DESIGN AND FABRICATION OF THREE PHASE 1 HP I.M. DRIVE USING V/F CONTROL

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the degree of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

(Power Electronics, Machines & Drives)

By

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Undertaking for Originality of the Work

I **Udit V. Vyas**, Roll No. **12MEEP30**, give undertaking that the Major Project entitled **"Design and Fabrication of three phase 1 hp I.M. Drive using V/F Control"** submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Power Electronics Machines** & **Drives, Electrical Engineering**, under Institute of Technology of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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This is to certify that the Major Project Report entitled **"Design and Fabrication of three phase 1 hp I.M. Drive using V/F Control"** submitted by **Mr.Udit V. Vyas (Roll No: 12MEEP30)** towards the partial fulfillment of the requirements for the award of degree in Master of Technology (Electrical Engineering) in the field of Power Electronics, Machines Drives of Nirma University is the record of work carried out by him/her under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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Abstract

Applications of solid-state converters for Variable Frequency Drives are popular in industrial systems. The ac to dc and dc to ac conversion is frequently used to provide Variable Frequency with Adjustable Voltage for constant torque. The design and fabrication of a Variable Frequency Drive(VFD) based on Sinusoidal Pulse Width Modulation(SPWM) Technique for a three Phase Induction Motor using a 16f877 PIC micro controller. The work involves implementation of an open loop control scheme for an induction motor. The technique is extensively used in industry as it provides the accuracy required at minimum cost. Voltage/frequency(V/f) controlled motors are used to maintain maximum torque up to base speed. The speed of the induction motor need to be varied, there are need to control the frequency with respect to output voltage of the inverter for maintaining V/f ratio to achieve constant flux.

To vary the output voltage of the inverter, the modulation index of the carrier signal has to be changed. Amplitude of Carrier signal varies inversely as the three phase output voltage adjust with change in frequency respectively. By changing amplitude of carrier signal and compare with constant amplitude of reference signal output six SPWM pulses carried out through 16f877 PIC micro controller. This pulses are used to trigger the three phase inverter through TLP250 driver IC and thereby speed of the motor can be controlled.

The short circuit dc current and ac over current sense through LEM sensor and CT respectively. The fabrication of short circuit current and over current protections with the use of op-amps and merge them to make reliable control of Induction motor.

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Abbreviations

VFD .... Variable Frequency Drive
VFDs .... Variable Frequency Drives
IM .... Induction motor
MI .... modulation index
PF .... power factor
PFC .... power factor correction
HP .... Horse Power
kW .... Kilo watt
EMF .... Electro magnetic force
PIC .... programmable intelligent controller
IGBT .... Insulated Gate Bipolar Transistor
MOSFET .... Metal Oxide Field Effect Transistor
SCR .... Silicon controlled rectifier
PWM .... Pulse Width Modulation
SPWM .... Sinusoidal Pulse Width Modulation
OC .... Over Current
SC .... Short circuit current
ADC .... Analog to digital converter
IC .... Instruction Cycle

Nomenclature

V_{rms} .... rms Output Voltage

V_o .... output Voltage

T .... Torque

T_m .... Maximum torque

I_r .... rotor Current

V_{in} .... Input AC Voltage

f_c .... Carrier Frequency

V_{dc} .... Voltage at DC link

V_{max} .... maximum output at rated frequency

P_{dc} .... Power at DC link

V_p .... Voltage at primary side

V_s .... voltage at secondary side

m_o .... Modulation Index

m_f .... Modulation frequency

A_r .... Peak amplitude of reference signal

A_c .... Peak amplitude of carrier signal

a .... winding turn ratio

f_r .... reference frequency

f_b .... base frequency

N_s .... synchronous speed

p .... number of pole

R_f .... feedback resistor

R_1 .... non inverting resistor

A .... Gain of the non-inverting op-amp

Chapter 1

INTRODUCTION AND LITERATURE SURVEY

1.1 Need for the Variable Frequency Drive

Various issues are realised to drive the induction motor. Earlier induction motor are design to drive specific load for its entire range due to the fixed supply frequency and the number of poles. The design and system requirement are particular for induction motor to drive the load. The results are deteriorate under the various loading condition and highly inefficient. Significant part of the input power was not going to useful work under varying loading condition of motor especially at low speed. for such particular design motor the operating range is restricted form 80% of the speed to 100% of the rated speed .

At the starting of the induction motor, the absence of the back EMF results in it to draw very high inrush current at beginning. This high inrush current may induced the voltage dip in the supply line, which may affect the performance of other utility equipment connected on the same supply line.

While operating, it is often necessary to quick start, stop the motor and also reverse it. The torque of the motor drive may have to be maintained so that the load does not influence of the input side, applications like cranes, hoists and conveyors. The speed and accuracy of starting, stopping and reversing operations increase the reliability of the system and the quality of the product. The star, stop and braking is required to drive the above application. Earlier, mechanical brakes were in use in drive for controlling. However, this type of braking is highly inefficient and make more time than electric controlling. The mechanical brakes require regular maintenance due to it produces heat while braking represents loss of energy.

A mechanical throttling device are used in many flow control applications to limit the flow. This controls are very ineffective due to, it wastes more energy because of the high losses and reduces the motor life due to generated heat. When the supply line is delivering the power at a Power factor less than unity, the motor draws magnetizing current which is rich in harmonics. This results in higher rotor loss due to winding of the IM which affecting the motor life. The pulsating torque generated due to harmonics which also affect the motor life. At high speed when frequency is high the pulsating torque is large enough to be filtered out by the motor self impedance. But at low speed, the pulsating torque appear in the motor speed pulsation. This results in jerky motion and affects the bearings and motor life.

All of the previously mentioned problems, faced by both consumers and the industry, strongly advocated the need for an intelligent motor control. With the advancement of solid state device technology (BJT, MOSFET, IGBT, SCR, etc.) and IC fabrication technology, which gave rise to high-speed micro controllers capable of executing real-time complex algorithm to give excellent dynamic performance of the induction motor. This such limitations are over come by using Variable Frequency Drives. They became popular in industry as IM can be controlled by user settings.

1.2 Introduction of Variable Frequency Drive

The induction motors are the most common motors used in industrial motion control systems, as well as in main power home appliances. Simple and rugged design, low-cost, low maintenance and direct connection to an AC power source are the main advantages of induction motors. Various types of induction motors are available in the market. Different motors are suitable for different applications. Although induction motors are easier to design than DC motors, the speed and the torque control in various types of induction motors require a greater understanding of the design and the characteristics of these motors. Although machine can generally operate at speed less than the maximum design speed, motors typically drive machine at a constant rate without controller.

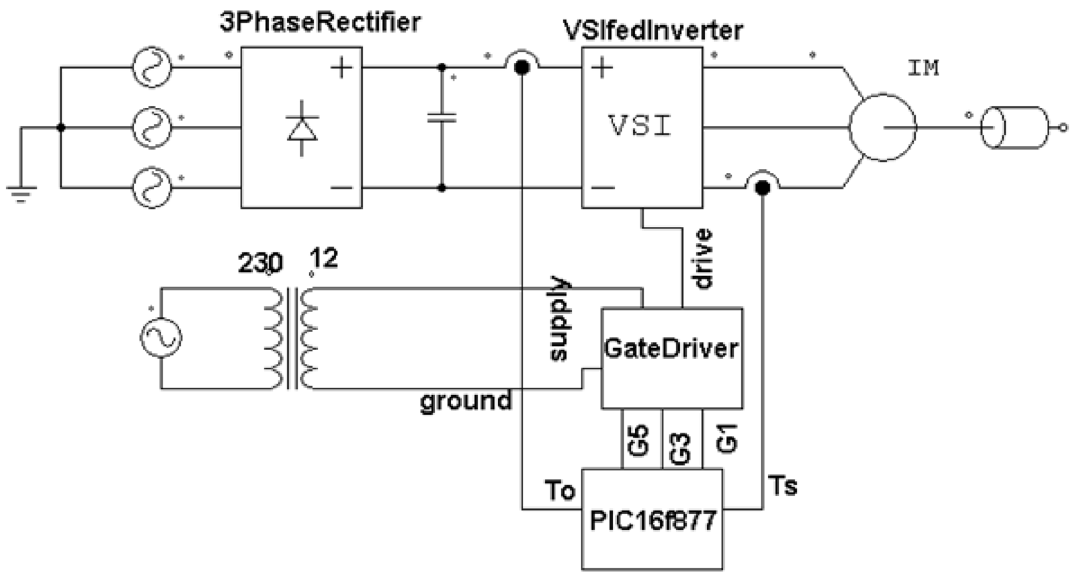

Figure 1.1: Block Diagram of VFD

The Variable Frequency Drive is a system made up of active/passive power electronics devices,(IGBT, MOSFET, etc.) a high speed central controlling unit (a micro controller, like the PIC16) and optional sensing devices, depending upon the application requirement. The basic function of the VFD is to act as a variable frequency generator in order to vary speed of the motor as per the user setting. The rectifier and the filter convert the ac input to dc with negligible ripple. The inverter, under the control of the PIC micro controller, synthesizes the dc into three-phase adjustable voltage, variable frequency ac. Additional features can be provided, like the over current protection, short circuit protection, open loop speed control, easy control setting, display and so on. With the rich feature set of the PIC16f877 micro controller, it is possible to integrate all the features necessary into a single chip solution so as to get advantages, such as reliability, accurate control, space saving, cost saving and so on.

1.2.1 Basic Principle

1) The base speed of the motor is directly proportional to supply frequency and is inversely proportional to the number of stator poles.

2) Torque is directly proportional to the ratio of applied voltage and the frequency of the applied ac current.

$$N_s = \frac{120 \times f}{p} \tag{1.1}$$

$$T = K \times \phi \times I \times cos\phi \tag{1.2}$$

Therefore, speed can be controlled by varying the input frequency of the applied alternating current and torque can be maintained constant by varying the amplitude in direct proportion to the frequency. These are the two basic aims of open-loop V/f control. Intelligent use of energy means higher productivity with lower active energy and lower losses at moderate costs. Variable frequency through variable speed and low power losses are paramount achieving such goals.

The number of poles cannot be changed once the motor is constructed. So, by changing the supply frequency, the motor speed can be changed. But when the supply frequency is reduced, the equivalent impedance of electric circuit reduces. This results in higher current drawn by the motor and a higher flux. If the supply voltage is not reduced, the magnetic field may reach the saturation level. Therefore, in order to keep the magnetic flux within working range, both the supply voltage and the frequency are changed in a constant ratio. Since the torque produced by the motor is proportional to the magnetic field in the air gap, the torque remains more or less constant throughout the operating range.

1.2.2 VFD Operation

The voltage and the frequency are varied at a constant ratio up to the base speed. The flux and the torque remain almost constant up to the base speed.

$$\frac{V_{max}}{f_{base}} = \phi \tag{1.3}$$

By selecting the proper V/f ratio for a motor, the starting current can be kept well under control. This avoids any sag in the supply line, as well as heating of the motor. The VFD also provides over current protection. This feature is very useful while controlling the motor with higher inertia. Since almost constant rated torque is available over the entire operating range, the speed range of the motor becomes wider. User can set the speed as per the load requirement, thereby achieving higher energy efficiency especially with the load where power is proportional to the cube speed.

