Design and Development of Speed Control of Induction motor drive using Pulse-Width Modulation

Jigar Vaidya[1], Vatsal Shukla[2], Darshan Kale[3]

[1]UG Student, Electrical Department,jdv27993@gmail.com , +91-9662532919
[2]UG Student, Electrical and Electronics Department,vatsal813@yahoo.com , +91-9427414560
[3]UG Student, Electrical Department,kaledarshandk@gmail.com , +91-8460864643

Abstract–Speed control of induction motor is one of the major problems for many industries. Designing the drive for speed control of induction motor by use of V/f method. This V/f control was done by Pulse-width modulation technique for single-phase induction motor. By using this method, speed control of induction can be done more accurately and precisely. This technique is currently used by Tesla motors for controlling speed of electric cars and implemented successfully upto 1 HP motor.

Keywords–Speed control, Induction motor, Pulse-width modulation, v/f method, power electronic devices, inverter, IEEE

INTRODUCTION

Synchronous speed can be controlled by varying frequency. Voltage induced in the stator is $E_1 \alpha \Phi*f$, where Φ is the air gap flux and f is the supply frequency. As we can neglect the stator voltage drop we obtain terminal voltage $V_1 \alpha \Phi*f$ thus reducing the frequency without changing the supply voltage lead to an increase air-gap flux which is undesirable. Hence whenever frequency is varied in order to control speed, the terminal voltage is also varied so as to maintain V/f ratio constant. Thus by maintaining a constant V/f ratio, the maximum torque of the motor becomes constant for changing speed. It provides us good range of speed, low starting current requirement, more stable operation and easy to implement.
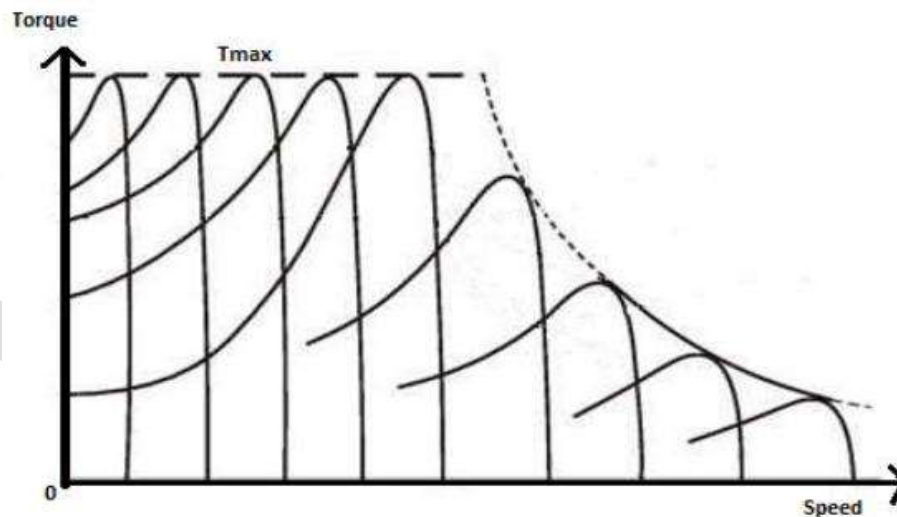

