A SEVEN LEVEL ASYMMETRIC CASCADED MULTILEVEL INVERTER DESIGN FOR INDUCTION MOTOR

[1]Lokendra arya, [2] Kanika Maheshwari [3] Jitendra Singh Shakya,
[1,] Master's scholar,[2] Master's scholar,[3] Asisstant professor,
[1,2,3,]Department of Electrical Engineering
[1,2,3,]SAMRAT ASHOK TECHNOLOGICAL INSTITUTE,VIDISHA, MADHYA PRADESH

***Abstract*- A uni power semiconductor switch is hard to support medium voltage source directly. To overcome this crisis, multilevel inverters has been emerged as the solution that works with high voltage levels in more better way. Thus in the following paper we are analysing working of seven level multilevel inverter with induction motor drive using fixed frequency level shifted carrier based pulse width modulation technique through the harmonic analysis.**

***Key words*: Multilevel inverter, CHB MLI, pulse width modulation, phase disposition, total harmonic distortion**

1 Introduction

In last decade range of use of multilevel inverter has been increased due to their reduced energy consumption and increased system efficiency. Since cascaded multilevel inverter considered as a suitable tool for medium & high power applications. A uni power semiconductor switch is hard to support medium voltage source directly. To overcome this crisis, multilevel inverters has been emerged as the solution that works with high voltage levels in more better way. Larger utility applications and heavy loads have high power demands which can be met my multilevel inverter. Multilevel inverter helps in improving system's overall performance whether it is harmonics , total stress bearing of a motor, dv/dt stress and so on. In last decade various topologies of multilevel inverter has been introduced such as i)flying capacitors ii)diode clamped, ,and iii) cascaded or H-bridge. After going through literature reviews concluding that Asymmetric Cascaded MLI is considered to be a best topology for high voltage and power applications. We are using phase disposition modulation technique over asymmetric topology for analysis of the output voltage performance. As it is worth that phase disposition modulation gives great contribution in reducing THD of an inverter.

2 CASCADED H-BRIDGE MLI

2.1 Historical Background

Designing of heavy duty trucks &of so many military combat vehicles that have large electric drives have required high power electronic inverters in order to meet the high power demands that is greater than 250 kw. Development of lots of electric drives for such large vehicles ultimately results in increment of fuel efficiency, lower emissions, and better vehicle performance in terms of acceleration and braking. Thus multilevel inverters are best suited for these kind of applications due to their possibly high VA ratings. Traction is the most common and initial application of MLI, in both of static inverters as well as locomotives [4].Most recent applications for such power systems have a long list that contains stability enhancement [5], active filtering [8], high-voltage motor drive [6], high-voltage dc transmission [9], and most recent application is for variable speed drives of medium voltage induction motor [10].
The multilevel voltage source inverters special structure make them to attain high voltages and power levels without using transformers.If we talk about MLI, they are best suited to high voltage drives where low total harmonic distortion (THD)& electromagnetic interference (EMI) are required. A common function of the multilevel inverter is to generalize desired voltage from multiple levels of dc voltages. Thus, multilevel inverters can be easily provide the high power that is required for large Electric Vehicles or Heavy Electric Vehicles drive.
As increase in number of levels somewhere add more steps in synthesizing output waveform. Due to the addition of more steps to the output waveform its Total Harmonic Distortion(THD) decreases[1] says, which approached up to zero with the increasing number of levels. The structure of the multilevel inverter make it such that it doesn't results in any voltage sharing problems that usually encountered by the active devices .

The statement in favour of seven level inverter we doing our research on is that the seven & higher level schemes are not much expensive, while it is more efficient in terms of performance and the reliability tend to be improved with the high-voltage development and current intelligent power modules (IPM) which are having integrated gate-drives and self-protecting functions.

2.2 Fundamentals

Now a days in many industrial applications requires high power conversion system. Multilevel inverter become more popular and received more attention due to their ability to operate in higher power application, multiple switches, high voltage. Multilevel inverter is effective for increasing power and reducing harmonics of ac waveforms. A multilevel inverter has so many advantages over the conventional one. First, the voltage stress on each switch is decreased due to series connection of the switches, so the rated voltage and consequently the total power of the inverter could be safely increased. Second, change of voltage is decreased by (dv/dt) is due to the lower voltage swing of each switching cycle. Third is low harmonic distortion and last but not the least is lower acoustic noise and electromagnetic interference. Due to the bi-directional switches, the multilevel converter can also work as both rectifier and inverter.

Main advantages of multilevel inverter includes:

A. Using lower rating devices.
B. Higher voltage can be generated.
C. Increased number of voltage levels produce low THD and better voltage waveform.
D. In Modulation operation switching frequency can be reduced .
E. While using it in induction motor, induction motor becomes more accessible & safer.