Continuous operation over almost the entire range is smooth, except at very low speed. This restriction comes mainly due to the inherent losses in the motor, like frictional, windage, iron, etc. These losses are almost constant over the entire speed. Therefore, to start the motor, sufficient power must be supplied to overcome these losses and the minimum torque has to be developed to overcome the load inertia. The user can easily limit flow of harmonics from line to motor and hence, near unity PF power can be drawn from the line. The noise flow from the VFD to the line can

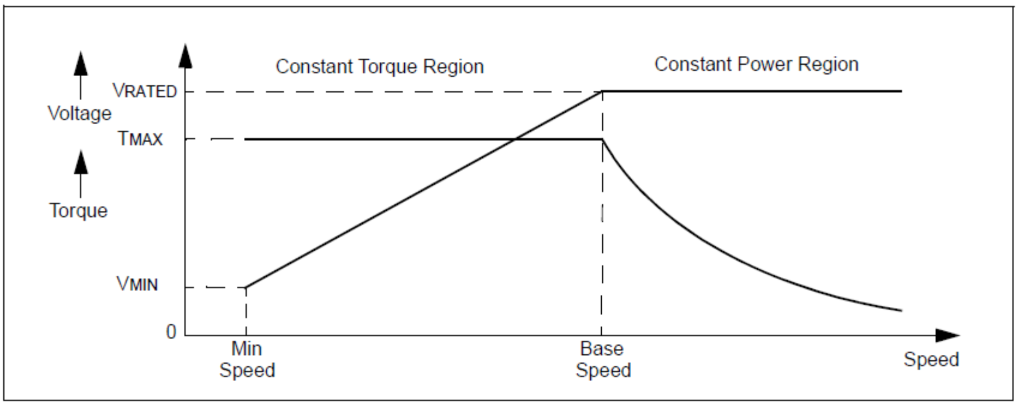

Figure 1.2: V/f curve of IM

entirely be stopped.

Beyond the base speed, the supply voltage cannot be increased. Increasing the frequency beyond the base speed results in the field weakening and the torque reduces. Above the base speed, the torque governing factors become more nonlinear as the friction and windage losses increase significantly. Due to this, the torque curve becomes nonlinear. Based on the motor type, the field weakening can go up to twice the base speed. This control is the most popular in industries and is popularly known as the constant V/f control.

1.2.3 VFD for Multiple Motors

A single VFD has the capability to control multiple motors. The VFD is adaptable to almost any operating condition. There is no need to refuel or warm up the motor. For the given power rating, the control and the drive provided by the VFD depends solely on the algorithm written into it. This means that for a wide range of power ratings, the same VFD can be used. Due to ever evolving technology, the price of semiconductors has reduced drastically in the past 15 years and the trend is still continuing. This means the user can have an intelligent VFD at such an inexpensive rate that the investment cost can be recovered within 1 to 2 years, depending upon the features of VFD.

A Variable Frequency Drives provides more efficient way to control of varying flow rates and pressures. VFDs are also often called variable speed drives, variable frequency inverters, or frequency converters. VFDs are used for motor control in diverse applications. Before investing in VFDs, consider the type of load and potential benefits. Motor loads fall into three categories: constant torque loads, constant horsepower loads, and variable torque loads.

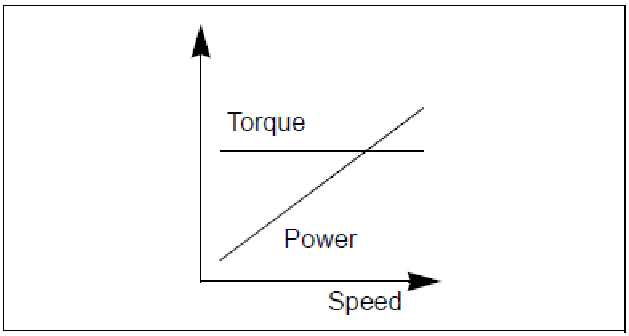

Figure 1.3: Constant torque variable speed load

Constant torque loads have torque that remains constant regardless of the speed at which the system is running. This category of load includes conveyors, robotics, positive displacement pumps, and compressors. The advantages of VFD drives for this application are precise speed control, soft starts and stops, and energy savings for lower speed operation.

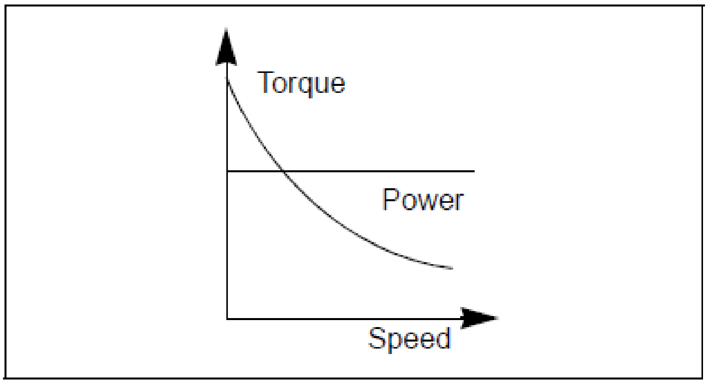

Figure 1.4: Constant power load

Constant horsepower loads are loads in which power does not vary, regardless of speed. The torque here varies inversely with the speed of the motor. Examples of constant horsepower loads include lathes, drilling, and milling. Since power remains constant for this application, a VFDs would not achieve any energy savings, though qualitative benefits could still be realized. Here, qualitative benefits refer to non-quantifiable factors, such as better process control.

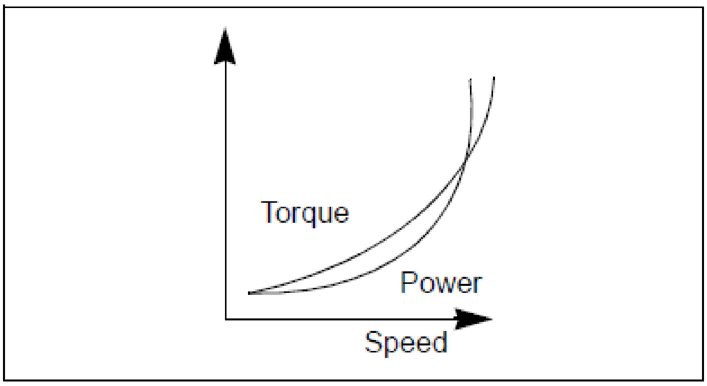

Figure 1.5: Variable torque variable speed load

Variable torque loads maintain torque that varies directly with the speed squared, and power that varies directly with the speed cubed. Since fan and pump efficiencies decrease at reduced speeds, significantly decreases motor energy use and demand. Due to the energy savings potential, VFDs are most commonly used for this load type. Typical applications are centrifugal fans, blowers, and pumps. Additional benefits are more precise process control and maintenance savings from reduced stress on the system.

Variable frequency drives also have the potential to reduce system maintenance and related costs. Control with a VFDs affords the capability to soft start a motor, which means the motor can be brought up to its running speed slowly rather than abruptly starting and stopping. Soft starting a motor results in less mechanical stress on equipment and, over time, less maintenance is required. Similarly, running the motor at lower speeds extends the lifetime of other equipment components, including shafts and bearings. VFDs has efficiently controlled the motor speed with maximum torque by power electronics and allow the control over the flow of power an attribute on converter energy efficiency.

1.2.4 VFD as Energy Saver

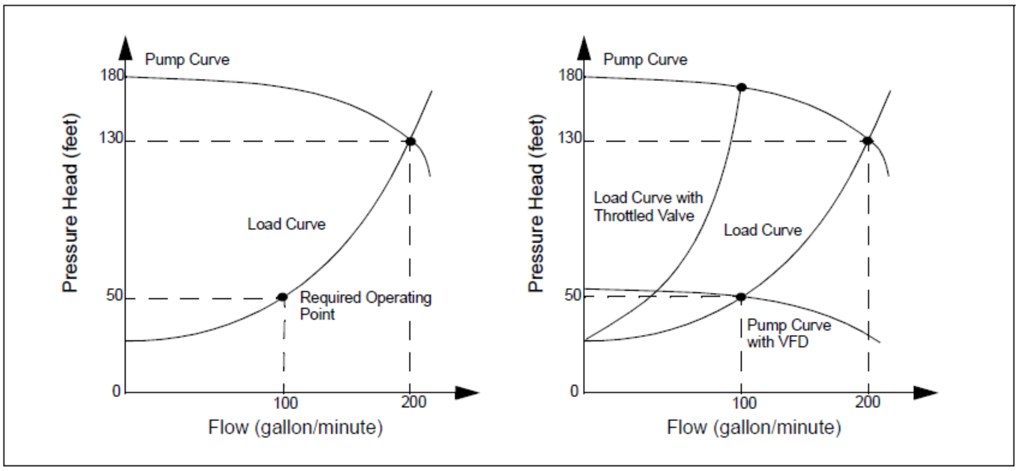

Figure 1.6: VFD as energy saver

In many applications, the input power is a function of the speed like fan, blower, pump and so on. In these types of loads, the torque is proportional to the square of the speed and the power is proportional to the cube of speed. Variable speed, depending upon the load requirement, provides significant energy saving. A reduction of 20% in the operating speed of the motor from its rated speed will result in an almost 50% reduction in the input power to the motor. This is not possible in a system where the motor is directly connected to the supply line. In many flow control applications, a mechanical throttling device is used to limit the flow. Although this is an effective means of control, it wastes energy because of the high losses and reduces the life of the motor valve due to generated heat.

There are various reasons for selecting of VFDs

1) Smooth start and stop
2) Ease of programming
3) Low investment cost for development
4) Flexibility to add additional features with minimal increase in hardware cost
5) Same VFD for wide ranges of motors with different ratings
6) Ease of mass production
7) Ever decreasing cost of semiconductors due to advancement in fabrication technology
8) Energy efficient solution

Limitations of VFDs

1) Very poor PF at low load
2) Induce power line harmonics
3) poor torque below 6Hz operation

Application of VFDs

1) screw compressor

2) Transportation

3) pumps

4) ventilator

5) machine tools

6) robotics

7) Hybrid electric vehicles

8) conveyors

9) feeders

1.3 Literature Survey

1.3.1 Zhenyu Yu, Arefeen Mohammed and Issa Panahi

"A Review of Three PWM Techniques"

It is clear that the rms output voltage of an inverter using SPWM depends on the modulation index. Higher output voltage can be obtained by increasing modulation index towards 1. However, sinusoidal PWM inverter output voltage waveforms deterioration when modulation index above 1. The characteristics of a SPWM pulses, it eliminates all harmonics less than or equal to 2N-1, where "N" is defined as the number of pulses per half cycle of the sine wave. The output voltage of the inverter contents harmonics. However, the harmonics are pushed to the range around the carrier frequency and its multiples. The even number of harmonics are shown in the inverter output voltages when the pulses carried out by sine and triangular comparison are not synchronise. It easily synchronise when modulation frequency is higher than 21.

1.3.2 Rakesh Parekh

"Variable frequency drive"

This is Microchip technical note. VFDs are used for motor control in diverse applications. Motor loads fall into three categories: constant torque loads, constant horsepower loads, and variable torque loads. Variable frequency with adjustable output voltage employ for constant torque loads that torque remains constant up to the base speed at which the system is running. Above the base speed the voltage of the system cannot increase so power drawn by the motor is constant so it called constant horsepower loads, regardless of speed. Control with a VFD affords the capability to soft start a motor, which means the motor, can be brought up to its running speed slowly rather than abruptly starting and stopping.

1.3.3 Matina Lakka, Eftichios Koutroulis, Apostolos Dollas

"Design of a High Switching Frequency FPGA-based SPWM Generator"

Implementation of the SPWM algorithm, input of the system is modulation index MI which ranges from 0 to 1. This value has to be converted in fixed point arithmetic. This conversion is achieved by multiplying the MI with value ranging from 0 to 255. From this the values of reference and carrier also limits in the range of 0 to 255. This values are store in array an then fetch for comparison to achieve require pulses.

1.3.4 Muhammad H. Rashid

"Power Electronic Handbook"

The output voltage of the inverter is proportional to MI. Amplitude of carrier signal is inversely proportional to MI. Maximum use of DC link can be achieved with less harmonic distortion by SPWM method. When MI ≤ 1 the notches appear by comparing the peak of the sine signal and carrier signal are high and there by vary linearly with the output voltage. when MI is low, the inverter output voltage and current is smooth to drive IM due to high notches and output voltage varies linearly with MI. when MI increase to 1 the notches decrease due to modulation frequency decreases. By changing input Frequency of the drive not only MI varies but modulation frequency also varies. As high modulation frequency gives good synchronization between sine and carrier waves which are used to generate SPWM pulses by comparing each sine to carrier.