FIGURE 1 V/f Method

Principle of Pulse-width Modulation

In this method of modulation two pulses are compared in comparator (Generally one wave is Sinusoidal and another wave is Triangular wave) and intersection of two waves determines the switching instants and commutation of the modulated pulse, in fig 2, A_c is the peak value of triangular carrier wave and A_m is peak value of sinusoidal wave. The carrier and reference waves are mixed in a comparator as in fig 1, when sinusoidal wave has magnitude higher than the triangular wave, the comparator output is high otherwise it is low. When triangular carrier wave has its peak coincident with zero of the reference sinusoidal, there are $N=\frac{f}{2f}$ pulse per half cycle. Here the ratio of V_r/V_c is called as Modulation Index (MI) and it controls the harmonics content of the output voltage waveform.
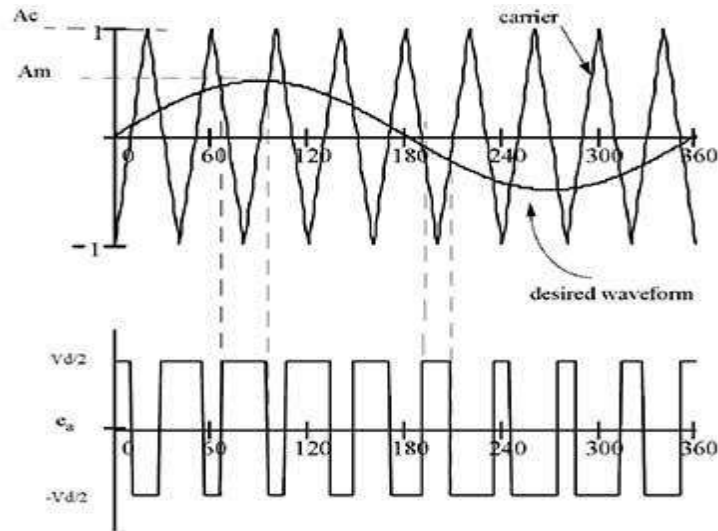
FIGURE 2 Basic idea of PWM

MATLAB simulation of PWM inverter

An inverter is circuit which is converting a DC power input into an AC power output at a desired output voltage and frequency. This conversion is achieved by controlled turn-on and turn-off of devices like IGBT, TRIAC etc. The output voltage of an inverter should be strictly sinusoidal but outputs are usually rich in harmonics and are always non-sinusoidal. Square wave or quasi-square wave voltage are also acceptable. The control circuit of a PWM Generator. The PWM signals are obtained by comparing the sinusoidal wave with a pulse train and modulating the pulse width accordingly. The PWM signals are applied to gates of IGBT's so as to trigger them. While one pair of IGBT's are fed signals from the relational operator (>=) and other pair of IGBT'
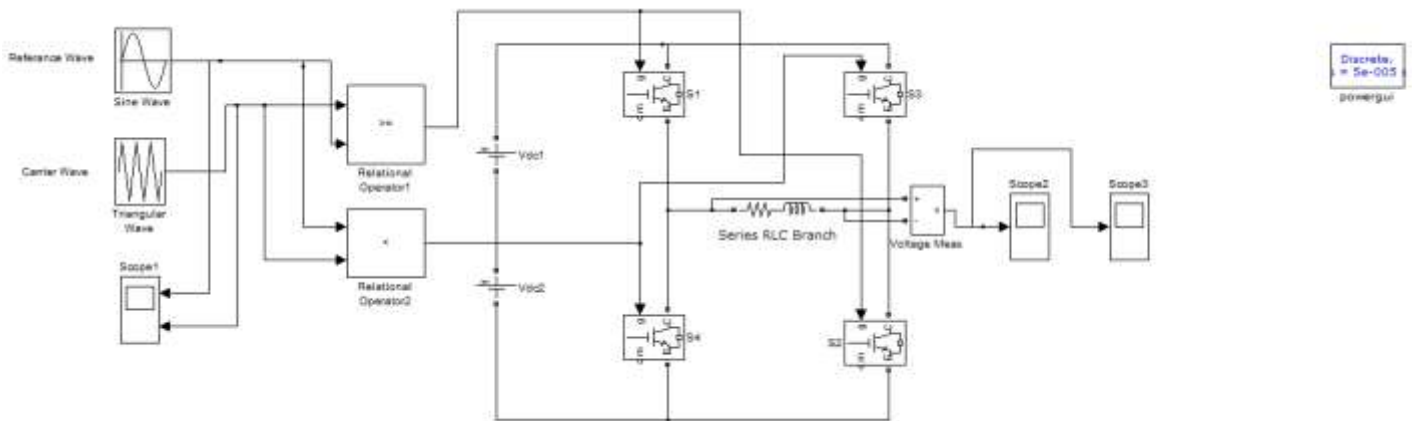

