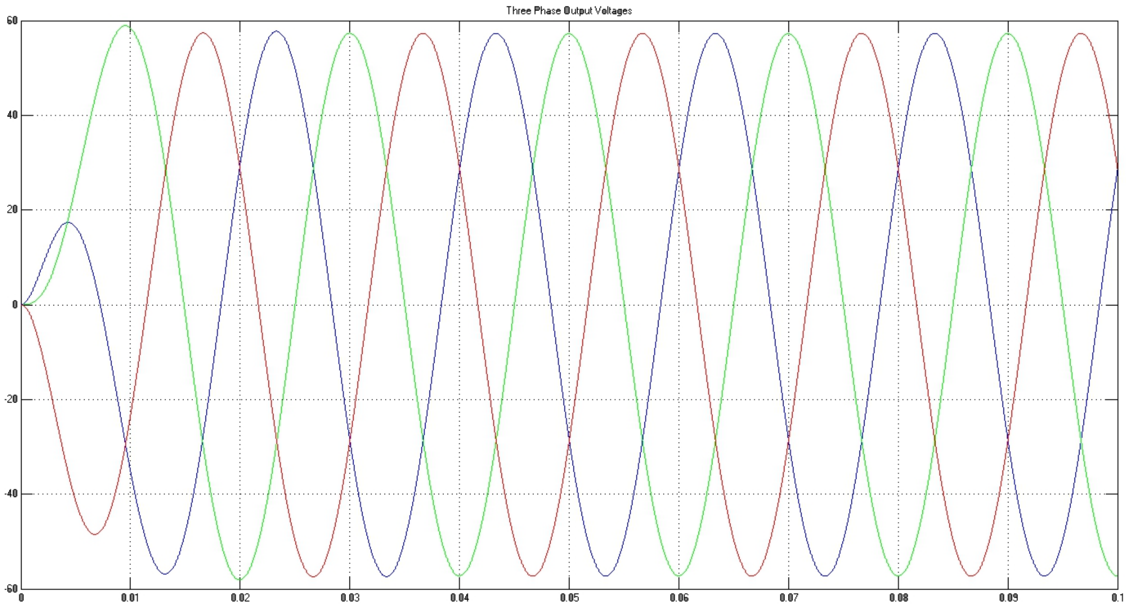

Fig (4.6) Output voltage for three level diode clamped MLI by using SVPWM .

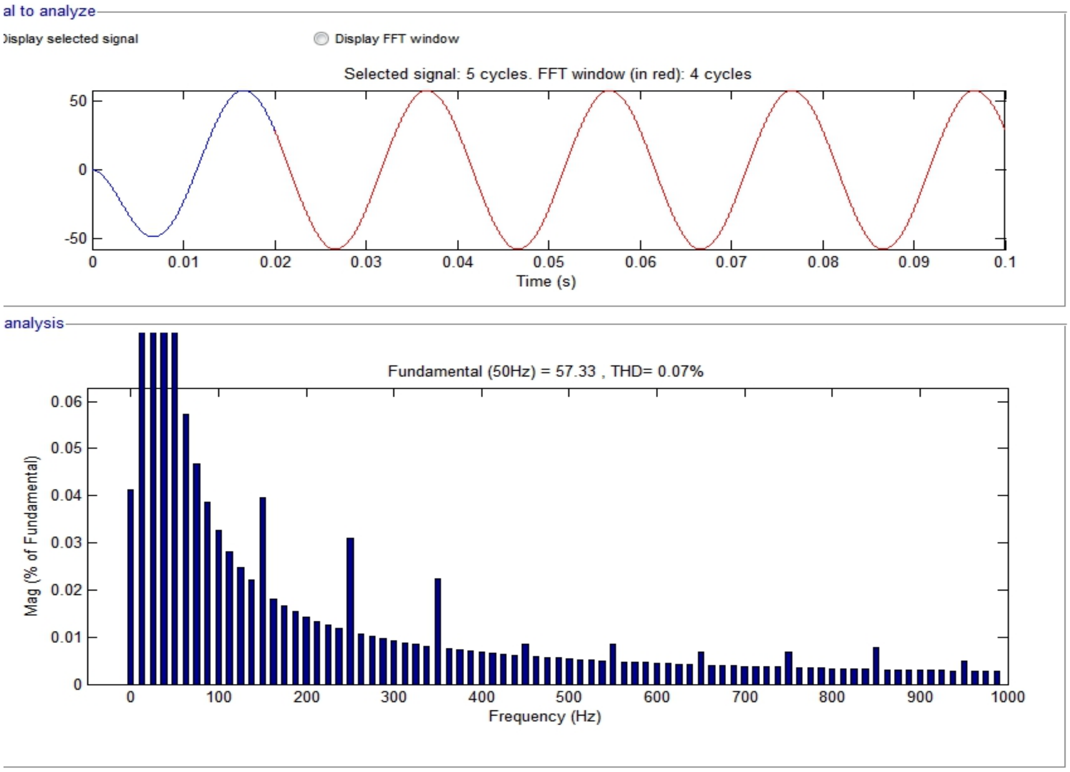

Fig (4.7) Output voltage with corresponding Fourier spectrum of three level diode clamped ML by using SVPWMI

4.5 THD values of cascaded Seven level multilevel inverter

Simulate cascaded seven level inverter to find how the THD is affected by the modulation . The value of THD so obtained for various modulation techniques implemented in a cascaded eleven level inverters is tabulated as shown in table

Table (4.2) Comparison of THD for different modulation technique

	IPD	SVPWM
THD for three level Diode clamped MLI	0.58	0.07

CHAPTER FIVE

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORKS

5-1 Conclusion

In this thesis the simulation of seven –level diode clamped multi level inverter has been simulated by using the IPDPWM and space vector techniques. A MATLAB SIMULINK model, and simulation results for different modulation indexes were presented. The THD analysis has been done for different Modulation techniques. From the THD analysis we can say that the THD for space vector techniques less when compared with IPDPWM technique and higher VRMS. DC source can be replaced by renewable energy sources .

5-2 Future Work

This study focused on single-phase topologies of MLI to enhance their quality. Suggestions for further research are discussed in four specific areas: Three-phase multilevel inverter and carrier based pwm strategy, power factor correction (PFC), multilevel inverter converter and space factor PWM strategy, and application.

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