Chapter 2

PWM TECHNIQUE

2.1 Modulation Techniques

Pulse width modulation(PWM) techniques are gradually taking over in industrial applications. PWM techniques are characterised by constant amplitude pulses but the width of these pulses is, however modulated to control inverter output voltage and to reduce its harmonic contents. Choice of a particular PWM technique depends upon the permissible switching losses and harmonics contents in the inverter output voltage. The device are switch on and off within each half cycle to control inverter output voltage. There are several techniques of Pulse Width Modulation(PWM). The switching losses and harmonic reduction are principally depended on the modulation strategies used to control the inverter output voltages.

1) Single pulse modulation

2) Multiple pulse modulation

3) Sinusoidal pulse width modulation

    1) Unipolar pulse width modulation

    2) Bipolar pulse width modulation

4) Space Vector based modulation

2.1.1 Unipolar SPWM Technique

Using this Technique due to ease of implement and control and Compatible with todays digital micro controller make this technique reliable to use with low power dissipation.

Three-phase VSI are used for the medium to high power applications. The main purpose of these topologies is to provide a three-phase output voltage, where the amplitude and frequency of the voltages should always be controllable. Although most of the applications require sinusoidal output voltage.

The Sinusoidal Pulse Width Modulation (SPWM) technique has been used for controlling the inverter as it can be directly controlled the inverter output voltage and output frequency according to the sine function. SPWM techniques are characterized by constant amplitude pulses with different duty cycles within period. The width of these pulses are modulated to obtain adjustable inverter output voltage and also reduce its harmonic contents. SPWM is the mostly used method in motor control and inverter application in industry and commercially. Three 120 phase shift sine(reference) waves and a high frequency triangular(carrier) wave are used to generate SPWM signal. Generally. The frequency of these sinusoidal waves is chosen based on the required inverter output frequency. The triangular carrier wave is usually chosen based on notches required for inverter output voltage.

It defines the on and off states of the switches of one leg of a VSI by comparing a reference signal Ar(desired ac output voltage) and a triangular waveform Ac(carrier signal). In practice, when Ar $\geqq$ Ac the upper switch S1 is on and the complementary switch S4 is off, similarly when Ar $\leqq$ Ac the lower switch S4 is on and the upper switch S1 is off. For three phase SPWM there are three 120 phase shifted reference signals are compare with one carrier signal whose amplitude depends on modulation index(MI) and three pairs of VSI are switches on and off for adjustable output voltage of the inverter at the desire frequency controlled by VFD.

The frequency of carrier wave choose based on device switching losses and harmonics content at the output side of load. Switching losses and harmonic contents are inversely proportional to each other or vice-versa. For high carrier frequency harmonic contents are minimise but it increases switching losses across the IGBT. For low carrier frequency switching losses are low but at the time high harmonic contents deteriorates inverter output voltage. so adjust carrier frequency to minimise both switching losses and harmonics contents of the output voltage.

For SPWM, a high frequency carrier wave Ac is compared with reference wave Ar of desired frequency. the comparison of Ac and Ar waves determines the switching instants. Ac and Ar are Peak values of carrier and reference waves respectively. when Ar is higher or lower than Ac comparator output goes high or low, switching take place and it will trigger IGBTs to give control output voltage.

modulation index

$$m_o = \frac{A_r}{A_c} \tag{2.1}$$

Normalized modulation frequency

$$m_f = \frac{f_c}{f_r} \tag{2.2}$$

The ratio of Ar/Ac is called modulation index(MI), the amplitude of fundamental component of output voltage is proportional to MI, for linear operation MI $\leq$ 1. thus the output voltage is controlled by varying MI and it controls the harmonic contents in the line current. MI $\geq$ 1 called over modulation, in this mode motor work in constant power mode, the speed is more than synchronous speed with maximum output voltage.

$$V_{rms} = \frac{m_o \times V_{dc}}{\sqrt{2}} \tag{2.3}$$

$$m_o = \frac{V_{rms} \times \sqrt{2}}{V_{dc}} \tag{2.4}$$

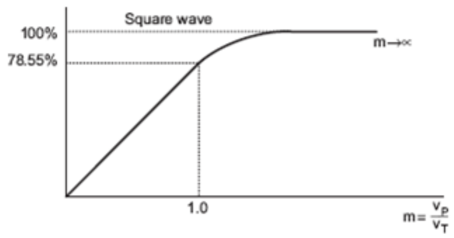

Figure 2.1: Inverter fundamental output voltage varies with MI

In the range of MI 0 to 1 the inverter output is proportional to MI. when the MI reach up to 1 The output voltage of the inverter increase linearly up to maximum rms voltage. Figure shows linear inverter output voltage increase linearly in range of 0 to 1 of MI. For MI $\geq$ 1 the inverter output no more in linear range. Further increase in MI, the notches in the middle of the sine wave are disappear and it react as square wave output.

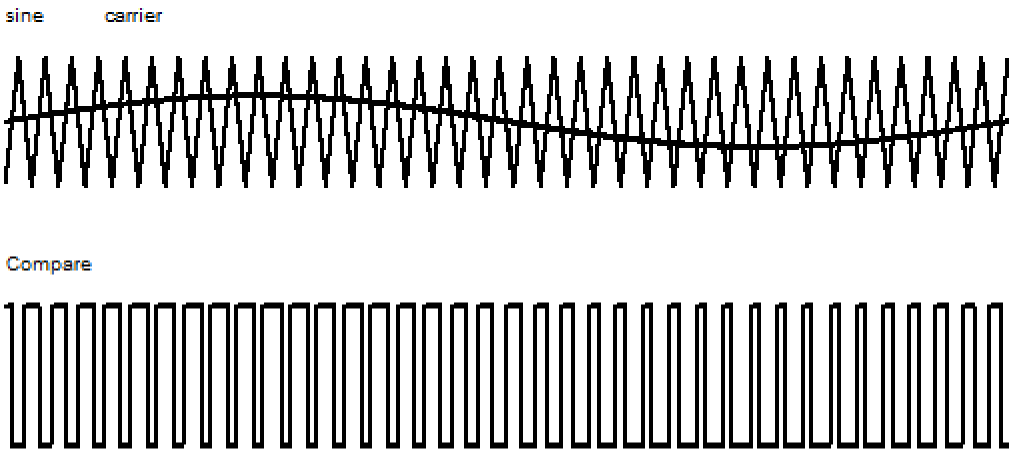

Figure 2.2: sine triangular waveforms at 0.4 MI and compared output

When MI $\leq$ 0.7. The carrier frequency amplitude is very high compare to reference frequency, synchronism between carrier and reference can be made easily and The pulse width per half cycle are very narrow. Inverter output voltage less due to narrow pulse width.

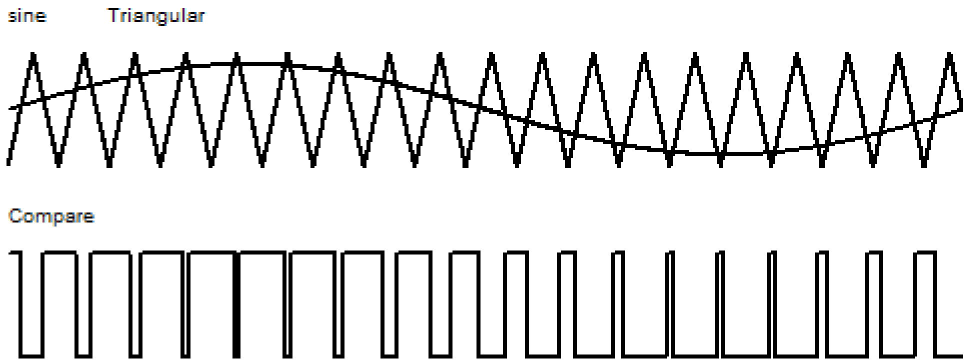

Figure 2.3: sine triangular waveforms at 0.8 MI and compared output

When MI ≥ 0.8. The carrier frequency amplitude is quite high compare to reference frequency, The pulse width per half cycle are increase by increase MI or nearer to the one. so harmonics contents are very low and far away from the lower order harmonics.

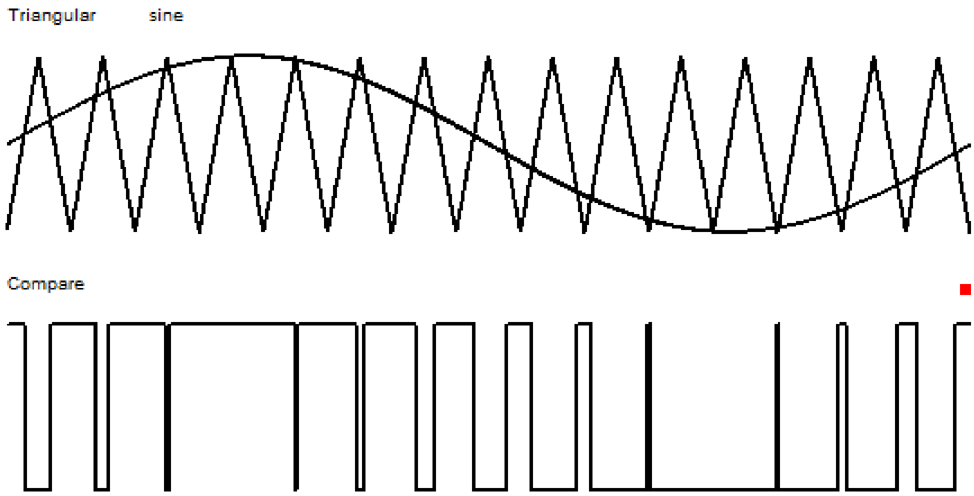

Figure 2.4: sine triangular waveforms at 1.0 MI and compared output

When MI ≥ 1. The amplitude of carrier frequency is equal, the pulse width per half cycle are increase due to some notches are disappear comparing to high amplitude reference frequency. In this mode lower order harmonics are major contributes due to less notches per half cycle.

2.1.2 Modulation Strategy

Table I: Modulation strategy

Sr no.	Frequency	Modulation index	Amplitude of carrier wave	Inverter output voltage
1	10	0.2	5	59
2	15	0.3	3.33	88
3	20	0.4	2.5	117
4	25	0.5	2	147
5	30	0.6	1.67	176
6	35	0.7	1.42	206
7	40	0.8	1.25	235
8	45	0.9	1.11	264
9	50	1.0	1.0	294

largest harmonic amplitude in the output voltage are associated with harmonic order

$$Hamonics_{order} = \frac{f_c}{f_s} + 1 \tag{2.5}$$

The ratio between the carrier wave and reference wave must be an odd integer N to achieve the N number of pulses per half cycle. Increases number of pulses per cycle lower order harmonics can be easily eliminated or shifted away from the lower order harmonics to the higher order harmonics of switching of triangular wave.

Pulses per cycle

$$2N = \frac{f_c}{f_s} \tag{2.6}$$

In unipolar SPWM technique amplitude of triangular wave is change due to controlling modulation index. Control is achieved by taking MI from 0 to 1 at frequency from 0 to 50 Hz for maximum linear regulated output. change in supply frequency changes in modulation index MI and amplitude of triangular wave changes so com-

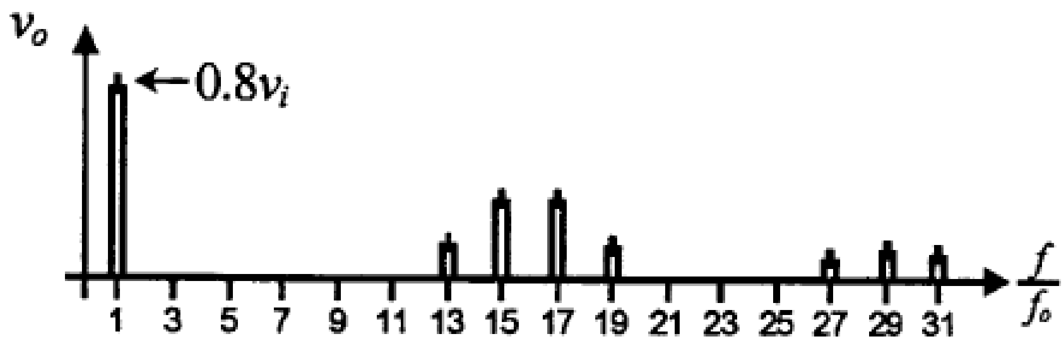

Figure 2.5: Harmonic spectrum of output voltage

paring reference waves with carrier wave and generate SPWM pulses. Generated SPWM pulses have a characteristics that it have fundamental sine frequency output with variable pulse width within each period. output wave seems as sine wave which have eliminating lower order harmonics achieve low THD. so it can directly fed to the induction motor to control the speed and constant torque with less power or energy.