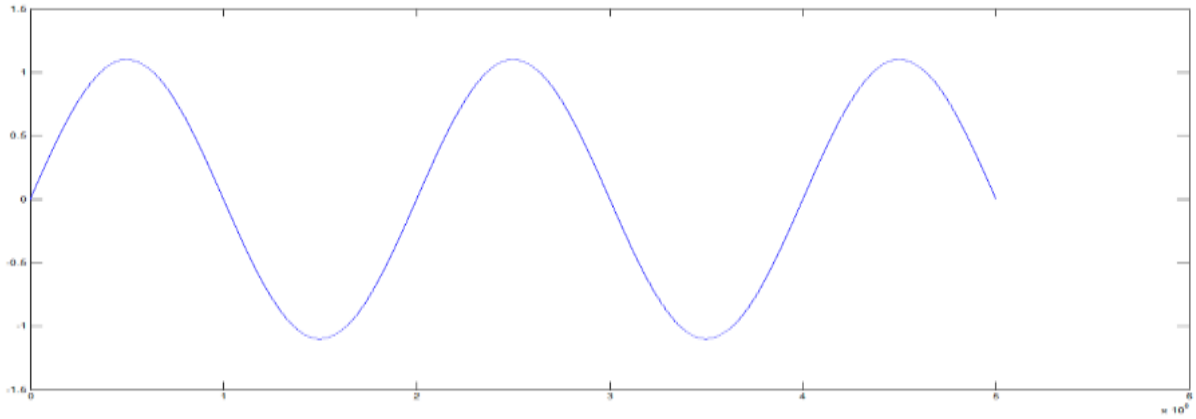FIGURE3.1 Simulation model of Single-phase Pulse-width modulation inverter

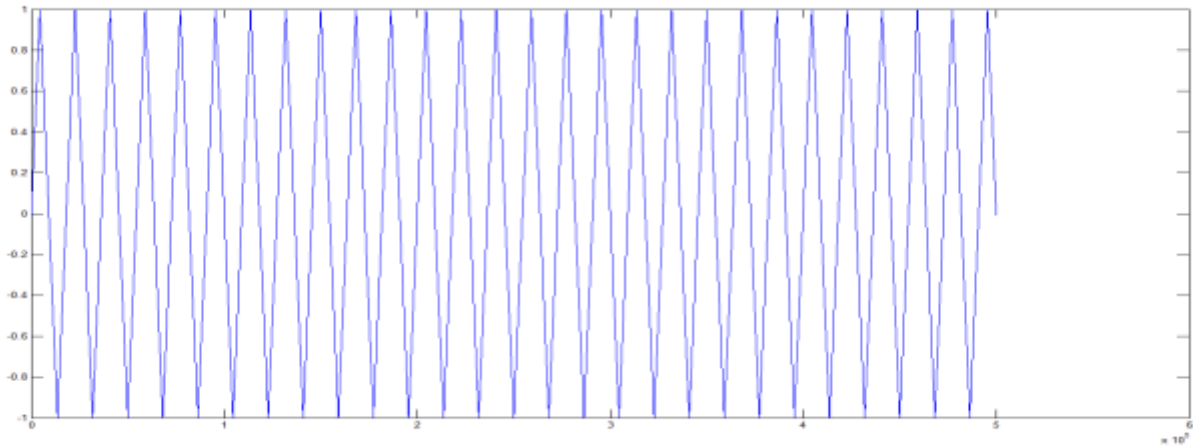Figure 4 Input sinusoidal Reference wave) of PWM inverter

