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Speed Control of Induction Motor using Multilevel Inverter

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Abstract: **Multilevel converters are mostly used for high power applications because of their ability to operate at higher output voltages and produces lower levels of harmonic components in the switched output voltages. One of the major problems in electric power quality is the harmonic contents. There are several methods for indicating the quantity of harmonic contents. The most widely used measure is the total harmonic distortion (THD). As the number of levels increases the harmonic content will get reduced. SPWM technique is used to alleviate harmonic components of output voltage. Multilevel inverter can be realized by cascading H-Bridges. Cascaded or H-bridge multilevel inverter with separated DC sources is the most feasible topology to use as a power converter for medium and high power applications. A better application can be the speed control of induction motor. By frequency control method, i.e. by varying the duty cycle of the PWM pulses given to the mosfet, speed of the induction motor can be controlled.**

Keywords: **multilevel; harmonic; cascade; H-bridge; speed control; induction motor; frequency control.**

1. INTRODUCTION

Adjustable Speed Drives (ASDs) are the essential and endless demand of the industries and researchers. They are widely used in the industries to control the speed of conveyor systems, blower speeds, machine tool speeds and other applications that require adjustable speeds. In most cases, AC motors are preferred to DC motors, in particular, an induction motor due to its low cost, low maintenance, lower weight, higher efficiency, improved ruggedness and reliability. All these features make the use of induction motors in many areas of industrial applications. The advancement in Power Electronics and semiconductor technology has triggered the development of high power and high speed semiconductor devices in order to achieve a smooth, continuous and step less variation in motor speed. Applications of solid state converters/inverters for adjustable speed induction motor drive are wide spread in electromechanical systems for a large spectrum of industrial systems. Voltage or current converters generate discrete output waveforms which led the use of machines with special isolation and in some applications large inductances connected in series with the respective load. The distorted voltages and currents waveforms produce harmonic distortion additional power losses, and high frequency noise that can affect not only the power load but also the associated controllers. All these unwanted operating characteristics associated with PWM converters could be overcomed with multilevel converters in addition to the fact that higher voltage levels can be achieved.

The poor quality of output current and voltage of an induction motor fed by a classical two-level inverter is due to the presence of harmonics. The presence of significant amount of harmonics makes the motor to suffer from severe torque pulsations, especially at low speed, which manifest themselves in cogging of the shaft. It will also causes undesired motor heating and Electromagnetic interference. The reduction in harmonics calls for large sized filters, resulting in increased size and the cost of the system. Nowadays multilevel inverters are the promising alternative and cost effective solution for high voltage and high power applications including power quality and motor drive problems. Multilevel structure allows raising the power handling capability of the system in a powerful and systematic way. The advancements in the field of power electronics and microelectronics made it possible to reduce the magnitude of harmonics with multilevel inverters, in which the number of levels of the inverters are increased rather than increasing the size of the filters. The performance of multilevel inverters enhances as the number of levels of the inverter increases.

In this paper Multilevel inverter fed Single phase induction motor drive is designed. Multilevel is realized by cascading H-bridges with equal dc sources. The simulation of single phase three, five and seven level inverter is done using Matlab/Simulink. The FFT spectrums for the outputs are analyzed to study the reduction in the harmonics. The simulation and hardware implementation of speed control of induction motor is done for three level inverter.

2. CASCADED H-BRIDGE MULTILEVEL INVERTER

A cascaded multilevel inverter consists of a series of H-bridge also called single-phase full bridge inverter. Each of H-bridge unit has its own dc source and each H-bridge can produce three different voltage levels: +V, 0, and -V by connecting the dc source to ac output side by different combinations of the four switches S1, S2, S3, and S4 of one H-bridge and S5, S6, S7 and S8 of other H-bridge. The ac output of each H-bridge is connected in series such that the synthesized output voltage waveform is the sum of all of the individual H-bridge's outputs. By connecting the sufficient number of H-bridges in cascade and using proper modulation scheme, a nearly sinusoidal output voltage waveform can be synthesized. The figure shows the connecting diagram of single phase cascaded inverter.