Chapter 3

SIMULATION OF VFD WITH PROTECTION CIRCUIT

3.1 Simulation of VFD

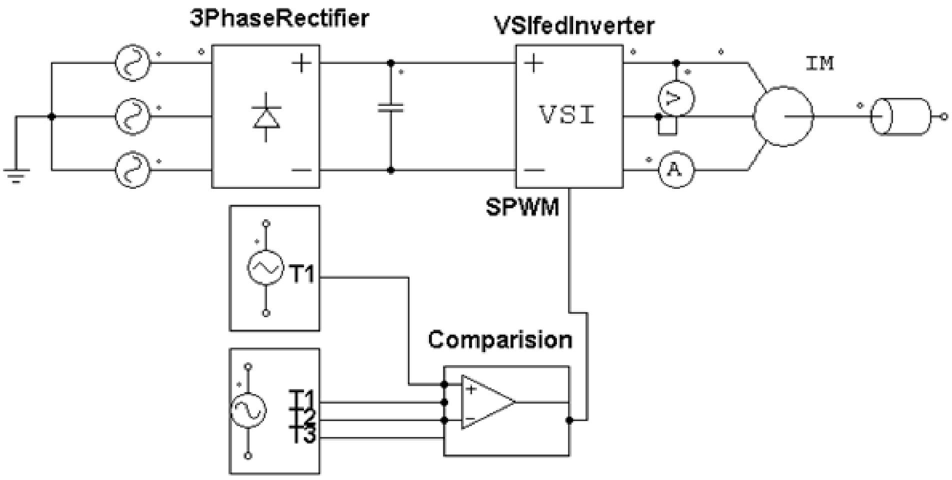

Figure 3.1: main simulation diagram

In simulation three sinusoidal wave is coming from matlab code and compare with outer triangular function to generate SPWM pulses. This pulses are fed to IGBT with a complementary pair with upper and lower IGBT. According to SPWM pulses

IGBT are on/off and induction motor gets supply. In simulation matlab code require frequency input which is used to calculate parameter of the drive. The modulation index and also Amplitude of triangular wave are calculation perform in matlab code to generate require V/f operation of the drive.

$$\frac{V_o}{f} = \frac{V_{max}}{f_{base}} \tag{3.1}$$

modulation index(MI) decide from the ratio of output voltage and input DC link supply. from MI we measure Amplitude of carrier signal.

$$A_c = \frac{A_r}{m_o} \tag{3.2}$$

From the equation we measure v/f ratio, modulation index and amplitude of carrier signal Ac. Ar/mo is multiply with carrier amplitude with respect to frequency input. It is compare with three sinusoidal signal and gives three output pulses accordingly. Three lags of IGBT pair are complementary so these three pulses are converted to six pulses by doing NOT Ic. shown in main simulation diagram. from these six pulses, three pulses are fed to upper IGBT switches and other three pulses are fed to lower IGBT switches to drive the inverter.

The output of inverter are connected to three phase 1 Hp Asynchronous wound motor with practical values of motor parameter with externally 50 Ω load per phase. The line to line voltage and line current are shown in figures with variable frequency input.

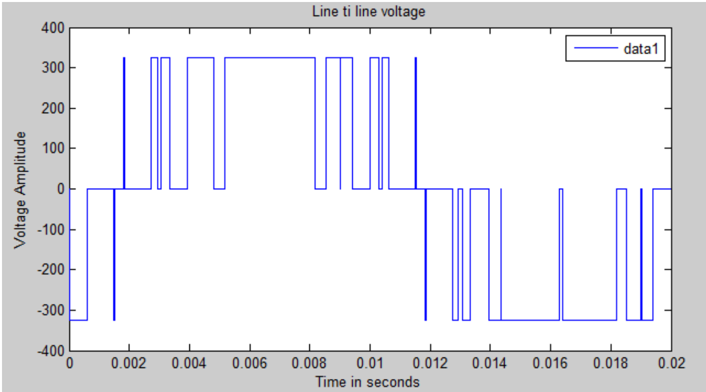

Figure 3.2: line to line voltage
scale x axis:1 cm = 2 millisecond, y axis:1 cm = 100 volt.

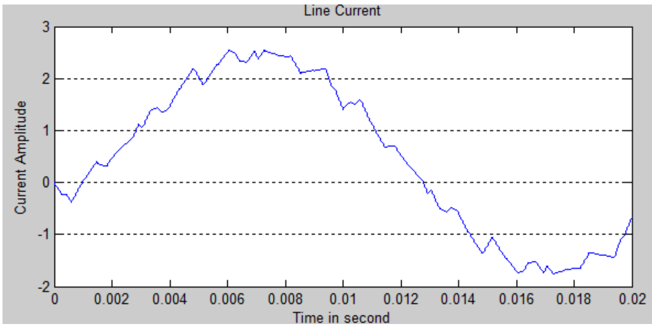

Figure 3.3: line current
scale x axis:1 cm = 2 millisecond, y axis:1 cm = 1 Ampere

Pulses appear in the line voltage is wider due to high modulation index and low modulation frequency to achieve the output voltage maximum with the maximum rated input frequency of the motor to operate on maximum speed.

Due to the wider pulses the line current appear with distortion and not smooth. The lower order harmonics contents are visible when MI reach above 1 and modulation frequency is also low. Rated 50 Hz input frequency modulation index becomes unity due to maximum linear inverter output voltage requires so peak amplitude of carrier and reference signal are same gives maximum linear output. The MI $\doteq$ 1 for 50 Hz operation gives maximum output voltage from the input DC link..

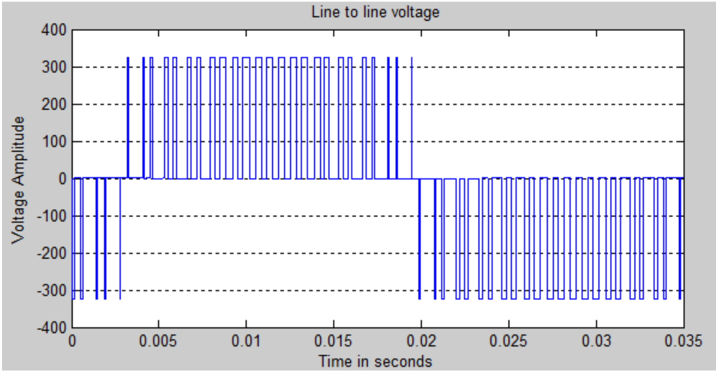

Figure 3.4: line to line voltage
scale x axis:1 cm = 5 millisecond, y axis:1 cm = 100 volt.

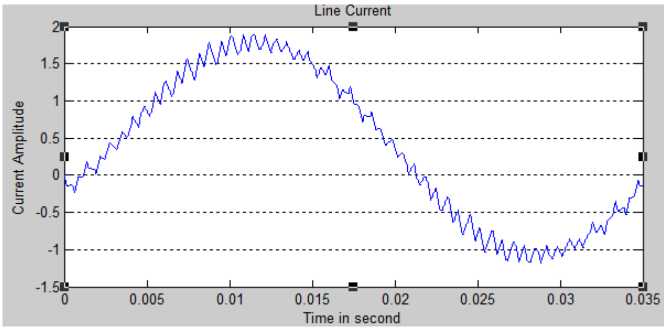

Figure 3.5: line current
scale x axis:1 cm = 5 millisecond, y axis:1 cm = 0.5 Ampere.

Due to the wide pulses the line current appear smooth but with some distortion. The harmonics contents are also lower due to high modulation frequency. 30 Hz input frequency modulation index becomes 0.6 due to adjustable inverter output voltage requires so peak amplitude of carrier increases than reference signal to gives adjustable output. The MI $\doteq$ 0.6 for 30 Hz operation due to adjustable output voltage received from the input DC link.

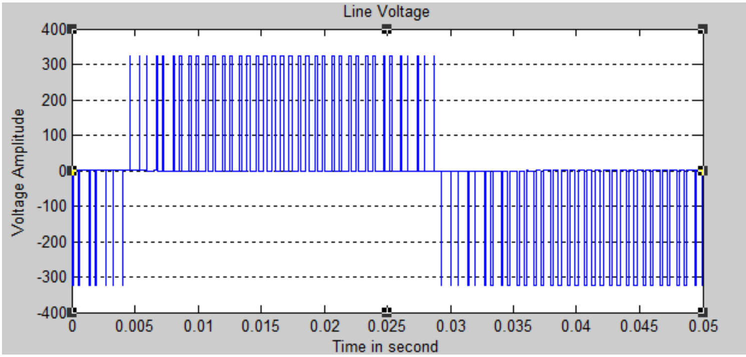

Figure 3.6: line to line voltage
scale x axis:1 cm = 5 millisecond, y axis:1 cm = 100 volt.

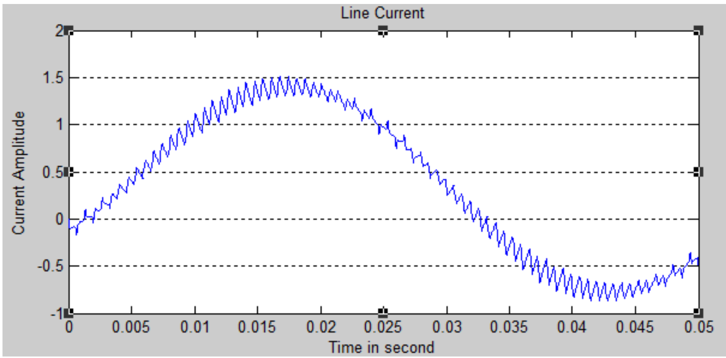

Figure 3.7: line current
scale x axis:1 cm = 5 millisecond, y axis:1 cm = 0.5 Ampere.

Pulses appear in the line voltage is narrow due to low modulation index and high modulation frequency to achieve the output voltage linear with the change in input frequency of the motor. Due to the narrow pulses the line current appear smooth. The harmonics contents are also lower due to high modulation frequency. 20 Hz input frequency modulation index becomes 0.4 due to adjustable inverter output voltage requires so peak amplitude of carrier increases than reference signal to gives adjustable output. The MI $\doteq 0.4$ for 20 Hz operation due to adjustable output voltage received from the input DC link.

3.1.1 Generating Torque

Maintain V/f ratio constant, the constant maximum torque at the shaft can be achieve. the simulation of constant torque up to base speed achieve shown in result. Above the base speed in constant power mode simulation results are carried out. The

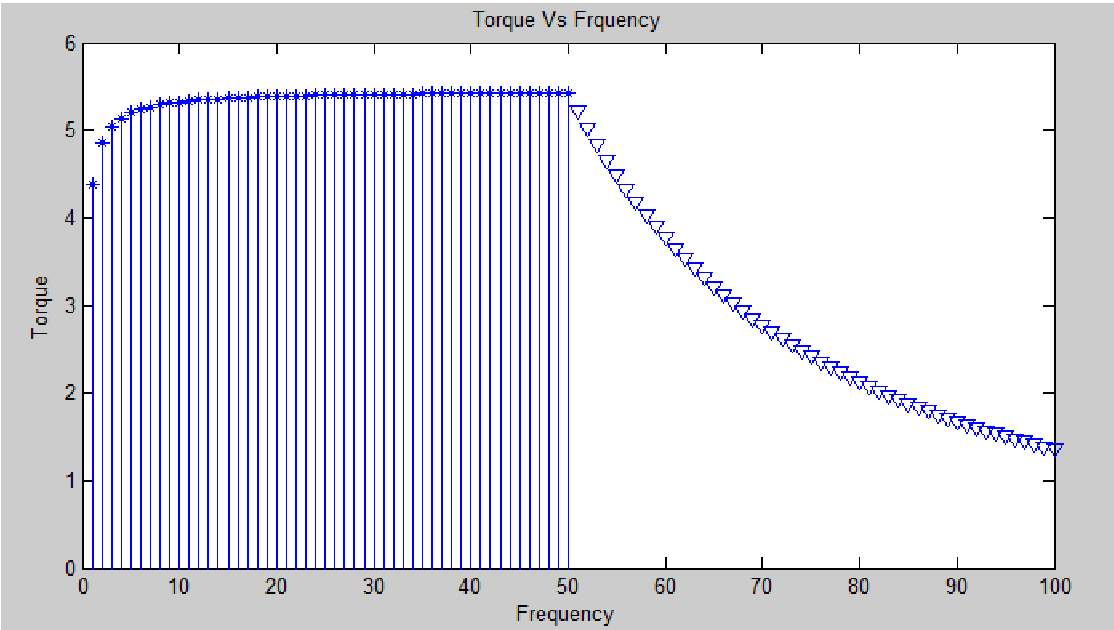

Figure 3.8: Torque Vs frequency
scale x axis:1 cm = 10 frequency, y axis:1 cm = 1 Nm.

calculation are taken on the basis of real motor parameters of three phase,1 Hp IM. This result shows that constant torque achieved above 6 Hz operation of VFD. Torque remains constant up to base speed. In this mode v/f ratio kept constant and torque measure for various frequency with adjustable voltages. Above synchronous speed in constant horse power mode torque decrease with increase in speed also shown.

