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Simplified PWM Technique for Multilevel Inverter Fed Induction Motor Drive to Reduce Total Harmonic Distortion

[1]S. Abdul Razak Miah,[2] Y. Chintu Sagar, [3]S. Farzana

[1]Assistant Professor, Dept. of EEE, ASKW, Kurnool
[2]Assistant Professor, Dept. of EEE, ASKW, Kurnool
[3]Assistant Professor, Dept. of EEE, ASKW, Kurnool

ABSTRACT

The multilevel began with the three level converters, the elementary concept of a multilevel converter to achieve higher power. Multilevel converters offer high power capability, associated with lower output harmonics and lower commutation losses. In the proposed project, simplified PWM technique has to be applied to formulate the switching pattern for two level inverter, three level and five level "cascaded multi-level inverter" fed induction motor drive using MATLAB/Simulink. Finally Total Harmonic Distortion of stator current of induction motor and output voltage of cascaded multi-level inverter has to be compared.

Keywords: multilevel, PWM technique, MATLAB/Simulink.

1. Introduction

An Inverter is a converter that converts DC-AC power. Inverter circuits can be very complex so the objective of this method is to present some of the inner workings of inverters without getting lost in some of the fine details. The word "inverter" in power electronics denotes a power conversion circuits that operates from a DC (voltage source/current source) and converts it into AC voltage or current.

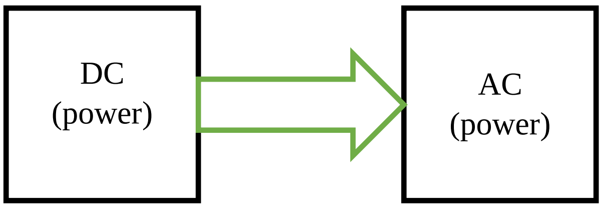

Figure 1: Inverter operation

Even though input to an inverter circuit is a DC source, it not uncommon to have this DC derived from an AC source such as utility AC supply. Thus 'for example the primary source of input power may be utility AC voltage supply that is converted to DC by an AC to DC converter and then inverted back to AC using an inverter. Here, the final output may be of a different frequency and magnitude than the input ac of the utility supply. Typical Applications such as Un-interruptible Power Supply (UPS), Industrial (induction motor) drives, Traction, HVDC.

Multi -Level Inverters (MLI)

Industrial applications require higher power apparatus at present. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application.

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Although multilevel inverters were basically developed to reach higher voltage operation, before being restricted by semiconductor limitations, the extra switches and DC sources (supplied by DC-link capacitors) could be used to generate different voltage levels, enabling the generation of stepped waveform with less harmonic distortion, reducing dv/dt and common-mode voltages. These characteristics have made them popular for high-power medium-voltage applications but the large number of semiconductor switches in these inverters, result in a reduction both of the reliability and efficiency of the drive.

The term multilevel began with the three-level converter. The concept of multilevel converters has been introduced since 1975. Subsequently, several multilevel converter topologies have been developed. However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage DC sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple DC voltage sources. The commutation of the power switches aggregate these multiple DC sources in order to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only upon the rating of the DC voltage sources to which they are connected.

Therefore, many power electronic researchers have made great effort in developing multilevel inverters with the same benefits and less number of semiconductor devices.

Importance of multilevel inverter

The importance of Multilevel Inverters has been increased since last few decades. These new types of inverters are suitable for high voltage and high power application due to their ability to synthesize waveforms with better harmonic spectrum and with less Total Harmonic Distortion (THD).

The Multi-Level Inverter [MLI] is a promising inverter topology for high voltage and high power applications. This inverter synthesizes several different levels of DC voltages to produce a stepped AC output that approaches the pure sine waveform.

It has the advantages like high power quality waveforms, lower voltage ratings of devices, lower harmonic distortion, lower switching frequency and switching losses, higher efficiency, reduction of dv/dt stresses etc. It gives the possibility of working with low speed semiconductors in comparison with the two-level inverters.

Total Harmonics Distortion (THD)

Harmonic currents are generated by non-linear electronic loads and they increase power system heat losses and power bills of end-users.

These harmonic-related losses

Reduce system efficiency

cause apparatus overheating

And increase power and air conditioning costs.

As the number of harmonics-producing loads has increased over the years, it has become increasingly necessary to address their influence when making any additions or changes to an installation.

Harmonic currents can have a significant impact on electrical distribution systems and the facilities they feed. It is important to consider their impact when planning additions or changes to a system. In addition, identifying the size and location of non-linear loads it should be an important part of any maintenance, troubleshooting and repair program.

Sources of Harmonic Distortion

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Non-linear components in the power system cause distortion of the current and to a lesser extent of the voltage. These sources of distortion can be divided in three groups:

1. Loads

2. The power system itself (HVDC, SVC, transformers, etc)

3. The generation stage (synchronous generators)

Trouble with Harmonics in Modern Power Systems

Harmonics are a distortion of the normal electrical current waveform, generally transmitted by nonlinear loads. Switch-Mode Power Supplies (SMPS), variable speed motors and drives, photocopiers, personal computers, laser printers, fax machines, battery chargers and UPSs are examples of nonlinear loads. As these higher frequency harmonic currents flow through the power system, they can cause communication errors, overheating and hardware damage, such as:

High voltages and circulating currents caused by harmonic resonance.