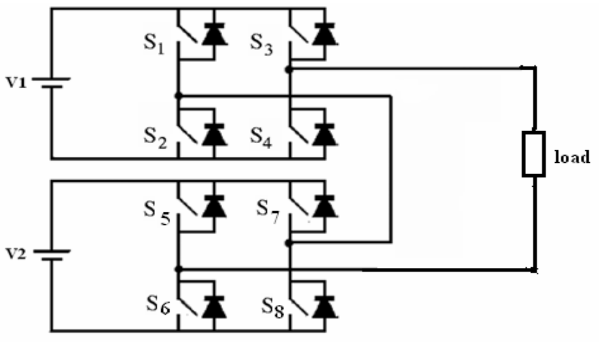

Fig.1 Single phase cascaded multilevel inverter.

V0	S1	S2	S3	S4	S5	S6	S7	S8
V1	0	0	0	0	0	0	0	0
V2	0	1	0	0	0	1	1	0
V3	0	1	1	0	0	1	1	0
-V2	1	0	0	0	0	0	0	1
-V3	1	0	0	0	1	0	0	1

Fig.2 Switching states of cascaded h-bridge inverter.

The AC terminal voltages of each bridge are connected in series. Unlike the diode clamp or flying capacitors inverter, the cascaded inverter does not require any voltage clamping diodes or voltage balancing capacitors. This configuration is useful for constant frequency applications such as active front-end rectifiers, active power filters, and reactive power compensation. Choosing appropriate conducting angles for the H bridges can eliminate a specific harmonic in the output waveform.

3. SINE PWM TECHNIQUE

Carrier-based sinusoidal PWM (SPWM) that uses the phase-shifting technique to reduce harmonics in the load voltage. In carrier based PWM schemes the for m level (m-1) carrier waves are used .The carrier base PWM schemes are classified into two they are (i) Phase shifted multi carrier modulation (ii) Level shifted multi carrier modulation The level shifted multi carrier modulation schemes are classified into three they are (i) In phase disposition method (ii) Alternative phase opposite disposition method and (iii) Phase opposition disposition method.

A. Phase disposition PWM technique:

The Principle of PDPWM technique is to use the several carriers with single modulating waveform .In phase disposition all the carriers are in phase and the carriers are disposed so that the bands they occupy are contiguous. The modulation wave is centred in the middle of the carrier set shows the multicarrier arrangement for PDPWM technique for ma is 0.8 and mf is 20.

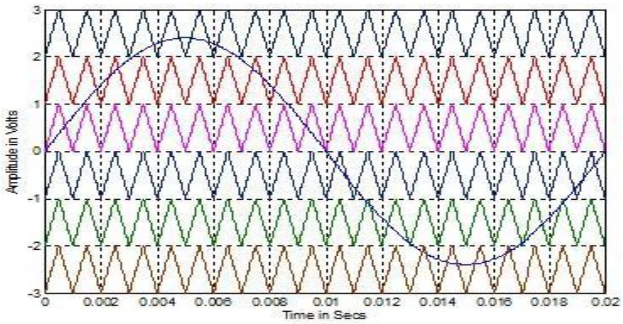

Fig.3 Carrier arrangement for PDPWM technique.

B. Phase opposition disposition (POD PWM) technique:

With the POD method the carrier waveforms above the zero reference value are in phase. The carrier waveforms below are also in phase but are 180 degrees phase shifted from those above zero. The POD method yields quarter wave symmetry for even mf and odd symmetry for odd mf. Figure 2.5 shows the multicarrier arrangement for POD method for ma is 0.8 and mf is 20.

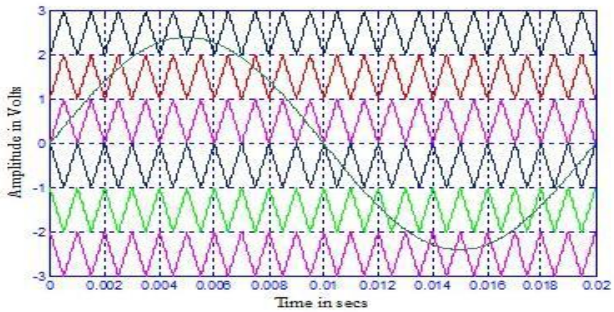

Fig.4 Carrier arrangement of POD PWM technique.