3.2 Protection Circuit

3.2.1 Over Current Trip

Over current protection require for any motor to limit the excessive current flowing through it. There are many sensor available in market. Choosing CT for ac current sensing due to good accuracy with low cost. Inverter output goes to the motor terminal passing through CT and sense inverter output current. with the help of high resistance across CT placed to make current signal into voltage signal because of op-amps are voltage controlled device. precision diode and buffer are two characteristics used to perform over current protection in op-amp. ac voltage signal fed to precision diode and convert it into half dc signal. This signal goes to buffer and makes dc output.

Burden resistor connect across the CT to convert current signal into voltage signal. This voltage signal first smooth by placing parallel resistor and high value capacitor network and then fed to op-amp pin-3 precision diode. Diode connect pin-1 to pin-2 which is feed back path so output of precision diode fetch from pin-2 of op-amp1 with high gain to make them half cycle signal. output signal further smooth by placing another pair of parallel resistor and high value capacitor. this RC pair makes them ripple DC signal and then the signal goes to pin-10 of op-amp2 buffer op-amp and pin-9 and pin-8 connect with resistor. output comes from pin-8 of op-amp2 which is stiff dc in nature. This stiff dc voltage is compare with reference voltage to provide user define over current limit.

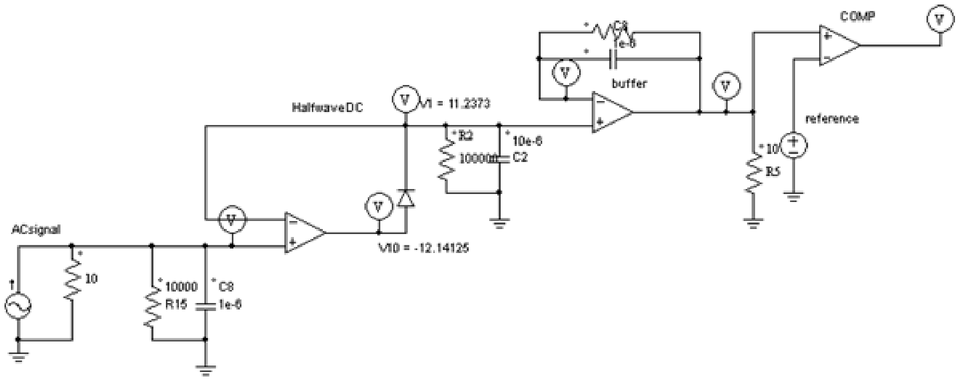

Figure 3.9: circuit diagram of over current protection circuit

In this circuit diagram 2 A current source is taken across the resistor and RC pair. this signal goes to op-amp circuit and another RC pair for smoothing the signal is shown. Their respective results are also shown.

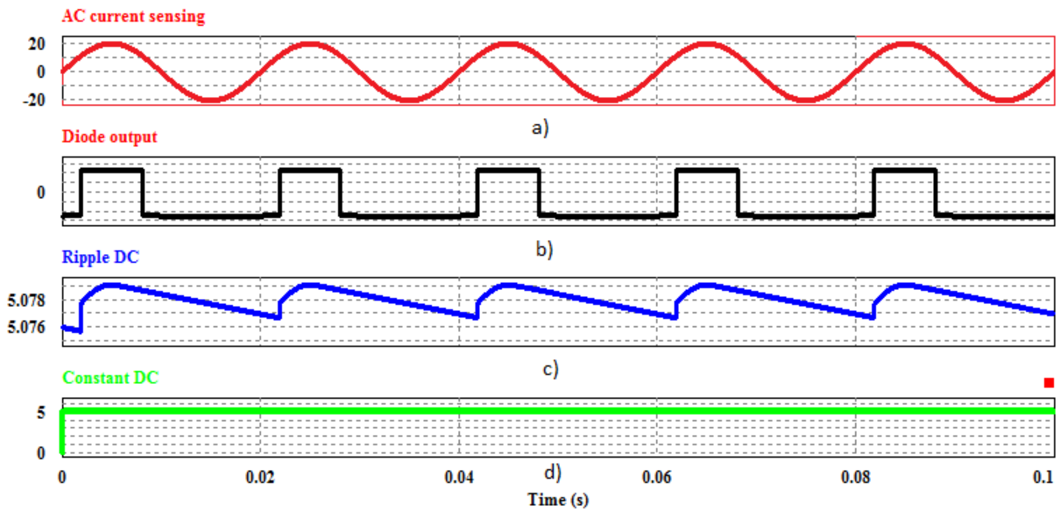

Figure 3.10: simulation Result a)AC current sense, b)Diode output, c)ripple current, d)DC output

scale x axis:1 cm = 20 millisecond, y axis:1 cm = Signal Amplitude.

3.2.2 Short Circuit Trip

Short circuit current protection is essential for any motor drive to make load, inverter healthy from the supply mains. There are many sensor available LEM, SN etc. in market. choosing LEM LA25-p sensor because of it gives 0.65 % accuracy to sense dc current at output side of DC link. This output current signal is convert into dc voltage signal by placing a suitable burden resistor in across output terminal of LEM and ground. voltage drop across the resistor is directly transfer current signal into voltage signal with form of some ripple dc and amplitude of this dc current in millivolt. Transform low level ripple dc signal to amplify and accurate dc signal placed op-amp characteristics as non inverting input. output dc signal have high amplitude depend upon gain A of non inverting op-amp.

$$A = 1 + \frac{R_f}{R_1} \tag{3.3}$$

Using LEM sensor gives 23 mV dc output signal as it detect 0.5 A in input side without op-amp . 640mv dc output signal with same current with op-amp above 125 V DC link. below 125V DC link LEM gives negative output voltage irrespective of current flowing through it.

Build up short circuit protection require +12V, -12V supply to give LEM sensor and op-amp circuit also. floating ground pin for measuring voltage across LEM and ground. this floating ground should connect with op-amp circuit to amplify DC signal.

Using non inverting characteristics of op amps build up the short circuit current protection circuit of AC motor. Connect a suitable burden resistance in across the terminal of LEM and ground to convert current signal to voltage signal.

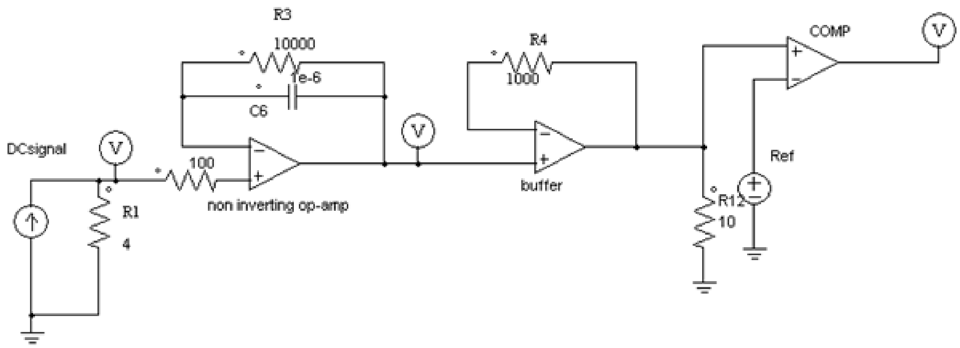

Figure 3.11: circuit diagram of short circuit current

This voltage signal is fed to pin-12 non inverting input of op-amp2. op-amp2 pin-14 output goes to pin-13 inverting input via parallel connection of high value resistor to amplify signal and gives pulsating high dc quantity. connect reasonable low value resistor in series with pin-13. This constant dc is compare with reference voltage and gives tripping signal.

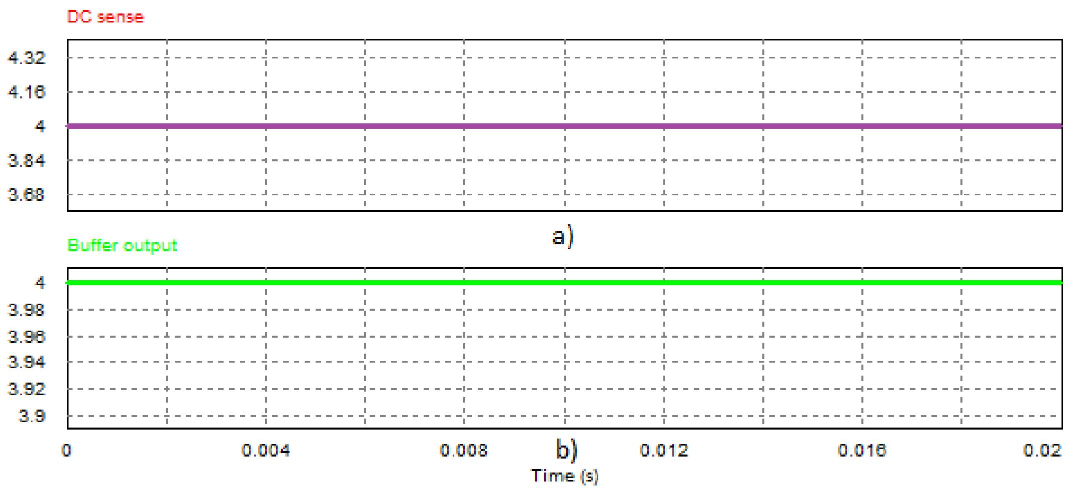

Figure 3.12: simulation Result a)DC sense, b)buffer output
scale x axis:1 cm = 4 millisecond, y axis:1 cm = Signal Amplitude.

3.2.3 Dead Band Circuit

Dead band circuit build for dead time require between the switching complementary pair of IGBT. The short circuit protection of the inverter IGBT lag provided by dead band circuit.

NOT and NAND gate IC require to build Dead band circuit. connecting two not Ic in series react like buffer Ic. The PWM pulse fed parallel to NAND gate pin-1 and same to buffer Ic. resistor and capacitor RC pair connect parallel to buffer Ic which gives specific delay time require for dead band circuit. The RC pair is connected in such a way that the charge time of the capacitor in series of resistor in micro second. so the signal at the pin of NAND gate arrived some micro second late then the original pulse of the function generator or controller. This signal fed to NAND gate pin-2, the NAND gate characteristic both the input are low then and then it gives high output.

according NAND gate logic output pulse at pin-3 received. For complementary same PWM pulse first fed to NOT gate and whole circuitry repeat for delay time require for dead band circuit. Then it fed to driver circuit to drive IGBT. Three phase circuit require 12 NOT gate IC, 15 NAND gate IC and 6 RC pair with specific r and c value which deliver specific dead time to the circuit. Three phase circuit require three pulses gives to dead band circuit content three lags of NOT and NAND Ic from which six complementary pulses carried out with specific dead time.