Internal energy losses in connected equipment increased and that may cause component failure and shortened life span of equipment.

Overheating of routine electrical equipment used like cables, transformers, standby generators, etc.

Excessive voltage distortion resulted by harmonics cause Equipment malfunction. Due to malfunctioning false tripping of branch circuit breakers occur.

Metering errors.

Fires in wiring and distribution systems

Generator failures

Crest factors and related problems

Lower system power factor, resulting in penalties on monthly utility bills.

Main feature of Multi-Level Inverter (MLI)

Even at low switching frequencies, smaller distortion in the multilevel inverter AC side waveform can be achieved (with stepped modulation technique).

Ability to reduce the voltage stress on each power device due to the utilization of multiple levels on the DC bus.

Important when a high DC side voltage is imposed by an application (e.g. traction systems).

Advantages of Multi-Level Inverter (MLI)

The attractive features of a multilevel converter can be briefly summarized as follows.

Staircase waveform quality:

Multilevel converters not only generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore EMC (Electro Magnetic Compatibility) problems can be reduced.

Common-Mode (CM) voltage:

Multilevel converters produce smaller CM voltage; therefore, the stress in the bearings of a motor connected to a multilevel motor drive 4 can be reduced. Furthermore, CM voltage can be eliminated by using advancedmodulation strategies

Input current:

Multilevel converters can draw input current with low distortion.

Switching frequency:

Multilevel converters can operate at both fundamental switching frequency and high switching frequency PWM. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency.

2. Proposed method

In the proposed project, simplified PWM technique has been applied to formulate the switching pattern for two level inverter, three level and five level "cascaded multilevel inverter" fed induction motor drive using MATLAB/Simulink. Finally Total Harmonic Distortion of stator current of induction motor and output voltage of cascaded multi-level inverter has been compared.