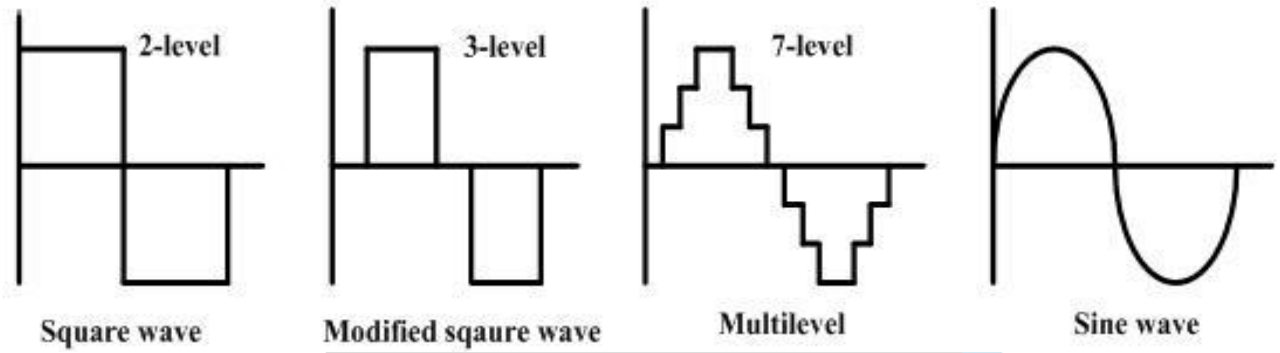

Figure 2.1 Different types of waves

2.3 Cascaded H-Bridge Multilevel Inverter:

Cascaded H-Bridge (CHB) topology is becoming very popular now a days specially in high-power consuming devices and adjustable-speed drive applications. A cascaded H-bridge MLI consist of number of series of H-bridges in its each phase. While unit of each H-bridge consist of its own DC source which in turn worked as a fuel or solar cell or battery for an induction motor .In the following topology the output voltage level is defined by m=2N+1,Where N= no. of Dc sources. This topology is based on the series connection of n individual cells, consisting of a single-phase H-bridge inverter with a dedicated dc source. The number of levels m is proportional to the number of isolated cells according to the expression m = 2n + 1.

Cascade inverters are considered to be ideal for induction motors that contains many separate dc sources (batteries) individually with each H-bridge unit. A MLI converts the dc voltage to variable voltage /variable frequency in order to drive the main induction motor [main thesis]. Following are the advantages of MLI that motivated us to work on the harmonic distortion reduction analysis of cascaded seven-level induction motor drives.

Cascaded H-Bridge Multilevel Inverter is better than the diode clamped inverter and flying capacitors inverter, as it requires less number of components in each switching levels. In Cascade H-Bridge Multilevel Inverter, the grouping of switches and capacitors is called H-bridge consisting of isolated DC Voltage source

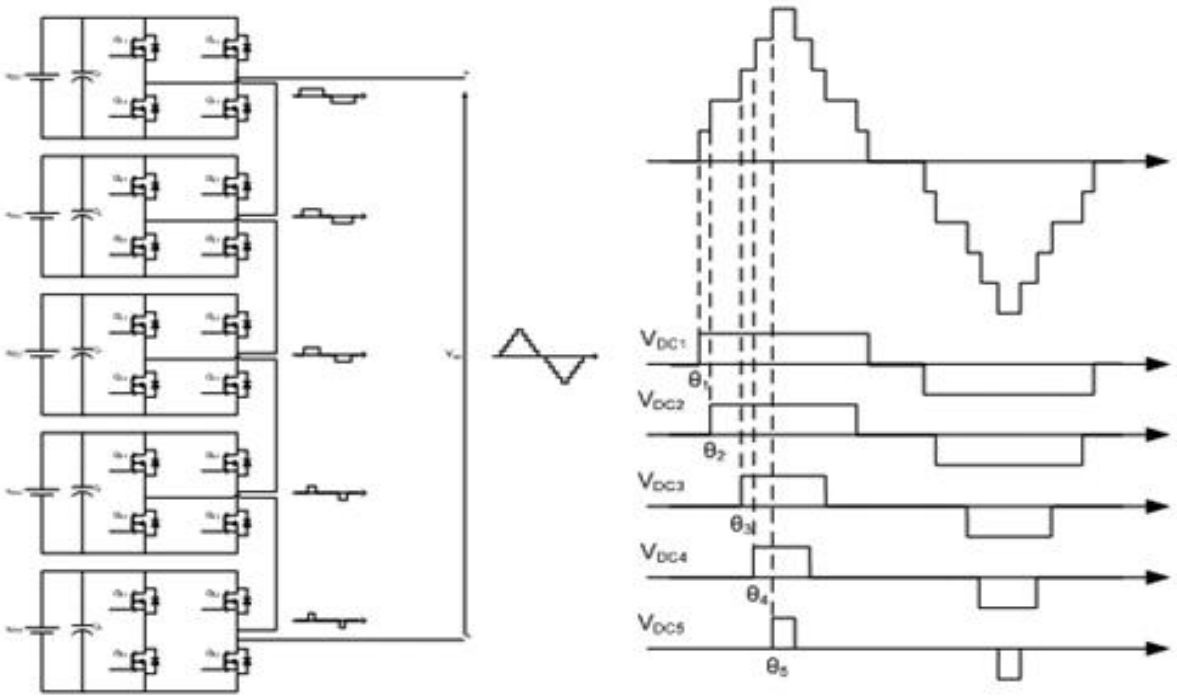

Figure 2.2 Cascade H-Bridge MLI and its output voltage

2.4 Advantages of CHB MLI:

Advantages:

i. The regulation of the DC buses is simple.
ii. Modularity of control can be achieved. Unlike the diode clamped and capacitor clamped inverter where the individual phase legs must be modulated by a central controller, the full-bridge inverters of a cascaded structure can be modulated separately.
iii. Requires the least number of components among all multilevel converters to achieve the same number of voltage levels.
iv. Soft-switching can be used in this structure to avoid bulky and lossy resistor-capacitor-diode snubbers.

2.5 Disadvantages of CHB MLI:

i. Separate dc sources are required, resulting in limited applicability.
ii. For a three-phase system, this type of inverter will require more switches than a more traditional inverter.
iii. Communication between the full-bridges is required to achieve the synchronization of reference and the carrier waveforms.
iv. Needs separate dc sources for real power conversions, and thus its applications are somewhat limited.

S 11	S 12	S 13	S 14	S 21	S 22	S2 3	S2 4	S3 1	S3 2	S3 3	S3 4	Output
0	1	0	1	0	1	0	1	1	0	0	1	V_{dc}
0	1	0	1	1	0	0	1	1	0	0	1	$2V_{dc}$
1	1	0	1	1	0	0	1	1	0	0	1	$3V_{dc}$
0	1	0	1	1	0	0	1	1	0	0	1	$2V_{dc}$
0	1	0	1	0	1	0	1	1	0	0	1	V_{dc}
0	1	0	1	0	1	0	1	0	1	0	1	0
0		0	1	0	1	0	1	0	1	1	0	$-V_{dc}$

1	**0**	**0**	**1**	**0**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**$-2V_{dc}$**
0	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**$-3V_{dc}$**
1	**0**	**0**	**1**	**0**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**$-2V_{dc}$**
0	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**1**	**0**	**$-V_{dc}$**
0	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**

Table 2.1 Switching pattern for symmetrical cascaded seven level inverter

3 MODULATION TECHNIQUES

Modulation is a kind of technique that is known for varying various properties of a signal, it is a technique used to encode a message that is information to transmit it from one place to another. Modulation happened in analog and digital signal and the device that performed the following operation is known as modulator.

Multilevel modulation technique is considered to be the best modulation technique in order to improve the bandwidth efficiency, with the help of the following modulation technique more information can be transferred per bit which results in more efficiency of bandwidth. The multilevel modulation techniques transferred more information at a time but at the same phase the following technique is also more sensitive towards noise.