C. Alternative phase opposition disposition (APODPWM) technique:

This method requires each of the six carrier waves for a seven level inverter to be phase displaced from each other by 180° alternately. The APOD method yields quarter wave symmetry for even mf and odd symmetry for odd mf. Figure 2.6 shows the multicarrier arrangement for APOD method for ma is 0.8 and mf is 20.

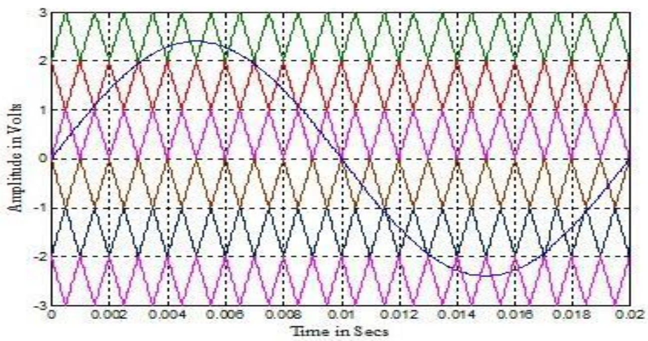

Fig.5 Carrier arrangement for APOD PWM technique.

4. SIMULATION AND THD ANALYSIS

A. Three level inverter:

Mosfet is driven by sine PWM technique. It consists of two carrier waves each of amplitude one and a reference sine wave. The switching frequency is 1200 Hz.

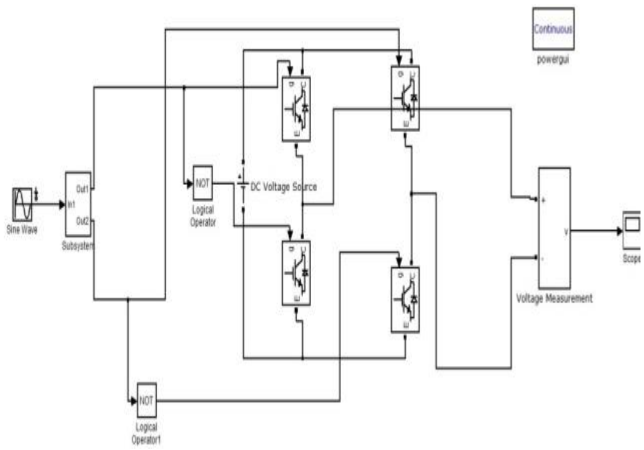

Fig.6 Three level inverter circuit diagram in matlab.

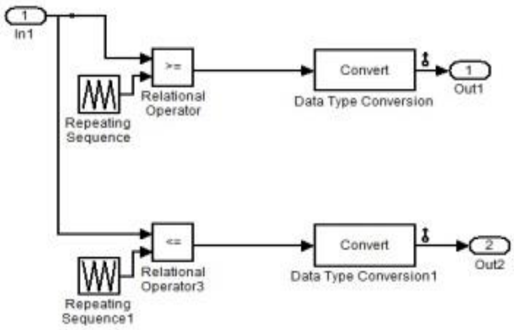

Fig.7 PWM generation.

The output waveform is obtained and its total harmonic distortion (THD) is analysed.

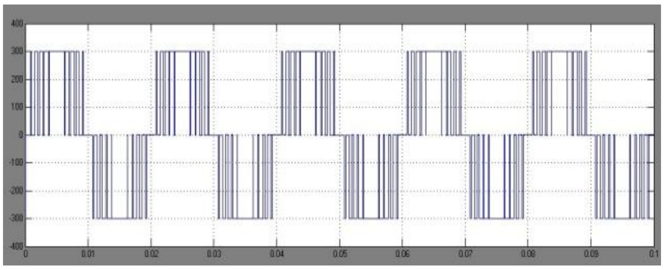

Fig.8Three level output waveform.