A Two-level Inverters

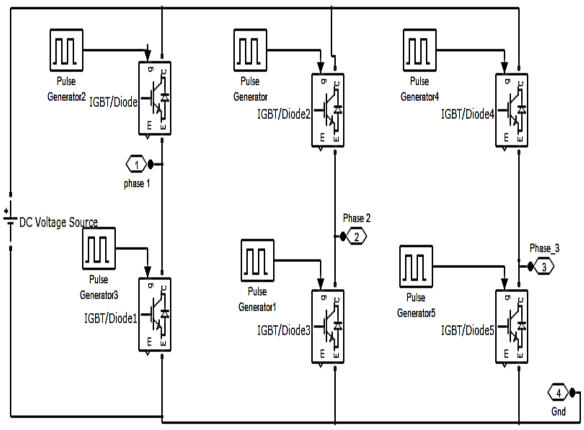

Figure 2: Basic two level inverter

B Diode Clamped

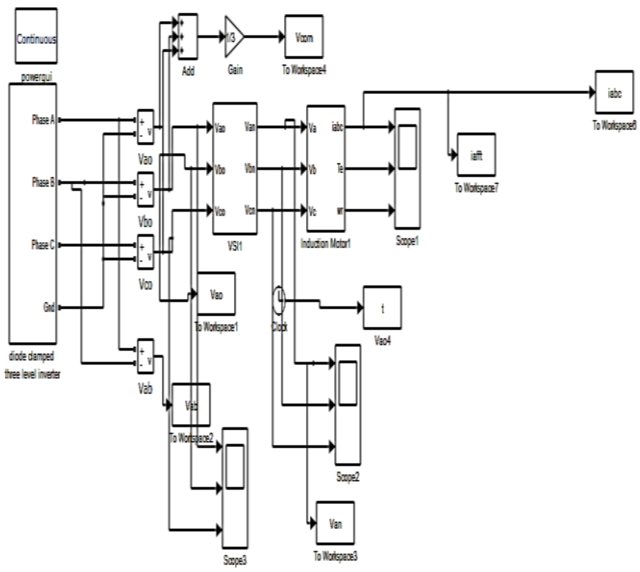

Figure 3: Block diagram of Diode clamped inverter

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Three-level

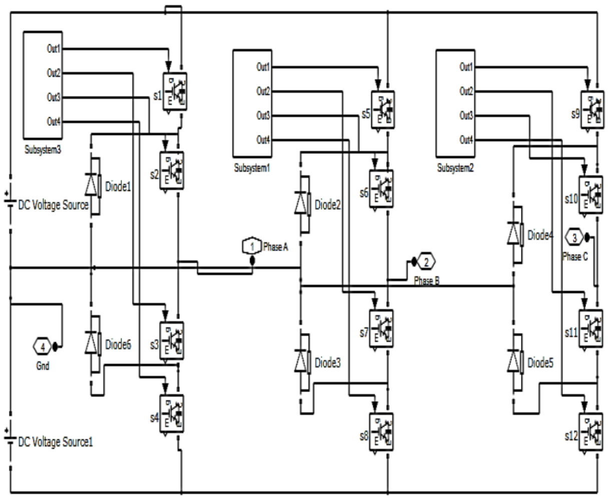

Figure 4: Block description of three phase three-level Diode clamped inverter

Five-level

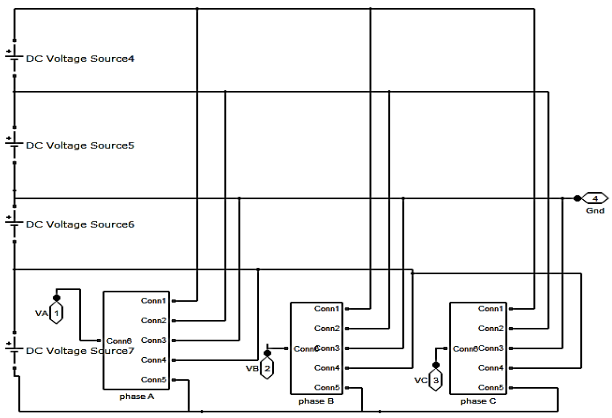

Figure 5 (i): Diode clamped five-level inverter

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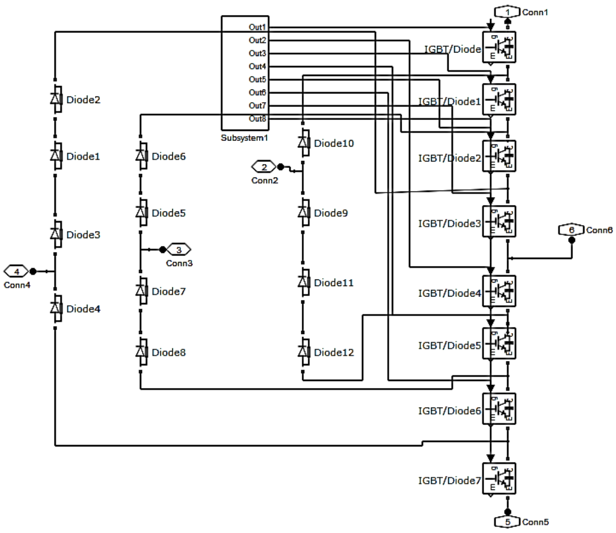

Figure 5(ii): Diode clamped five-level phase_A description

C C**ascaded H-bridge Multi-level inverter**

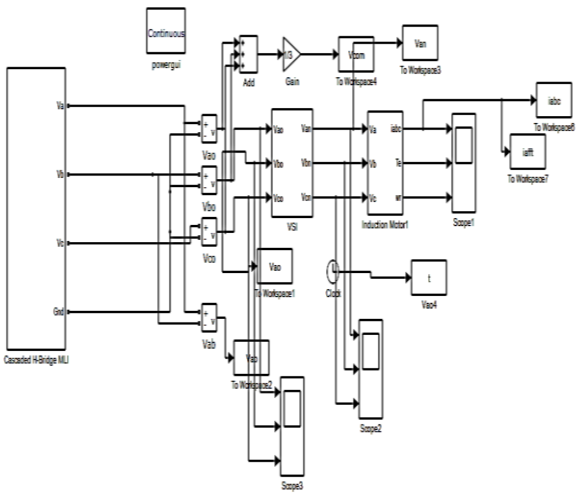

Figure 6: Cascaded H-Bridge Multi-level inverter

Three-level

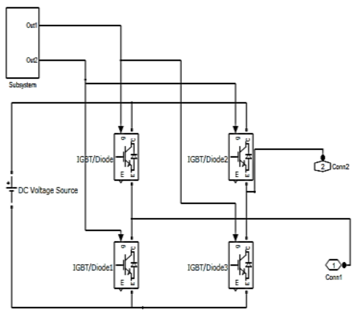

Figure 7: Cascaded H-bridge Three level inverter

Five-level

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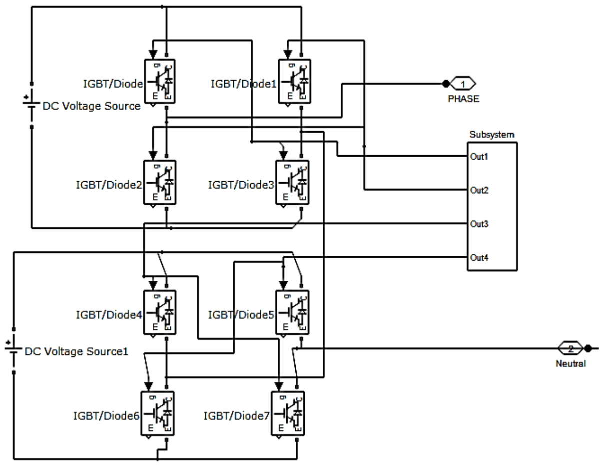