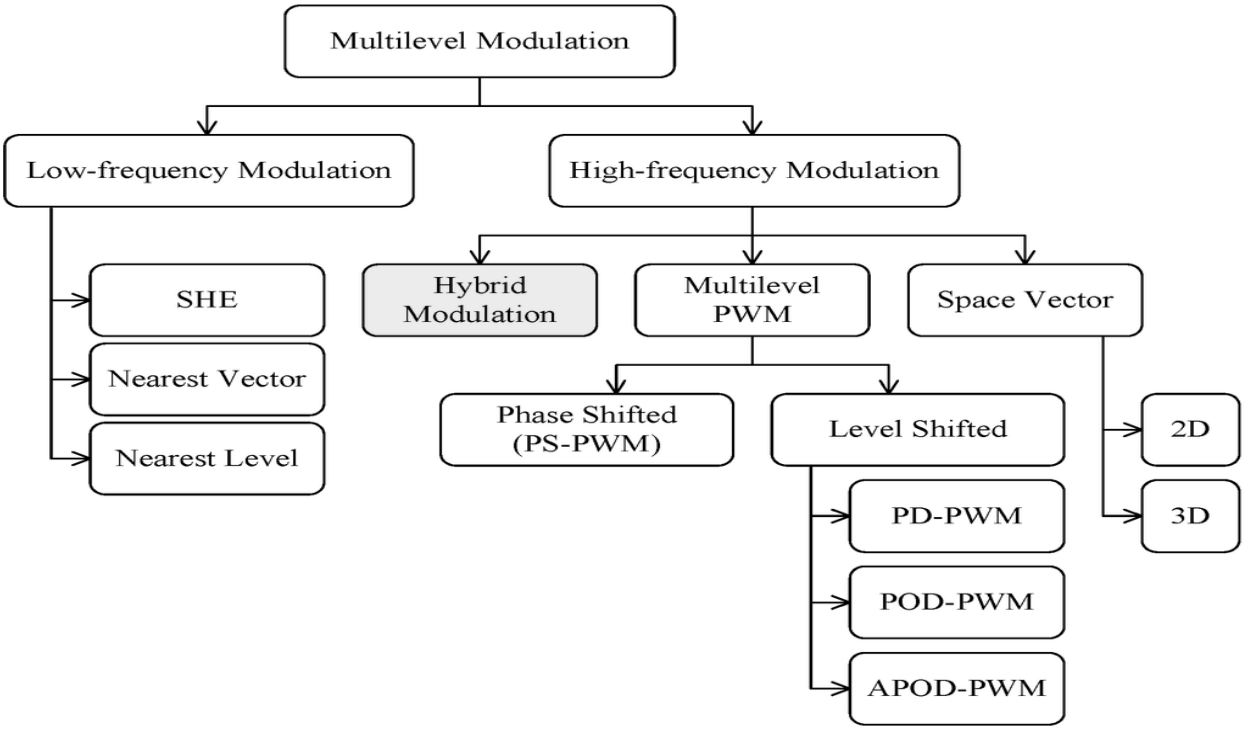

Figure 3.1 Hierarchy of different types of Multilevel Modulation techniques

Following technique differs from PS PWM only in the disposition of the triangular carriers, which in the following case are vertically situated one after another. There are three different strategies with different phase relationships for the level-shifted multicarrier modulation.In that paper we are focusing on Phase Disposition modulation for later ones one can refer to references.

Phase Disposition Modulation:

In the following thesis we are working with phase disposition modulation technique. In Phase Disposition method all (multiple) carriers are selected with same phase & frequency. In comparison to other modulation technique Phase Disposition PWM has

moderate voltage balanced capability. Phase Disposition PWM is use in order to balance capacitor voltage. PDPWM is significantly responsible for reduced total harmonic distortion. Results are obtained from simulation study, which consequently illustrates the improved performance of the overall system as compared to conventional one.

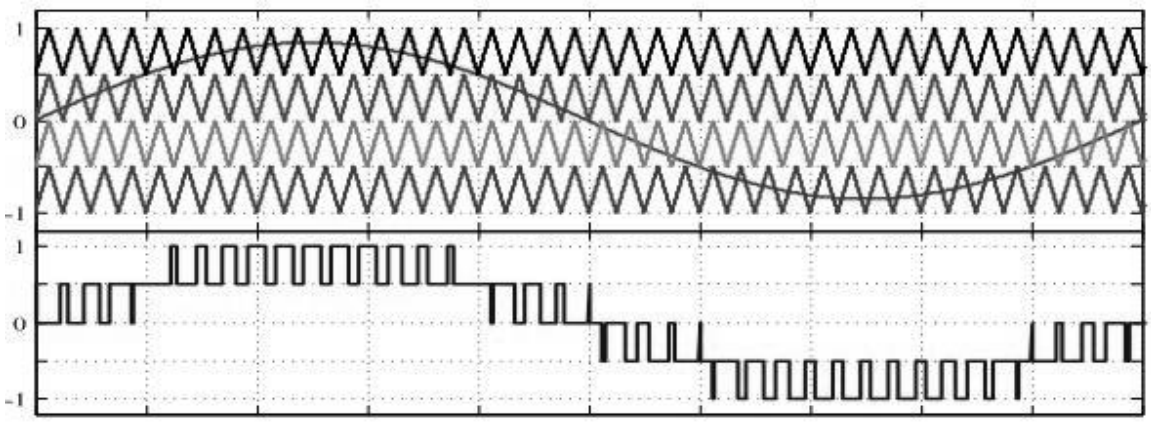

Figure 3.2 Output waveform of Phase Disposition Modulation

4 SIMULATION MODEL AND RESULTS

4.1 Proposed Model

The simulation model of the Seven level MLI shown in below diagram as :