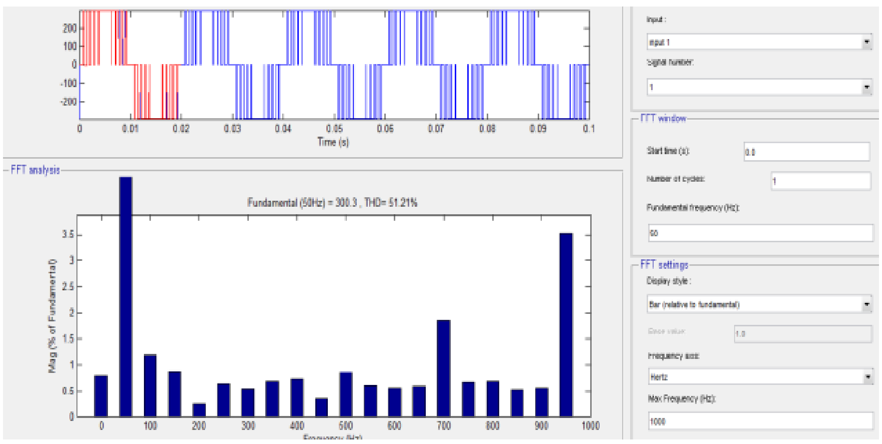

Fig.9 THD of three level.

B. Five level inverter:

Mosfet is driven by sine PWM technique. It consists of four carrier waves each of amplitude one and a reference sine wave. The switching frequency is 1200 Hz.

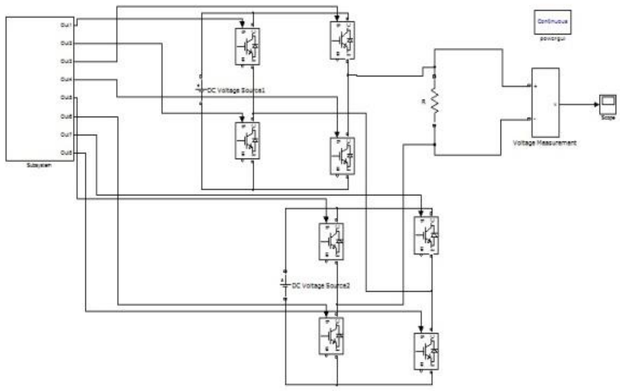

Fig.10 Five level inverter circuit diagram in matlab.

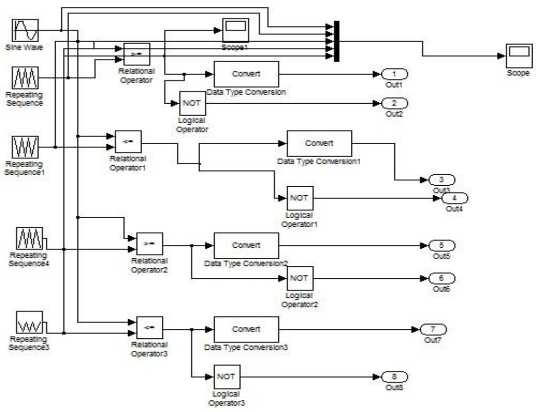

Fig.11 PWM generation.

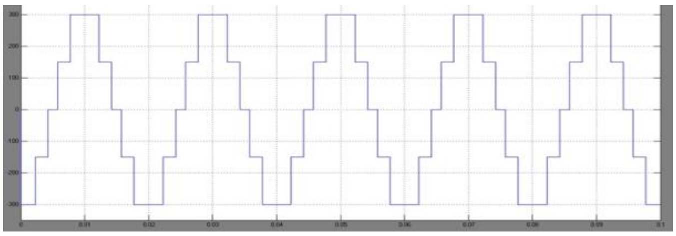

Fig.12 Five level output waveform.