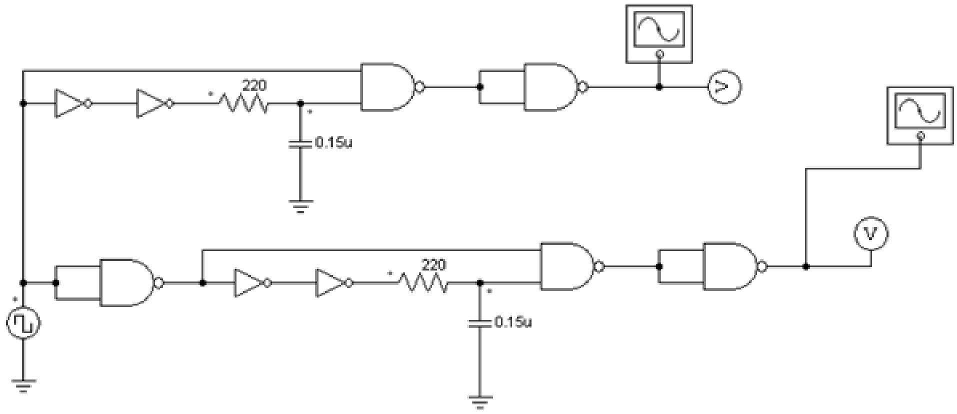

Figure 3.13: Schematic of Dead band circuit

In dead band circuit square wave high frequency pulse is use as a input. this pulse is fed to buffer and RC pair to insert particular dead time adjust in the circuit. for maximum output concern dead time of the circuit is very low up to 3 microsecond.

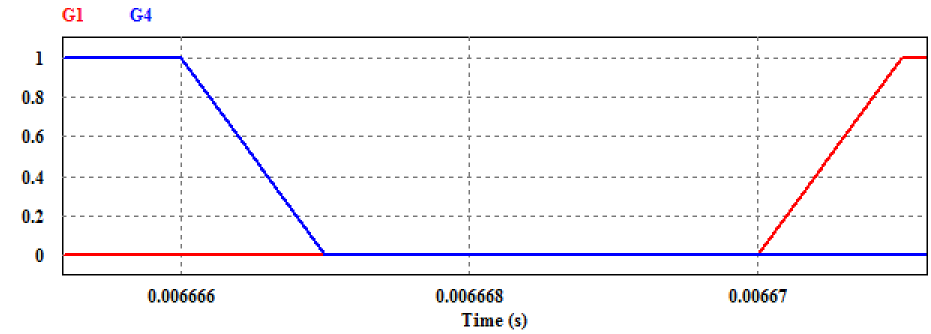

Figure 3.14: 3 microsecond Dead time between complementary pair of a) G1 and b) G4

scale x axis:1 cm = 2 microsecond, y axis:1 cm = Signal Amplitude 0.2 V.

Chapter 4

MICRO CONTROLLER BASED SPWM SIGNALS

4.1 Algorithm

In order to accomplish these major tasks PIC16f877 needs to be configured, monitor input signal, control and synchronize various internal modules such as oscillator and clock generator and configuration bits, ADC, PWM Unit, TIMER and I/O ports.

The major tasks of the power controller are listed below.

1) Set parameters limits as over current, short circuit current and v/f characteristics through manually buttons.

2) For SPWM generation press start button.

3) Give in between 0-5V to 10 bit ADC pin to perform desire range in between 0-50Hz frequency operation of SPWM inverter.

4) fetch and read value from ADC pin to calculate parameters.

5) Calculate modulation index and amplitude scaling factor for triangle wave

6) fetch and read sine wave look up table for desire frequency.

7) value read and shifted to obtain 3 phase sine wave from one sine look up table.

8) read triangular wave look up table and multiply with amplitude scaling factor.

9) compare 3 phase sine with triangular wave to obtain adjustable output voltage of SPWM inverter

10) 6 complementary pulses are carried out through port pin with specific dead band.

11) these 6 pulses are used to trigger IGBT through TLP250 driver Ic.

12) Stop PWM generation in case of Fault signal or stop button.

4.2 Flow Chart for Generating SPWM Pulses

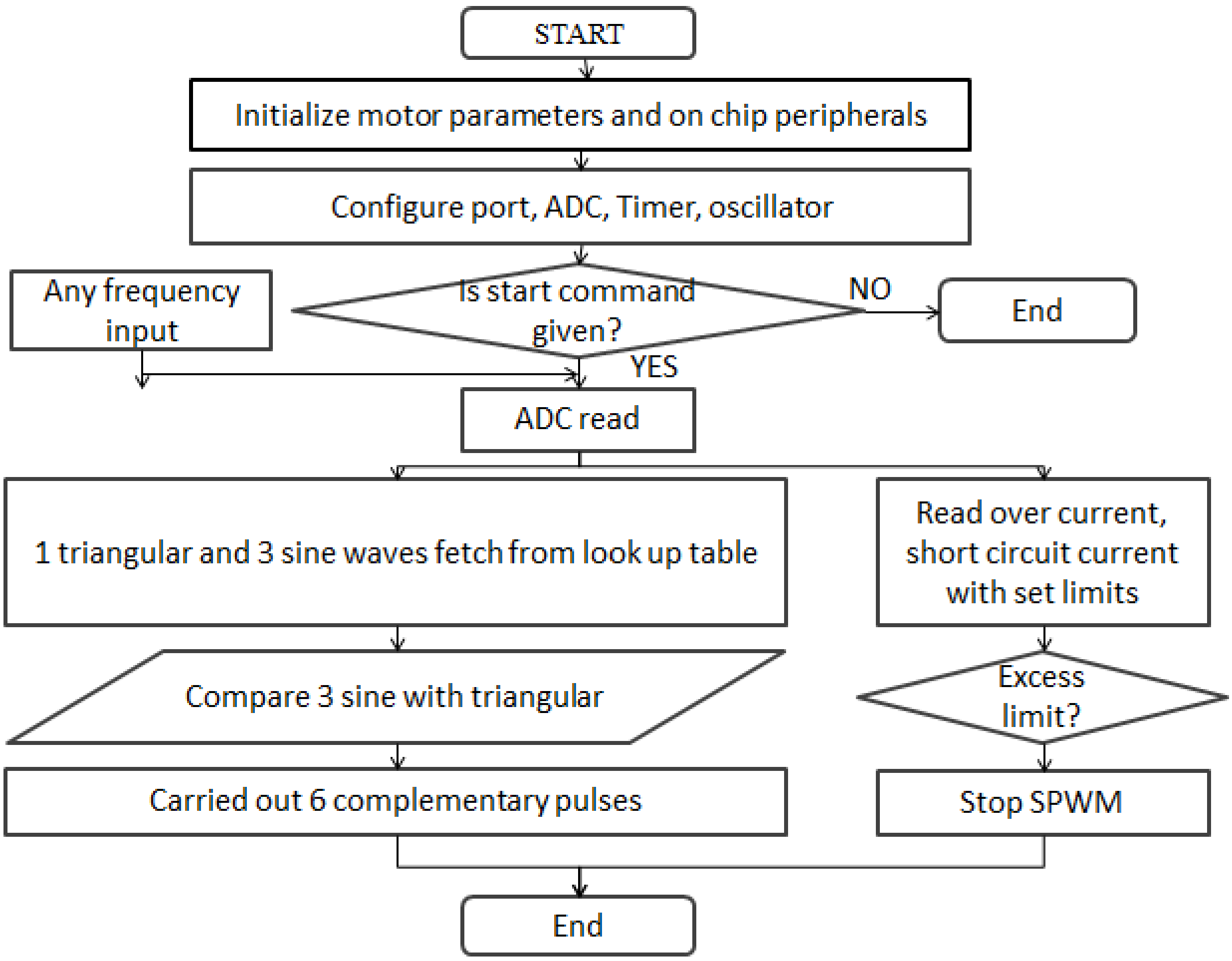

Figure 4.1: Main flow chart

4.3 Programming

4.3.1 ADC Initialization

The Analog to Digital(A/D) Converter module has eight inputs for the 40-pin devices. PIC 16f877 micro controller have in built 10 bit ADC port. 10 bit ADC means value store up to 1023 or 2^{10}. 0-5V input at ADC pin it can be digitalize or convert to number and store in the register. This values are further use for calculation of count timer, frequency input as per programme algorithm.

The A/D module has four registers.

1) A/D Result High Register (ADRESH)

2) A/D Result Low Register (ADRESL)

3) A/D Control Register 0 (ADCON0)

4) A/D Control Register 1 (ADCON1)

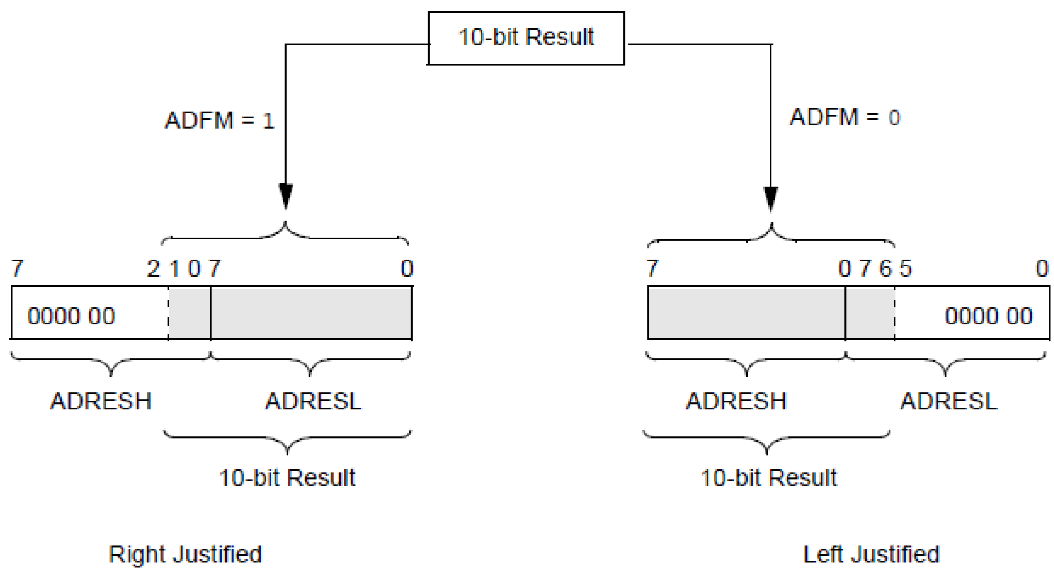

Figure 4.2: 16 bit ADC registers

PORTA is a bidirectional port. The corresponding data direction register is TRISA. Setting a TRISA bit 1 will make the corresponding PORTA pin an input. Clearing a TRISA bit 0 will make the corresponding PORTA pin an output. Reading the PORTA register reads the status of the pins, whereas writing to it will write to the port latch.Other PORTA pins are multiplexed with analog inputs for both the A/D converters and the comparators. The operation of each pin is selected by clearing/setting the appropriate control bits in the ADCON1 registers. The TRISA register controls the direction of the port pins even when they are being used as analog inputs. The user must ensure the bits in the TRISA register are maintained set when using them as analog inputs.

From the pin configuration 2 pin AN0 is used to perform Analog to digital convertor(ADC). PIC 16f877 is 8 bit micro controller, it can not store directly 10 bit data in ADC Registers. so data from ADC channel stored in ADC Result ADRESH:ADRESL register pair is the location where the 10-bit A/D result is loaded at the completion of the A/D conversion. This register pair is 16 bits wide. The A/D module gives the flexibility to left or right justify the 10-bit result in the 16-bit result register.

This results are can be used separately by using one ADRESH or ADRESL register which contain 8 bit data from the ADC channel. In ADRESL register contain lower 8 bit data and ADRESH contain higher 8 bit data which is shown in figure. This channel is used for calculation due to it represent Voltage signal in terms of number which is used for counting input frequency. From the input frequency the inverter output voltage, modulation index, Amplitude scaling factor of carrier wave can be calculate. then array logic and time delay are performed.

For PIC programming MP LAB IDE tool suit and MICRO C are used to programme implementation. PIC kit tool used to read,write and erase the programme hex file in PIC IC through general pic loader use for loading hex file.