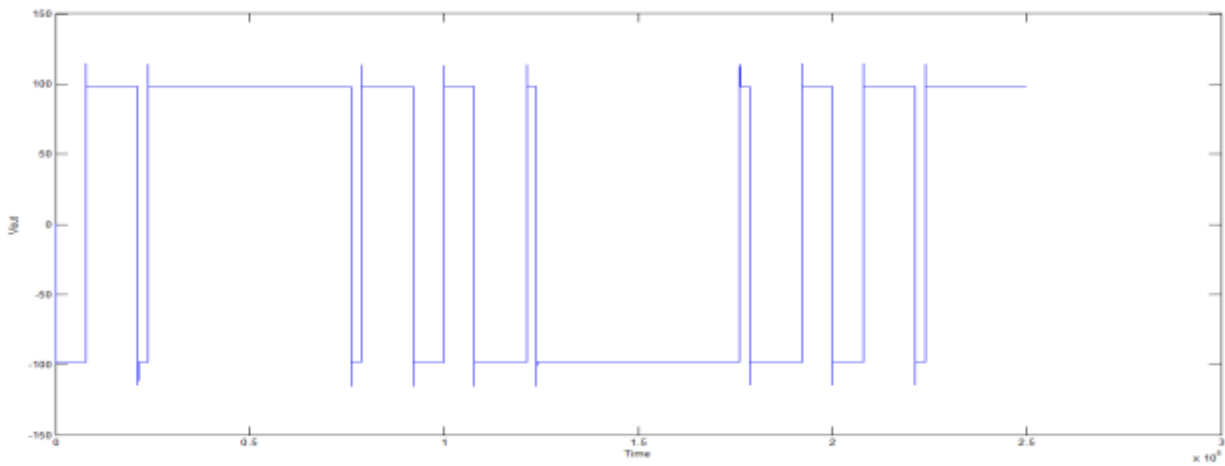Figure 5 Input triangular (carrier wave) waveforms of PWM inverter

Figure 6 Output waveform of PWM inverter

The distorted waveforms are generated due to harmonics generated in power electronic devices and distortion in electric power supply.

Hardware implementation

Figure 6 Actual Output of Control circuit

Figure 8 Silk layer of control circuit

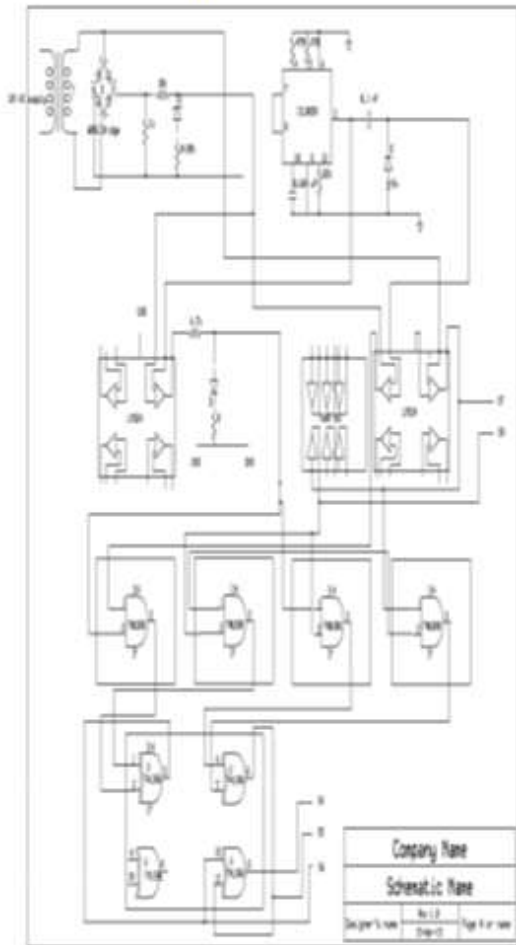Figure 9 Actual PCB of Control circuit

Figure 7 Circuit diagram of Control circuit

1) For MI less than one, largest harmonic amplitudes in the output voltage are associated with harmonics of order $f\ c/f$ =1 or 2N=1, where N is the number of pulses per half cycle, the order of dominant harmonic frequency can be raised, which can then be filtered out easily. It is observed from above that as N is increased, the order of significant harmonic increase and the filtering requirement are according minimized. But higher value of N entails higher switching frequency should be made.

2) For MI greater than one, lower order harmonics appear, since for MI > 1, pulse width is no longer a sinusoidal function of the angular position of the pulse.