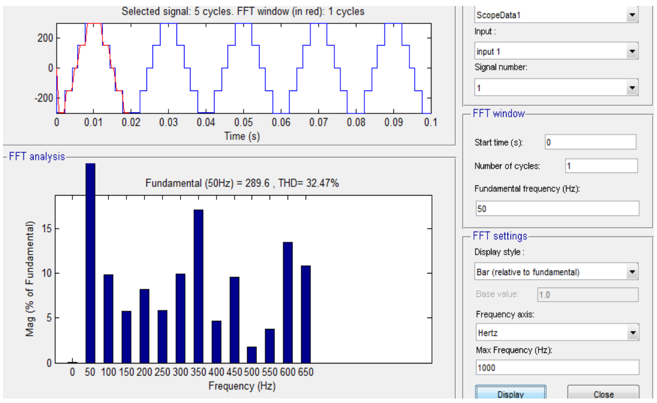

Fig.13 THD analysis.

C. Seven level inverter:

Mosfet is driven by sine PWM technique. It consists of six carrier waves each of amplitude one and a reference sine wave. The switching frequency is 1200 Hz.

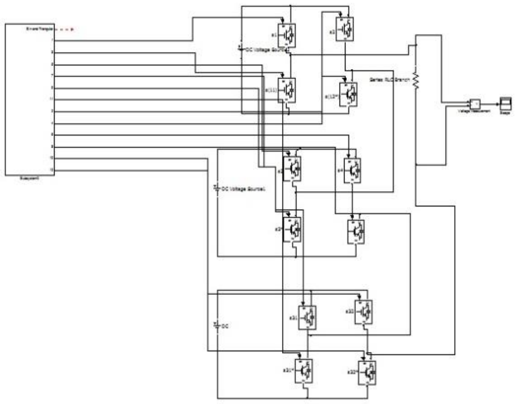

Fig.14 Seven level inverter circuit diagram in matlab.

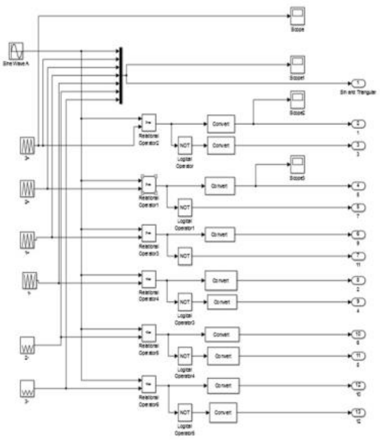

Fig.15 PWM generation.

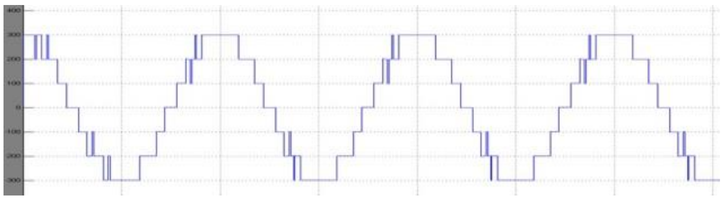

Fig.16 Seven level output waveform.

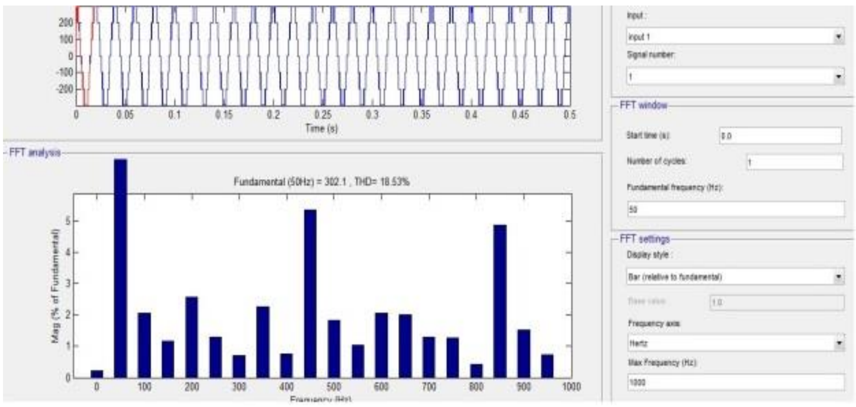

Fig.17 THD analysis.