4.3.2 Sine Look up Table

Making sine wave look up table means storing sine values in array in program memory by taking samples per cycle. Taking samples per cycle means taking values of sine wave per cycle.

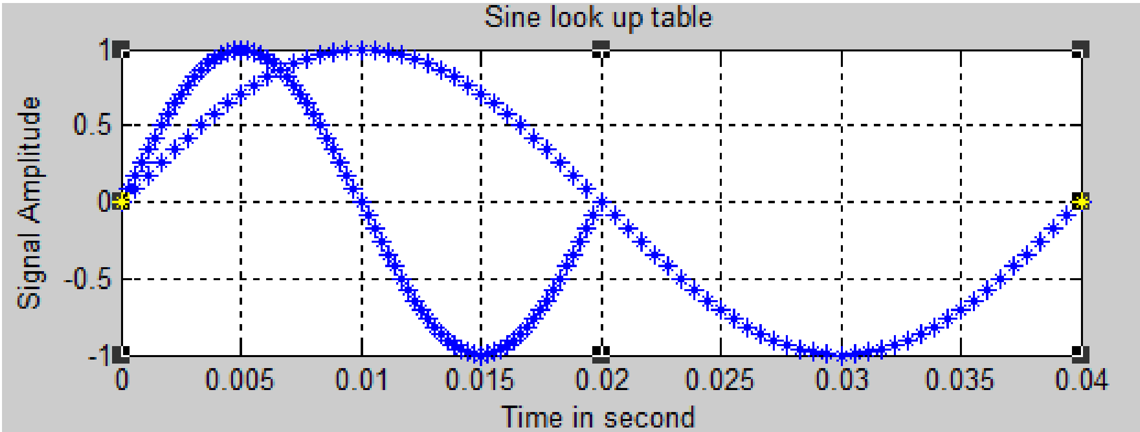

Figure 4.3: Sine look up table
scale x axis:1 cm = 5 millisecond, y axis:1 cm = 0.5 V Signal Amplitude.

Any frequency can be represent by taking samples of sine values with specified time interval which is shown in figure. Values are same for 50Hz sine wave and 25Hz sine wave with equal samples per cycle. This specific time interval use for generating desire sine frequency operation of SPWM inverter.

4.3.3 Triangular Look up Table

Making triangular wave look up table means storing triangular values in array in program memory by taking samples per cycle.

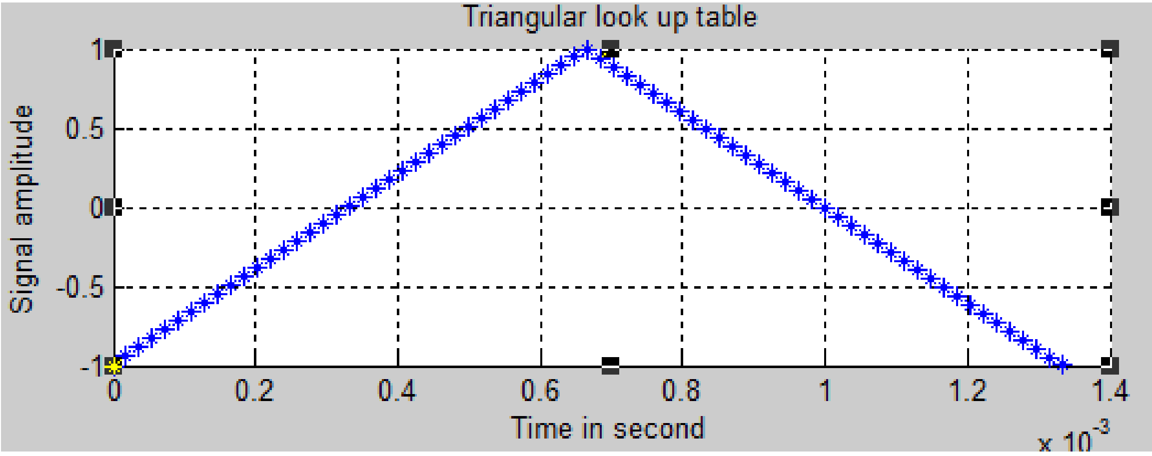

Figure 4.4: Triangular look up table
scale x axis:1 cm = 0.2 millisecond, y axis:1 cm = 0.5 V Signal Amplitude.

Carrier frequency 750 Hz are high compare to reference frequency. 50 Hz reference wave completing one cycle in every 20 ms and at that time carrier wave completes 15 cycles. From this carrier wave frequency moves 15 time faster than sine wave. every sample per cycle jump and fetch respective value carry by specific number of carrier sample from the triangular look up table and compare with sine sample from the sine look up table. Taking high sample rate the output pulses coming from the comparison of carrier and reference wave are more precise. Comparing 0-50Hz sine frequency with carrier frequency, the values store in triangular array are jump on specific array number at specific values of sine look up table to achieve real time SPWM signal from varying reference frequency.

Chapter 5

SIMULATION OF SPWM GENERATION

5.1 PIC Simulation

The simulation is carried out in MP Lab IDE tool suit. As shown in flow chart the sine and triangular signals are store in variable resister in PIC as array form. The sine signal and triangular signal value store in array are compare with each other and give pulses shown in figure. Simulation run on 20 MHz crystal frequency. 1 Instruction cycle made of 4 clock cycle. so Instruction cycle operate at 5 MHz. At 20 Mhz crystal frequency the PIC Ic can perform more than 4 lakhs instruction cycle per second.[9]

Samples are fetch per cycle which stores in array. The figure shows samples which are not in continuous mode but in discrete mode that values are store at a increment of specific time between two values of signal.

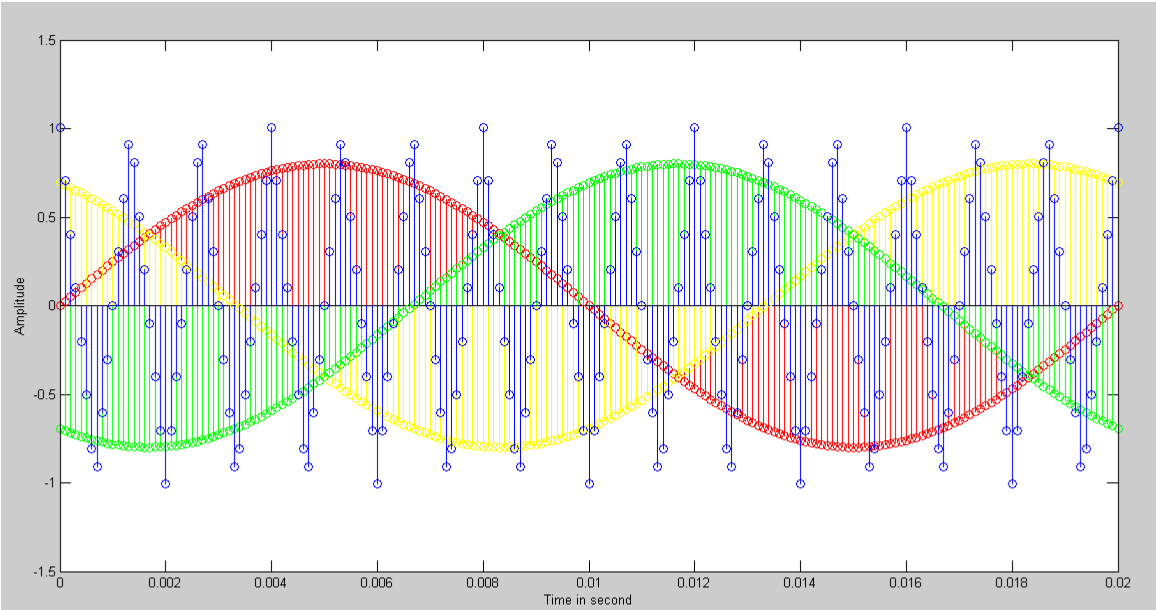

Figure 5.1: Sine and triangular sample
scale x axis:1 cm = 2 millisecond, y axis:1 cm = 0.5 V Signal Amplitude.

In continuous loop there are if and else condition for generating 6 complementary pulses with dead band from comparing sine and triangular values store in array by inserting specific delay time in cycle to require particular frequency performance of the drive or say to control output frequency of the drive. The triangular signal is multiply with scaling factor such that the modulation index very with frequency according to the adjustable linear output voltage.

In PIC 16f877 has four Port A, B, C, D. Each has eight pin which have specific register to perform particular task. Port A has 8 pin ADC channel. Port B and C are 8 bit wide and can be use for the input and output port to communication of peripherals with PIC and also it can be enable by perform interrupt function. In simulation using port B as output by selecting TRISB bit 0. the pin of RB0 and RB1 from the port B are used for generate complementary pulses of SPWM. other RB2 to RB5 pin are also use for six SPWM pulses.

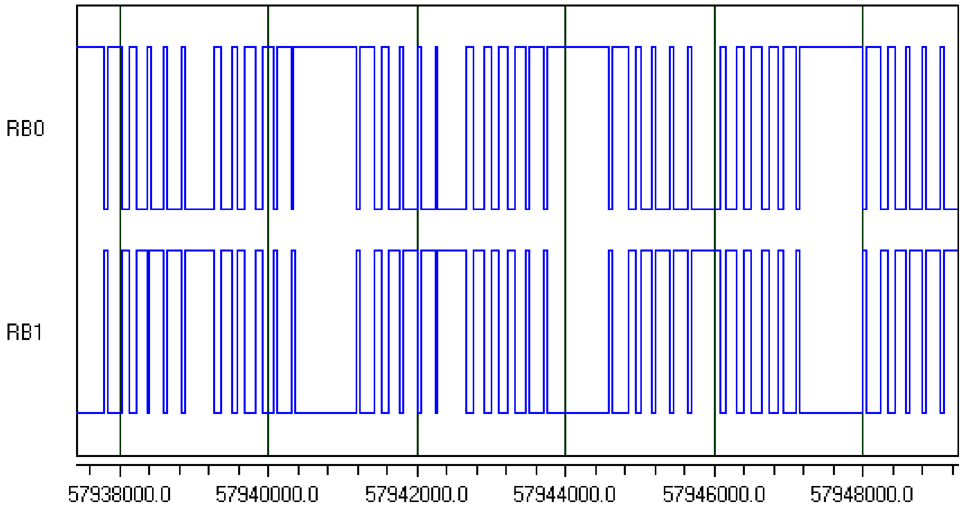

Figure 5.2: Simulation result complementary of SPWM pulses for MI =0.8 scale x-axis:0.4 ms/2000 Instruction cycle, y-axis:Signal Amplitude.

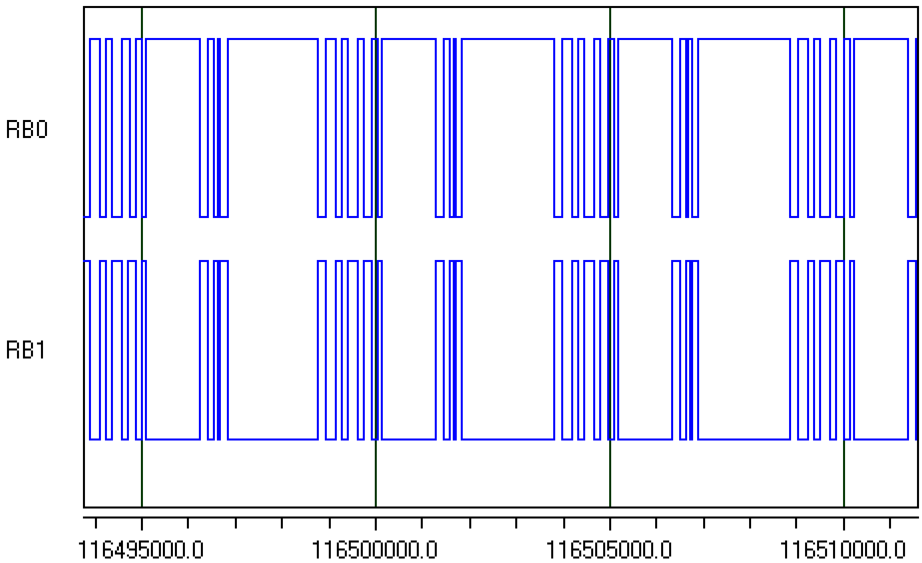

Figure 5.3: Simulation result complementary of SPWM pulses for MI = 1 scale x-axis:1 ms/5000 Instruction cycle, y-axis:Signal Amplitude

Chapter 6

HARDWARE IMPLEMENTATION

6.1 Current Sensors

There are many types of current sensors available in the market. when current in the circuit is too high to apply directly to measuring instruments, so current sensor used to produce reduced current accurately proportional to the current in the circuit, which can be conveniently connected measuring instruments.