Figure 8: Cascaded H-bridge Five level inverter

D Cascaded inverter

Three-level

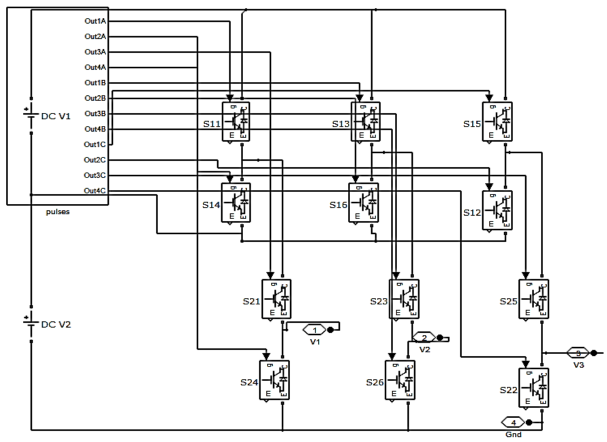

Figure 9: Three phase three-level Cascaded inverter

III SIMULATION RESULTS

A Two level inverter

SPWM:

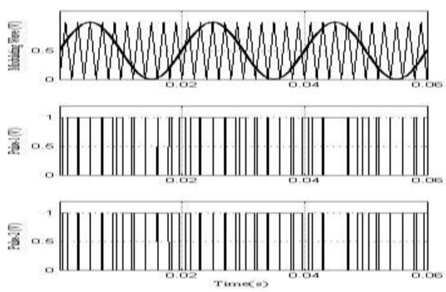

Figure 10: Modulating signal and pulses for three-level Diode clamped:SPWM

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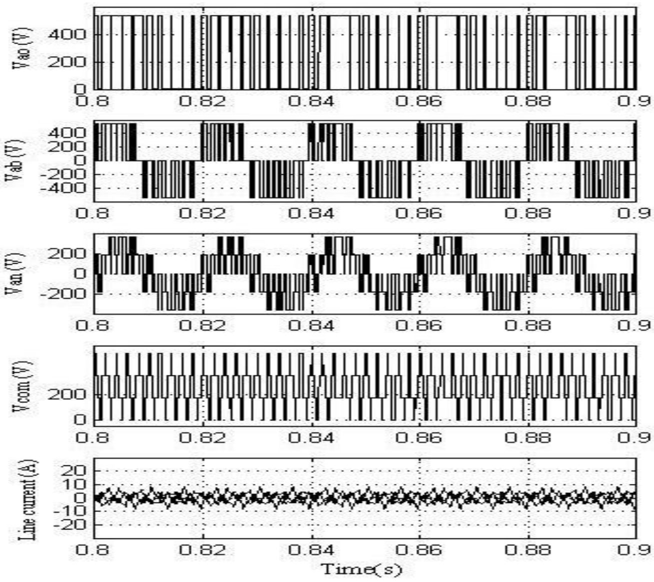

Figure 11: Voltages and currents of three-level Diode clamped inverter:SPWM

SVPWM:

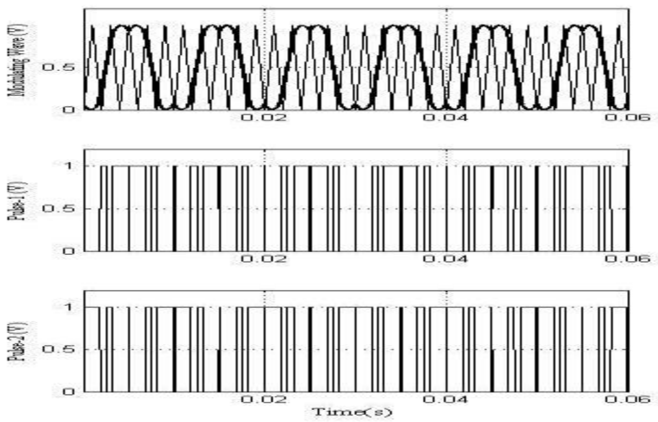

Figure 12: Modulating signal and pulses for three-level Diode clamped:SPWM

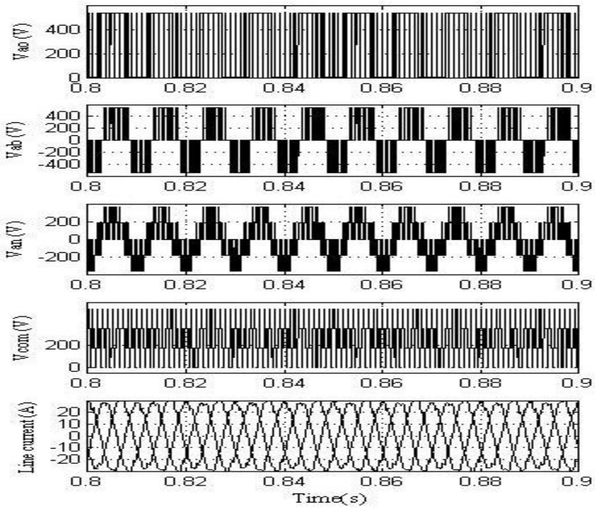

Figure 13: Voltages and currents of three-level Diode clamped inverter:SVPWM

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B Three level outputs:
Diode clamped:
Sinusoidal PWM:

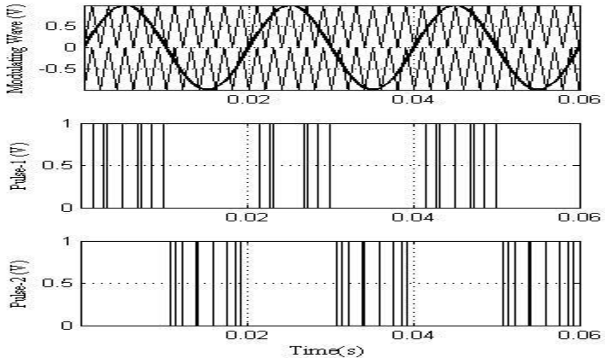

Figure 14: Modulating signal and pulses for three-level Diode clamped:SPWM

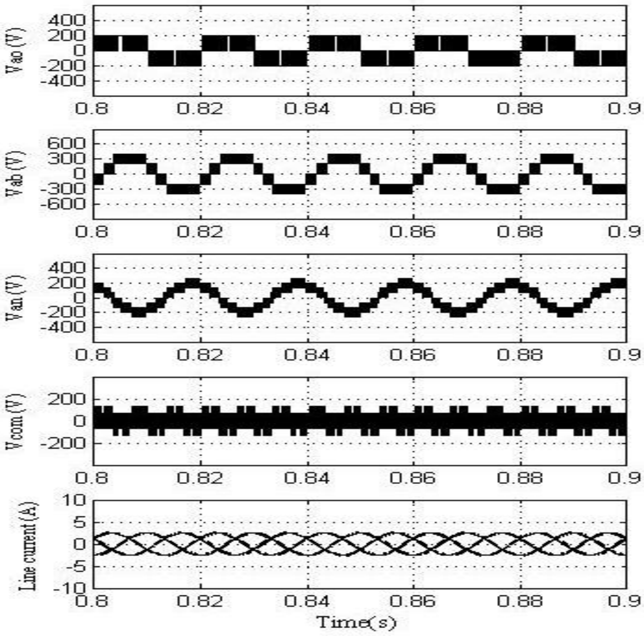

Figure 15: Voltages and currents of three-level Diode clamped inverter:SPWM

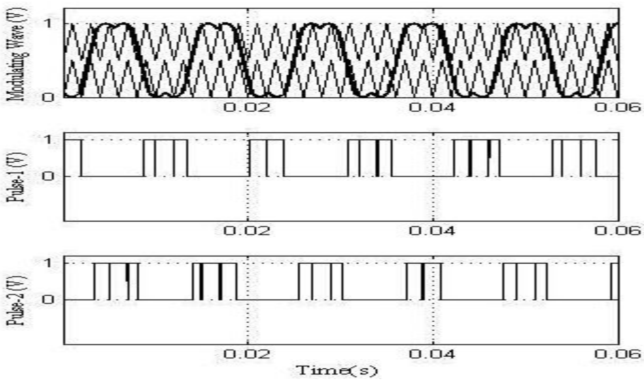

Figure 16: Modulating signal and pulses for three-level Diode clamped:SVPWM

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Space Vector PWM:

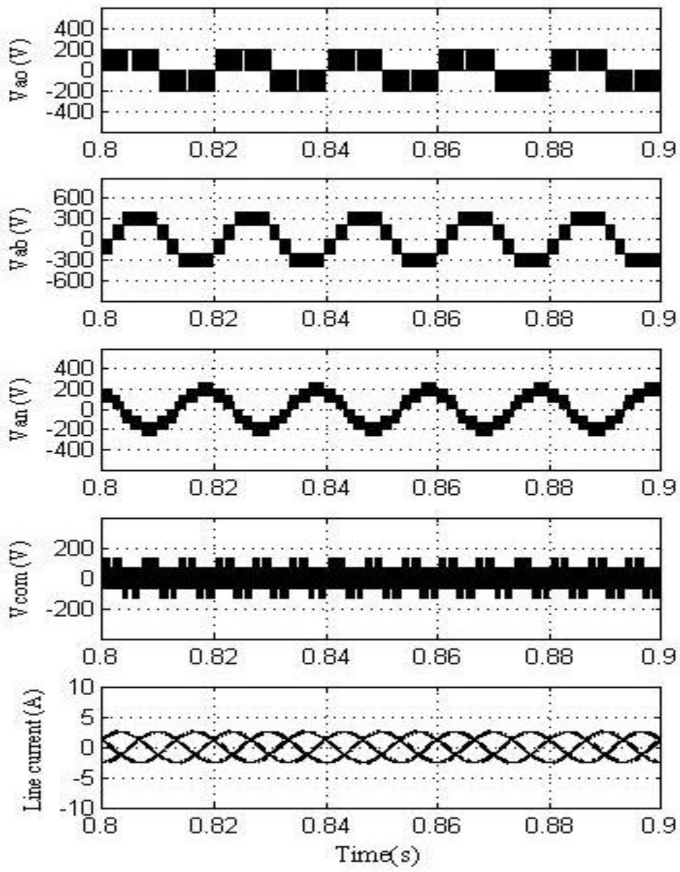

Figure 17: Voltages and currents of three-level Diode clamped inverter:SVPWM

Cascaded H-Bridge 3 -level inverter:

Sinusoidal PWM:

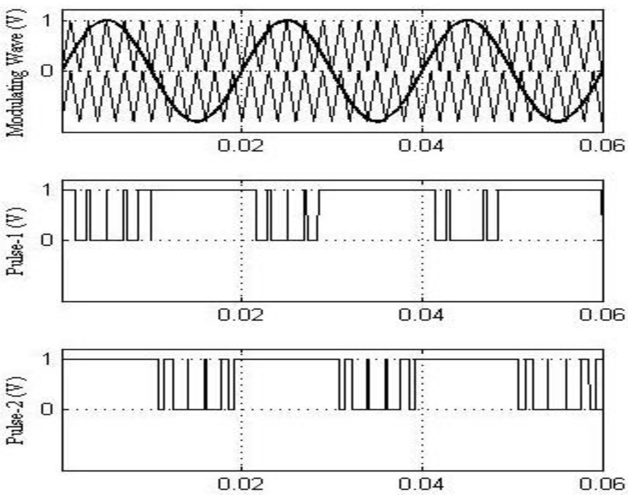

Figure 18: modulating signal and pulses for 3-level cascaded H-Bridge inverter: SPWM

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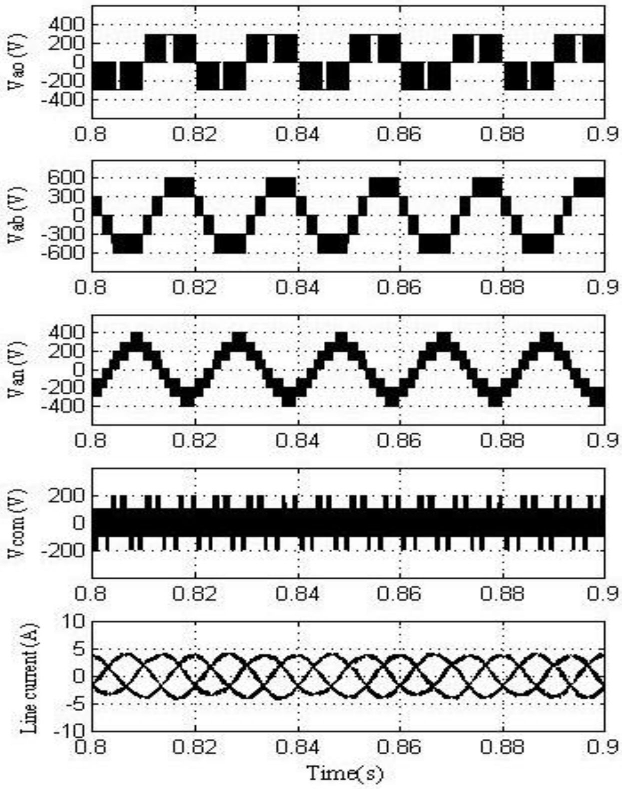

Figure 19: Voltages and currents of 3-level cascaded H-Bridge inverter:SPWM

Space Vector PWM:

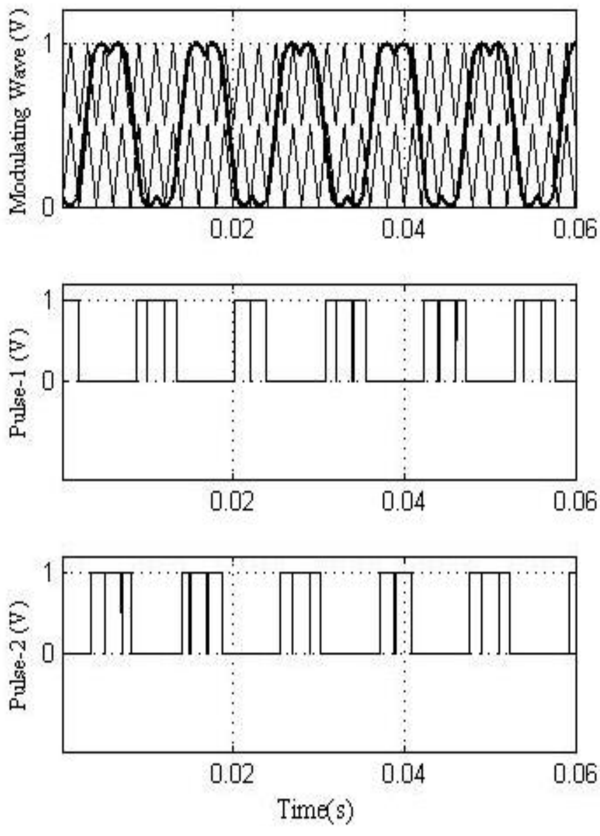

Figure 20: Modulating signal and pulses for 3-level cascaded H-Bridge inverter: SVPWM