5. SPEED CONTROL OF INDUCTION MOTOR

The design considerations for speed control system using frequency control have been divided into three parts such as PWM control circuit, driver circuit and H-Bridge inverter. Variable speed drive by using frequency control method is commonly used to control and change the speed of the single phase induction motor. It can vary the desired speed by changing the frequency of the PWM pulses given to the mosfets. Due to compact integrated circuit to obtained low cost high performance speed control. Mosfets are triggered with the PWM pulses of different duty cycles so as to control the speed of the induction motor. Based on the switching sequence the motor is run at different speeds.

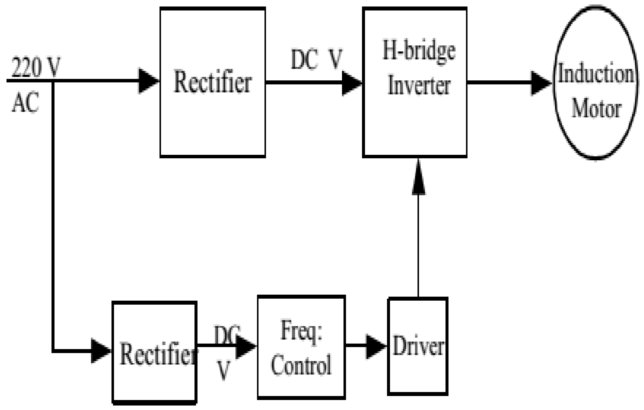

Fig.18 Frequency control.

A. Speed control using three level inverter:

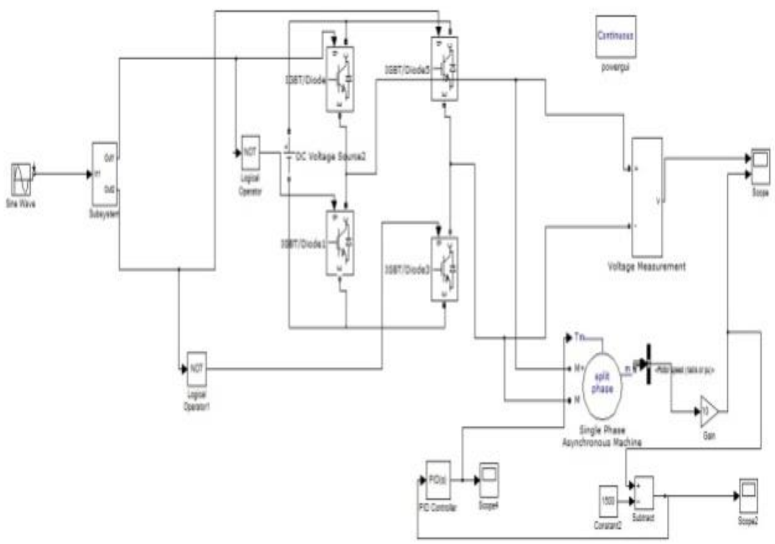

Fig.19 Closed loop speed control of induction motor using three level inverter.

The simulation results of speed control of induction motor using three level inverter for two different frequencies i.e. 50Hz and 75Hz , in matlab.

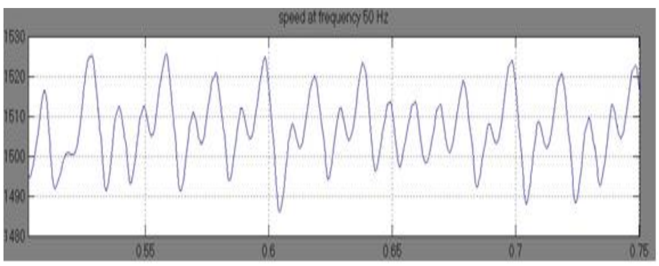

Fig.20 Speed at frequency 50Hz.

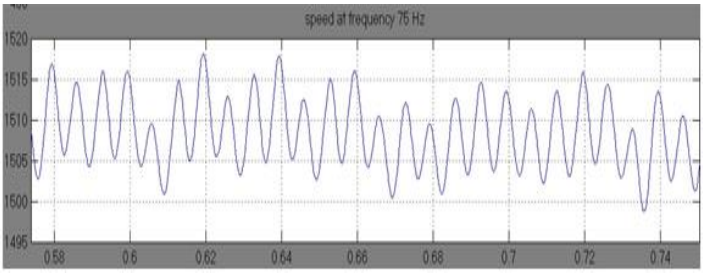

Fig.21Speed at frequency 75Hz.