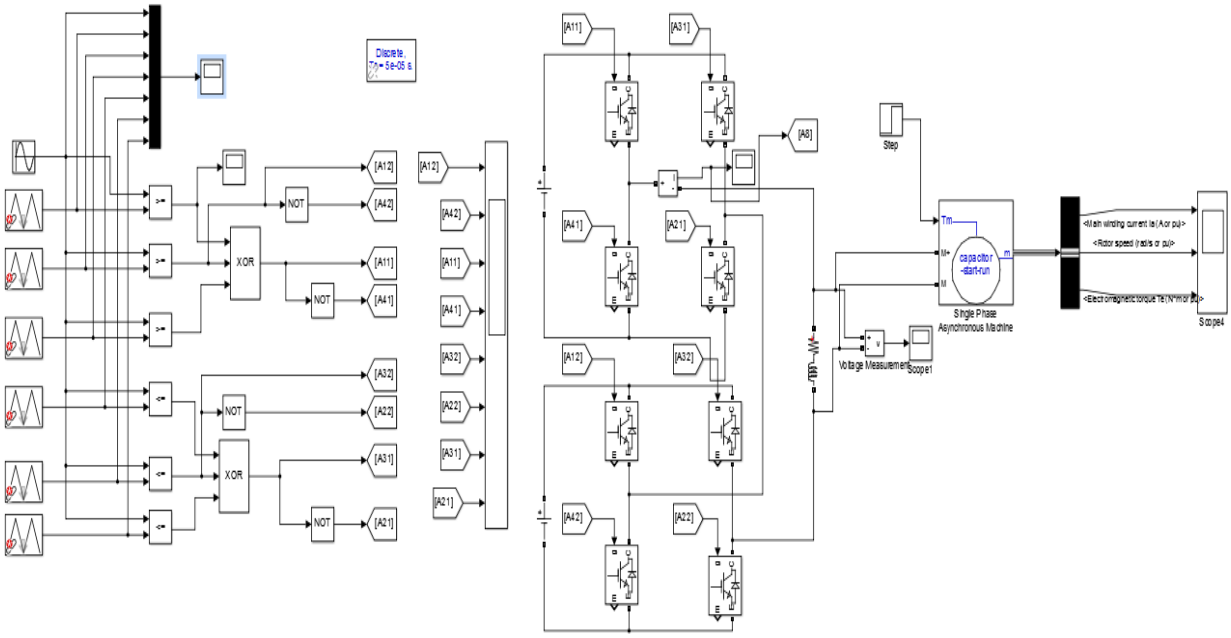

Figure 4.1 Simulation diagram of proposed 7-level multilevel inverter with induction motor

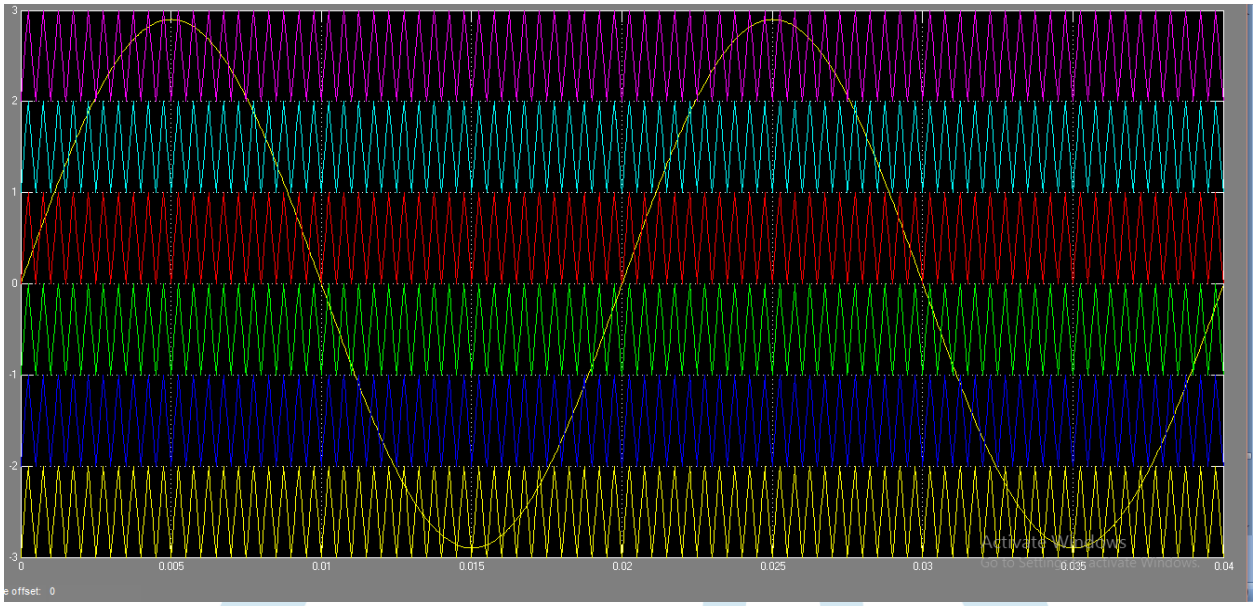

Figure 4.2 Simulation results of reference and carrier waveform for Seven-level MLI