Concept of over modulation:
1) With increase in the modulation index, the pulses having larger widths will start merging with each other. As the modulation index increase above "1". The over modulation takes place and the PWM waveform will degenerate to a square wave.

2) Due to over modulation harmonic distortion increase to a great extent. This is advantageous in application such as uninterruptable power supply (UPS)
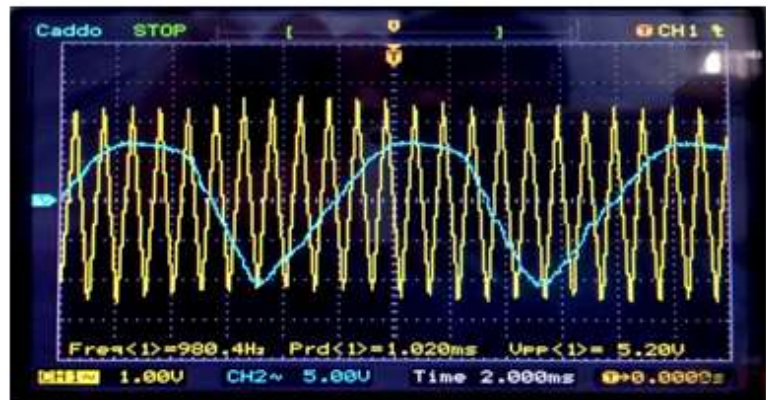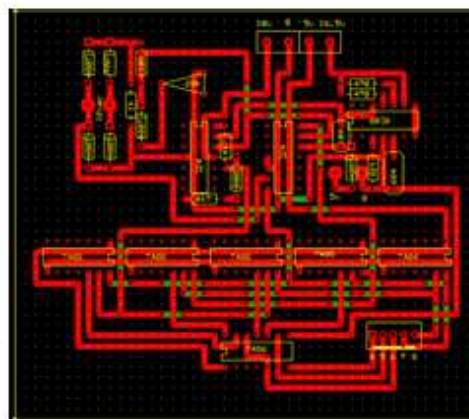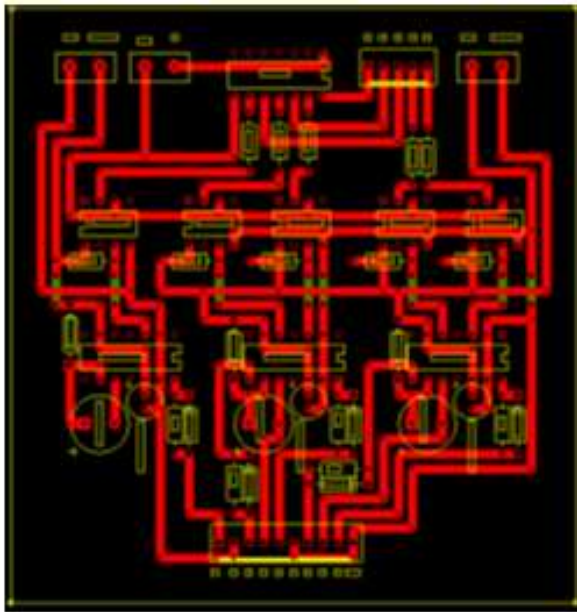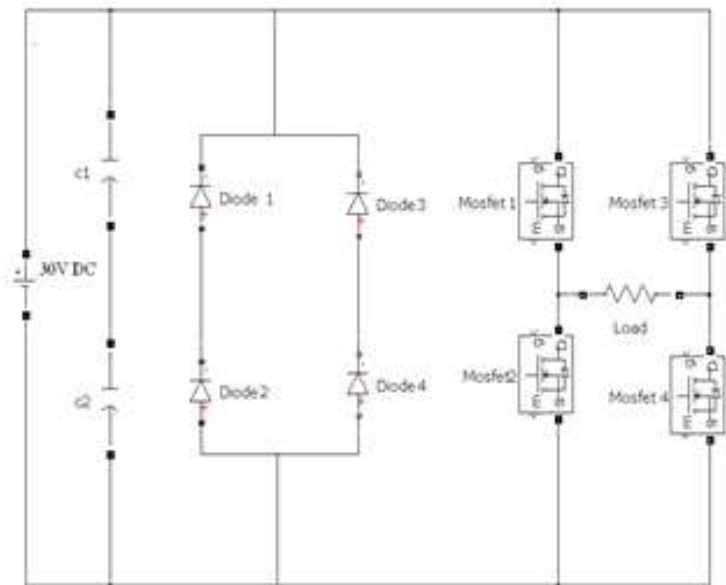
Figure 10 Silk layer of driver circuit