B. Speed control using seven level inverter:

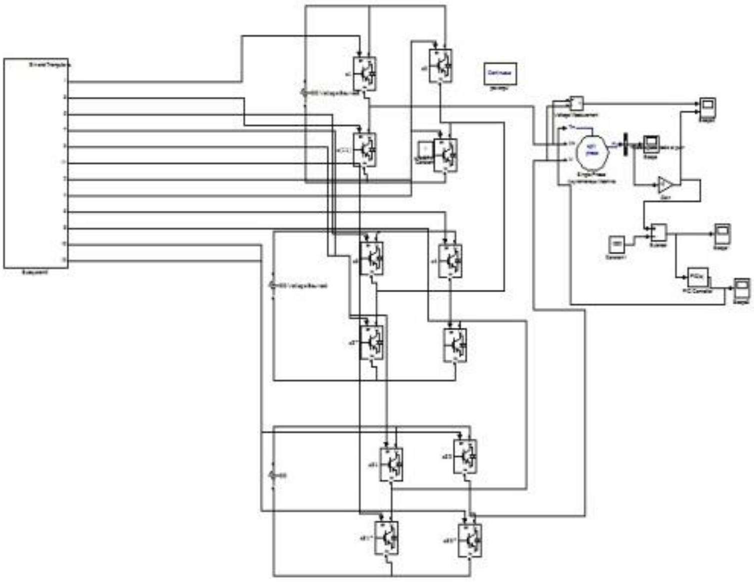

Fig.22 Closed loop speed control of induction motor using seven level inverter.

The simulation results of speed control of induction motor using seven level inverter for two different frequencies i.e. 50Hz and 75Hz , in matlab.

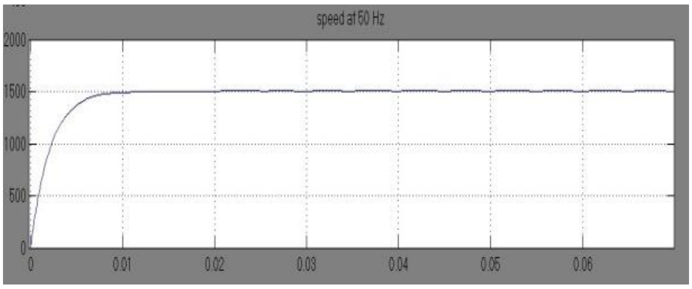

Fig.23 Speed at frequency 50Hz.

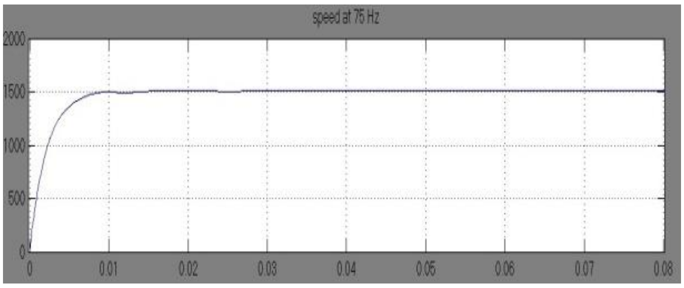

Fig.24 Speed at frequency 75Hz.

6. CONCLUSION

Three level, five level and seven level inverters are simulated in matlab and the total harmonic distortions of their output voltages are compared. It is found that the harmonics of a seven level inverter output voltage is the least compared to three and five level. A single phase induction motor is connected as the load of the inverter and the speed of which is controlled by varying the duty cycle of the PWM pulses given to the mosfet of the inverter. The presence of significant amount of harmonics makes the motor to suffer from severe torque pulsations, especially at low speed, which manifest themselves in cogging of the shaft and undesired motor heating and Electromagnetic interference. So multilevel inverters are the promising alternative and cost effective solution for high voltage and high power applications including power quality and motor drive problems.

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