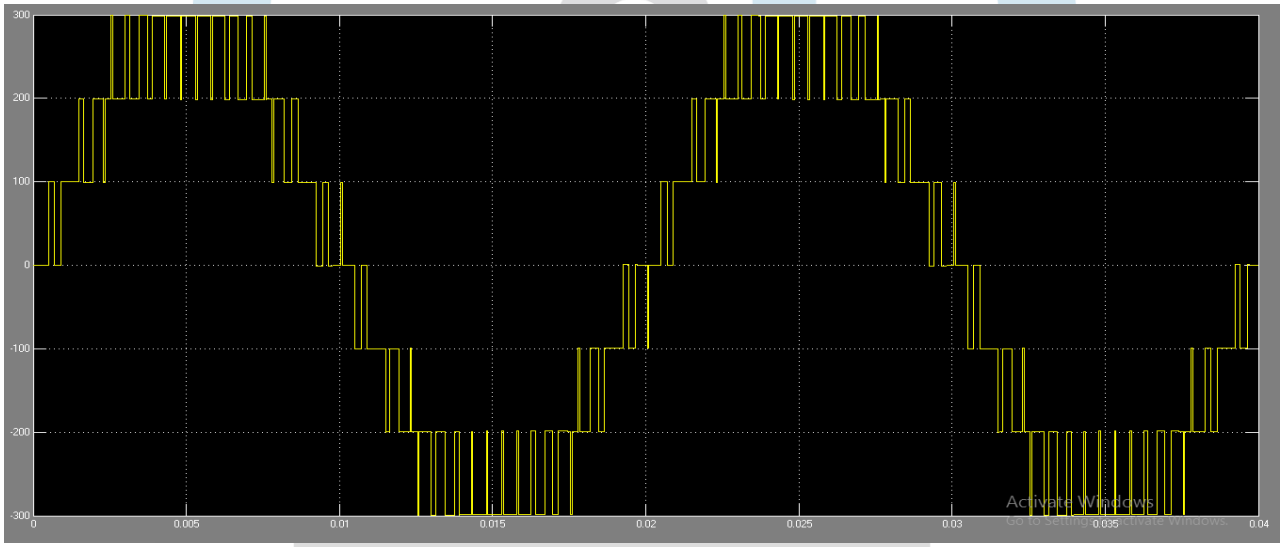

Figure 4.3 Simulation results of proposed system 7- level inverter for voltage with respect to time

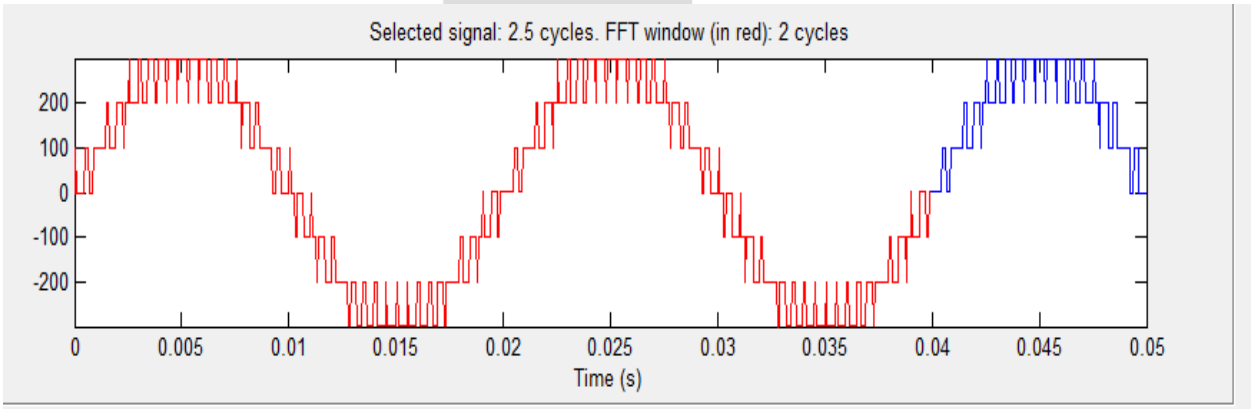

Figure 4.4 FFT diagram for two cycles for seven level inverter

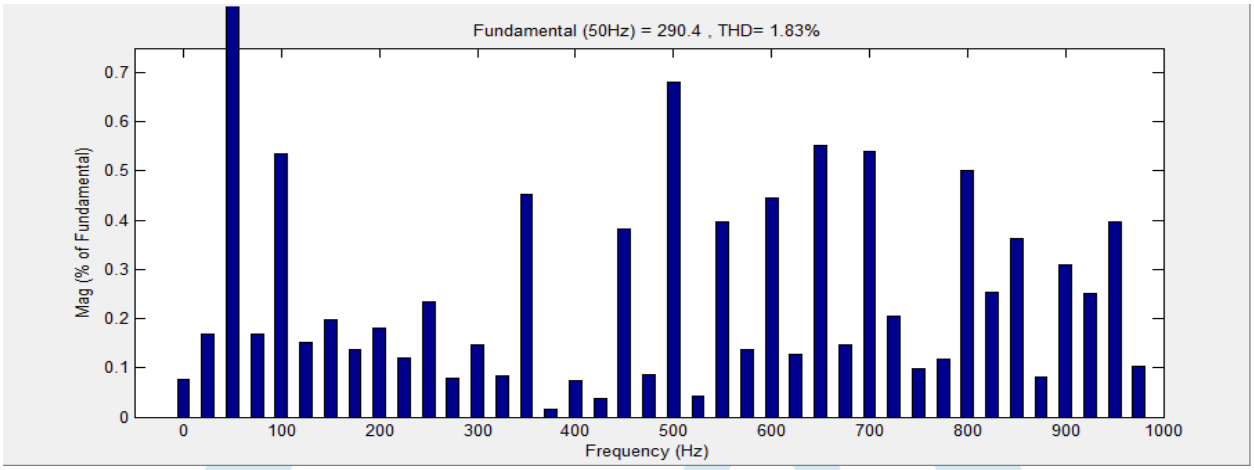

Figure 4.5 THD for output voltage of basic seven-level cascaded H-bridge inverter