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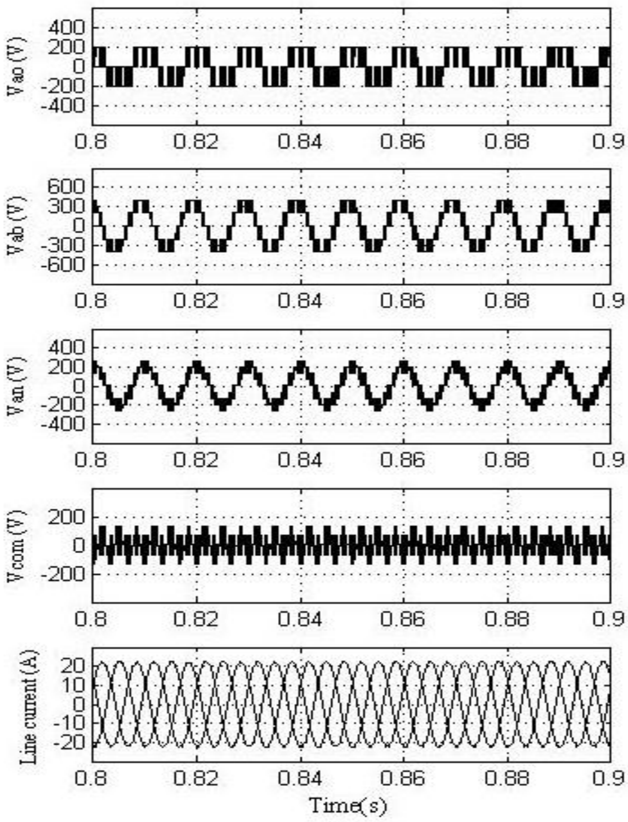

Figure 21: Voltages and currents of 3-level cascaded H-Bridge inverter: SVPWM

Cascaded three-level inverter:
Sinusoidal PWM:

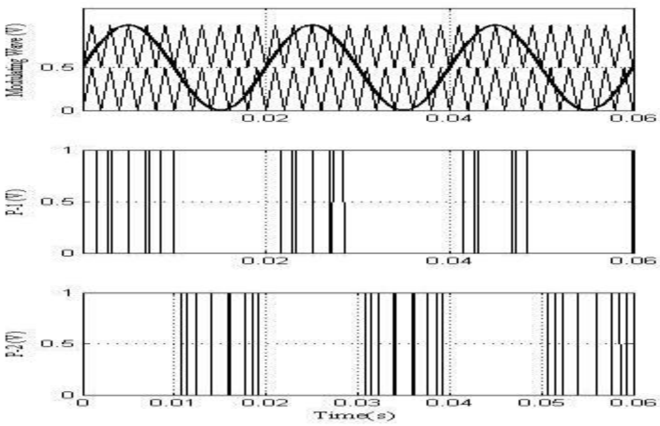

Figure 22: Modulating signal and pulses for 3- level cascaded inverter: SPWM

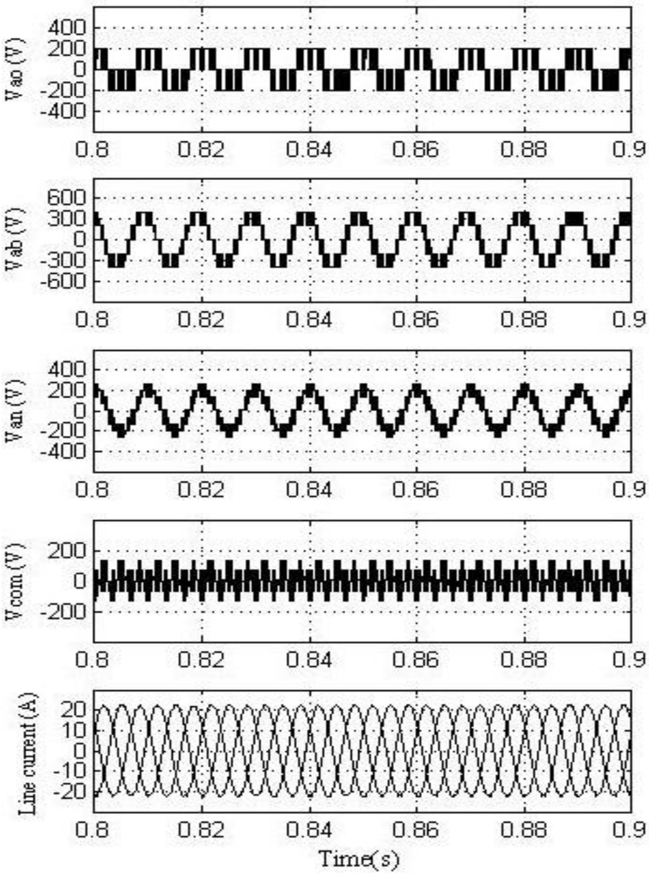

Figure 23: Voltages and currents of 3-level cascaded inverter: SPWM

SVPWM:

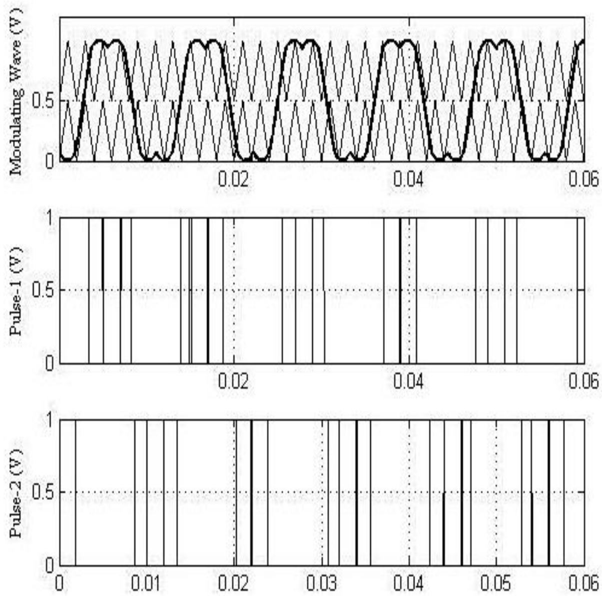

Figure 24: Modulating signal and pulses for 3-level cascaded inverter: SVPWM

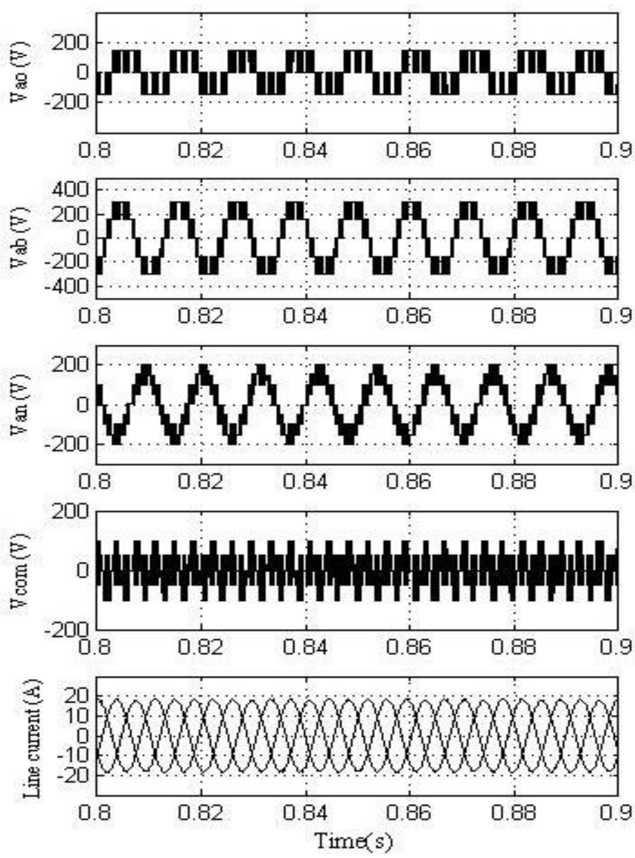

Figure 25: Voltages and currents of 3-level cascaded inverter: SVPWM

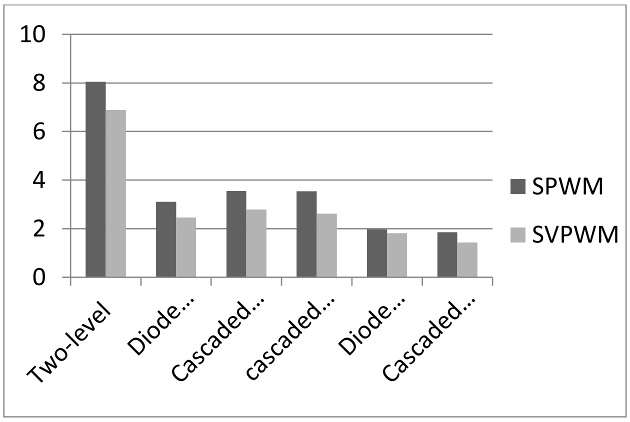

Figure 26: Flow chart for All Inverter FFT's

3. CONCLUSION

In this thesis, the simulation of two-level, three-level (Diode-Clamped, Cascaded H-Bridge and Cascaded) and five-level (Diode-Clamped, Cascaded H-Bridge) Inverters for SPWM and SVPWM techniques were performed using MATLAB/Simulink. %THD of stator current of induction motor of each Multi-level Inverter for SPWM and SVPWM Techniques have been presented.

From simulation results it is observed that the proposed Cascaded H-Bridge inverter topology consequence less % THD as compare with Diode Clamped multi-level inverter. Similarly the performance of Cascaded Multi-level Inverter is good in terms of total harmonic distortion as compare with Cascaded H-Bridge Multi-level Inverter.

4. Future Scope

Possible suggestions made for future work to present work carried out in this thesis are as follows

I. The proposed work can be extended to five-level Cascaded Multi-level Inverter topology.
II. The proposed inverter topologies can be extended using advance PWM algorithms.
III. The proposed work can be extended to closed loop systems such as vector controlled and direct torque controlled IM Drive.

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