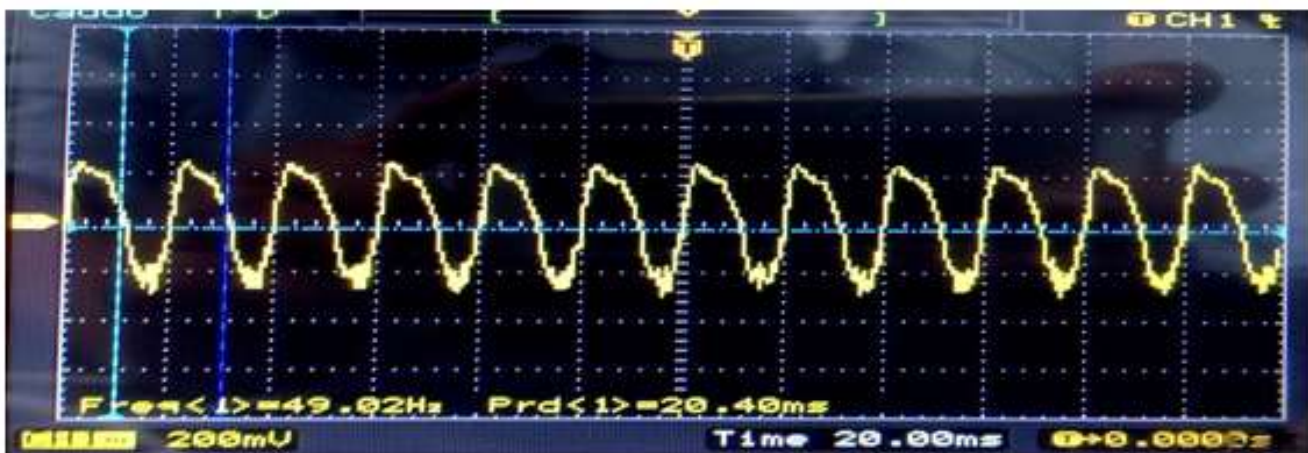Figure 11 Circuit diagram of Power circuit

Figure 12 Actual output of PWM inverter

The Power Circuit consists of 4 bi-directional IGBT's arranged in bridge-form. The input to the circuit is 100 V DC supply from battery or other power supply. The IGBT/Diodes are triggered in two distinct cycles. In the first cycle, from 0 to 180 degrees, S1 and S3 are triggered by applying signal to their gates. Thus they conduct during this period and output is obtained across the load.
In the next cycle, from 180 to 360 degree, S2 and S4 are triggered and they conduct during this period. Hence the output of 100 V is obtained the load in the opposite direction. Thus a DC supply voltage is converted to AC voltage across the load and Inverter action is obtained.

CONCLUSION

The speed control of induction motor can be achieved precisely by using the V/f method which has number of advantages rather than conventional method. By using of V/f method frequency as well as amplitude of voltage can be changed precisely. The amplitude of the either sine wave or triangular wave can be changed which is done by changing the value of the variable resistor. The PWM technique in which the sinusoidal and triangular wave is compared in control circuit and output is given to the power circuit via driver

circuit. Hence, by changing the value of the voltage as well as frequency and maintaining the ratio of V/f constant the amplitude of the wave can be changed and speed of the induction motor changed precisely and accurately.

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