4.3 Performance parameters of induction motor

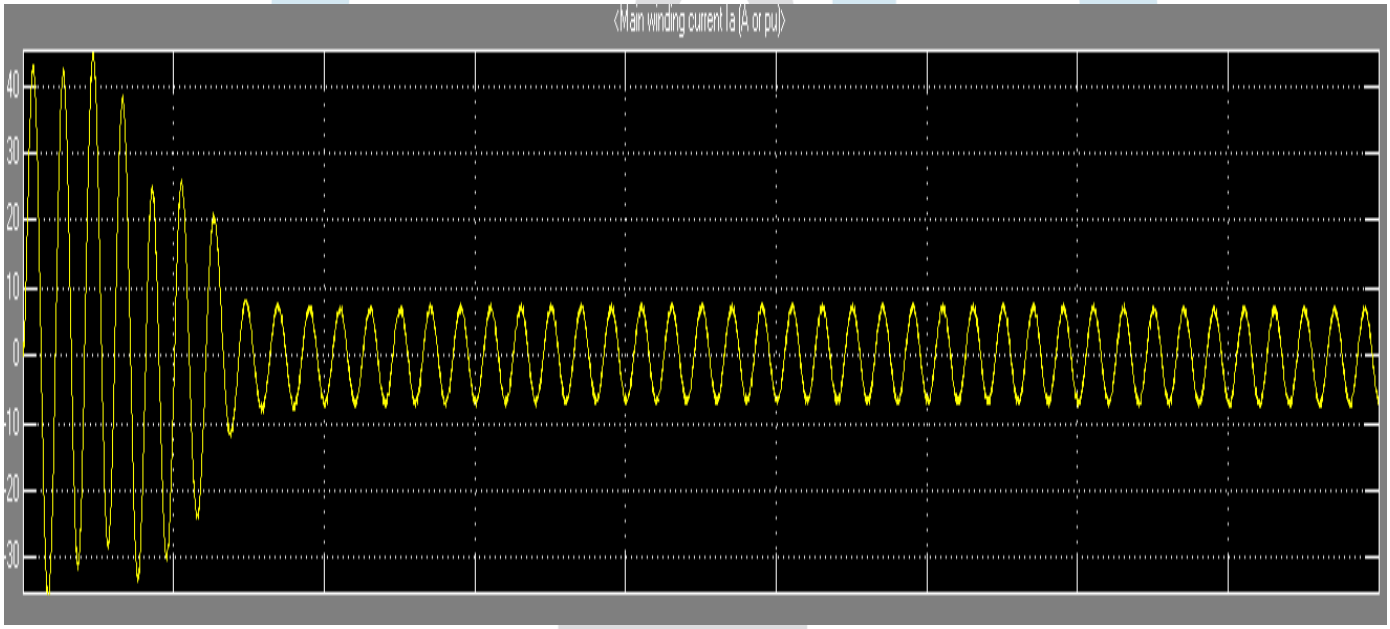

Figure 4.6 Main winding current of single phase induction motor

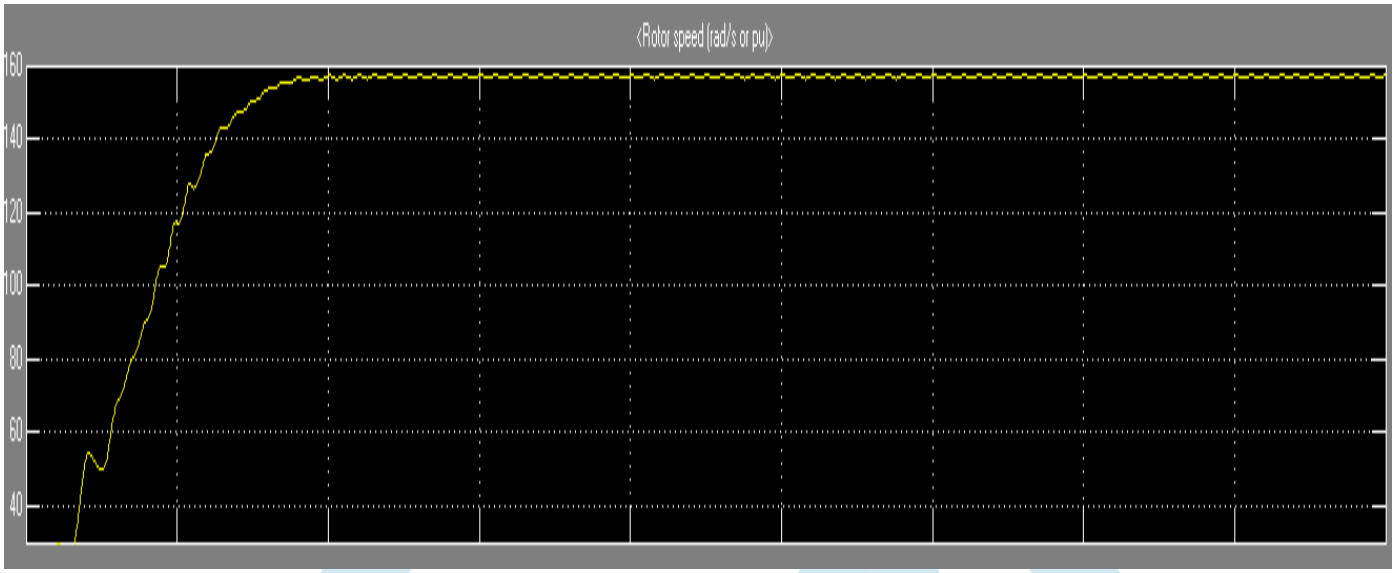

Figure 4.7 Speed of single phase induction motor

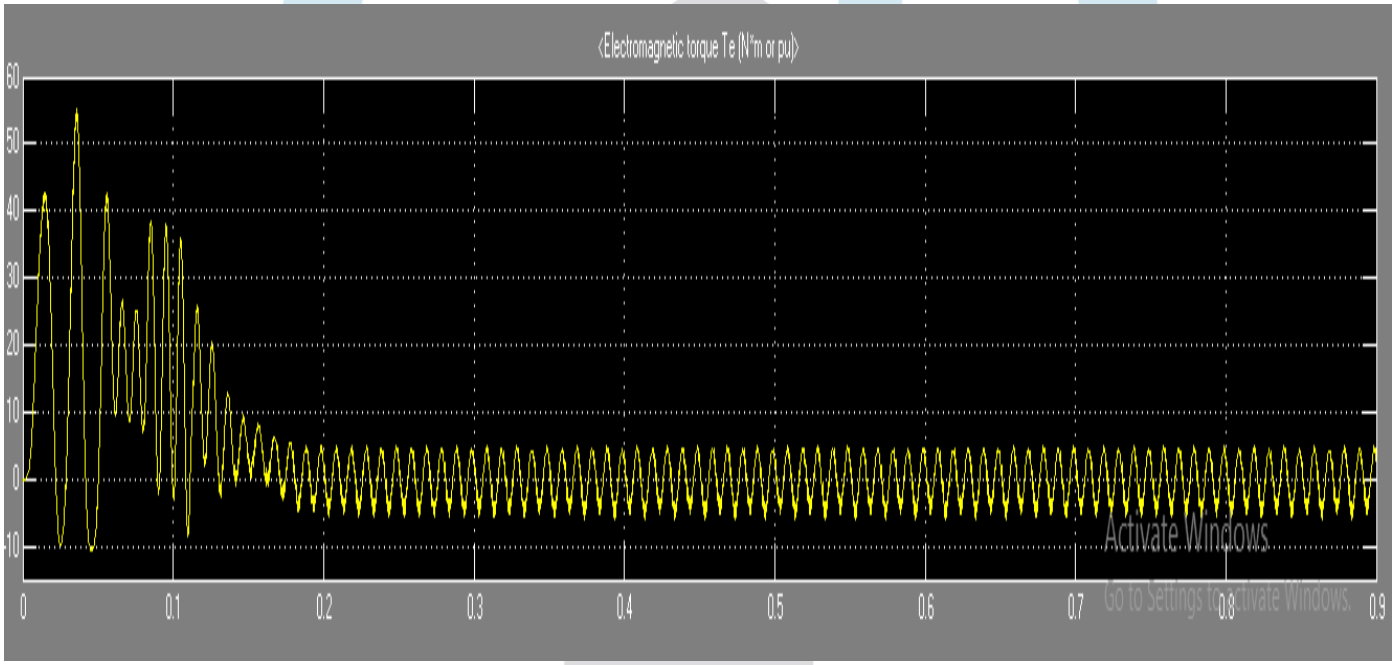

Figure 4.8 Torque of single phase induction motor for seven level inverter

5 CONCLUSION

In the following dissertation work we have presented types of multilevel inverter, their underlying topologies. Modulation techniques lie under pulse width modulation also explained which draws your attention towards the benefits of phase disposition modulation technique by comparing all of them together. The modes of operation and switching tactic of the new topology are presented. The simulation results and experimental results show that the PD modulation technique is a technique that can be effectively used to reduce higher order harmonics of the multilevel inverter & results in a remarkable decrease in the output voltage THD.

In the following dissertation simulation of five level and seven level inverters are eventually done. Conventional five-level inverter showed THD of 34.50% and seven-level inverter showed THD of 2.38%, while study taken in this dissertation for PWM technique whose all the carrier wave frequencies are same showed the THD of 1.83% for seven-level inverter

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