1) CT

2) Hall effect sensor

3) Resistor

4) Rogowski coil

(1) CT-current transformer is used for measurement of alternating electric currents. The operation of a transformer is based on two principles of the laws of electromagnetic induction. An electric current through a conductor, produces a magnetic field surrounding the conductor, and a changing magnetic field in the vicinity of a conductor induces a voltage across the ends of that conductor. CT are commonly used in

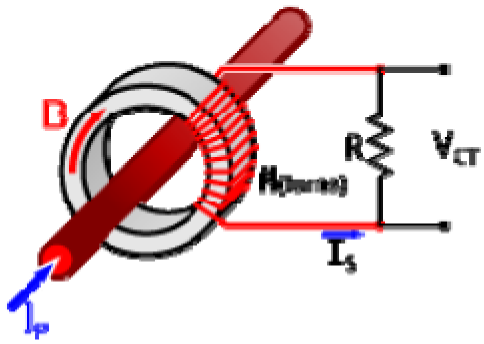

Figure 6.1: Current sense by CT

metering and protective relays in the electric power industry and commercially. CT has a primary winding, a magnetic core and secondary winding.

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} = a \tag{6.1}$$

Winding turn ratio of CT is kept 1:1200 means 1200 ampere primary side flowing 1 ampere in secondary side with isolator use as transformer.

Table I: CT Sensor rating

Sr no.	**Parameters**	**Values**
1	Range	10 A AC
2	Accuracy	1%
3	Temperature	85 C
4	Supply	Not needed
5	Conversion Ratio	1:1200
6	Secondary nominal current	83 mA
7	Measuring resistance	120 Ω

(2) The Hall effect is the production of a voltage difference across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current. It was discovered by Edwin Hall in 1879.

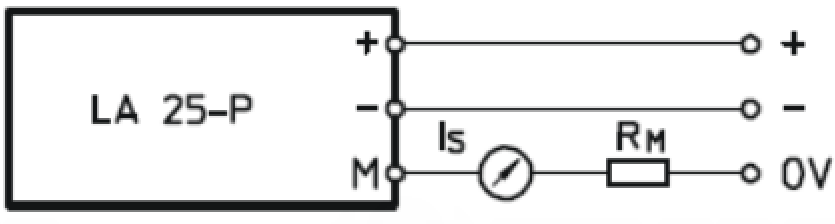

Figure 6.2: Connection circuit of LEM

The Hall coefficient is defined as the ratio of the induced electric field to the product of the current density and the applied magnetic field. It is a characteristic of the material from which the conductor is made, since its value depends on the type, number, and properties of the charge carriers that constitute the current.

Table II: LEM Sensor rating

Sr no.	**Parameters**	**Values**
1	Range	25 A DC
2	Accuracy	0.95%
3	Temperature	70 C
4	Supply	+12, -12 V
5	Conversion Ratio	1:1000
6	Secondary nominal current	25 mA
7	Measuring resistance	110 Ω

6.2 Power Supply

3 phase fixed AC supply is given to DC link which have parallel two capacitor through 6 diode or 3 phase full wave rectifier bridge. Build DC link circuit and tested on rheostat load as it gives high DC output voltage as shown in figure with input of 230V AC. This DC voltage fed to inverter module and convert it into AC for run ACIM.

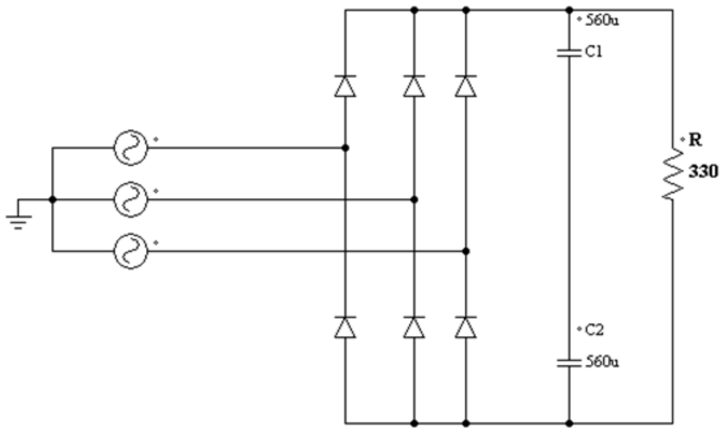

Figure 6.3: Schematic diagram of DC link

The voltage source inverter that use SPWM switching techniques have a DC input voltage (VDC) that is usually contents low ripple or constant in magnitude output. The inverter job is to take this DC input and to give AC output, where the magnitude and frequency can be controlled.

This DC link tested on 530 Ω rheostat with current capability up to 2 A which shows 325 V output DC.

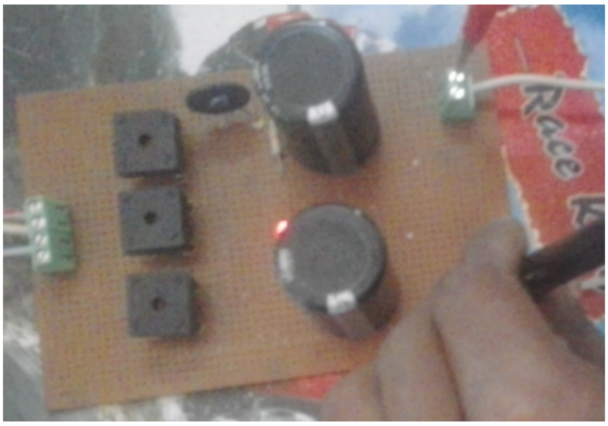

Figure 6.4: DC link voltage with R load

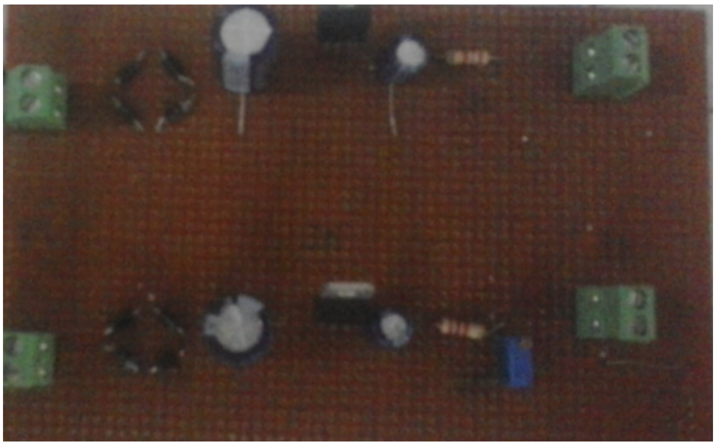

Figure 6.5: Supply for op-amp circuit

To drive control circuit as it contain op-amps for sensing over current and short circuit current and also for Driver and dead band circuit it require smooth DC supply. making +12, -12, 5V DC supply for control circuit.

6.2.1 Driver Circuit

Driver circuit gives require voltage gate pulses to trigger IGBT. 6 TLP250 ICs are use to drive IGBT which is shown in figure. PWM pulses fed to pin-2 and return or ground at pin-3 of TLP250. Vcc voltage is given at pin-8 and ground pin-5 are connected through capacitor to draw sufficient current for triggering IGBT. output pulses received at pin-6 which are fed to gate terminal of IGBTs. 12 V output from the pin-6 is shown in the figure.

Figure 6.6: Hardware circuit of TLP250

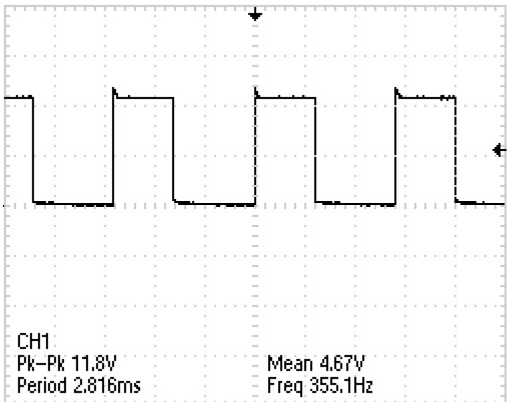

Figure 6.7: 12 V output from Driver circuit
scale x axis:1 cm = 1 millisecond, y axis:1 cm = 5 V.

6.3 Hardware Protection Setup

In this setup DC Link used for give dc voltage to load through from LEM sensor which measure current passing through it with the use of op-amp circuit shown in figure. Require supply for op-amp are also shown. In op-amp circuit two input are

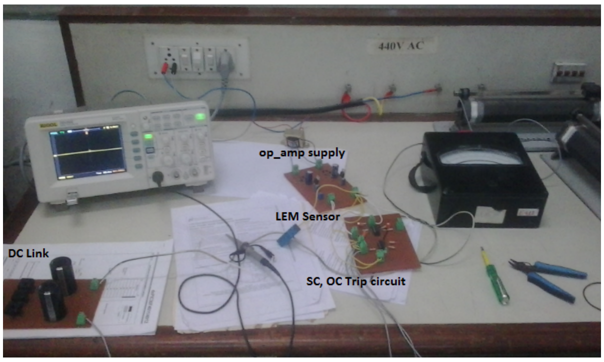

Figure 6.8: Hardware setup

taken one is coming from CT for over current protection and second from LEM sensor for short circuit protection. CT carry sinusoidal signal which is convert in to dc by op-amp circuit and LEM signal carry ripple with millivolt signal with smooth and amplify by op-amp circuit.

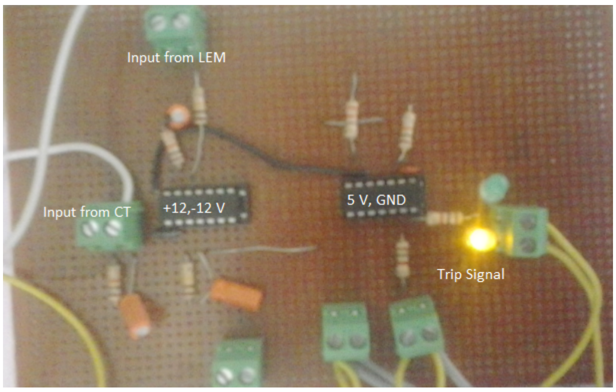

Figure 6.9: OC, SC current sensing circuit

The LEM Sensor have three terminals in which two require +12 V,-12 V power supply to its terminals and third is output sensing current with respect to ground. The result 23 millivolt carried out at 0.5 A dc current which is measure by LEM. DC

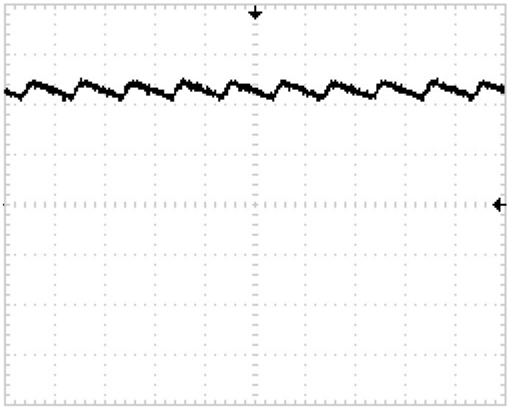

Figure 6.10: Current sense by LEM Sensor
scale x axis:1 cm = 10 millisecond, y axis:1 cm = 10 millivolt.

ripple voltage signal is fed to non inverting amplifier in which it can amplify signal easily with selective gain. then it goes to buffer which make its output constant or ripple free. Using op-amp the 0.5 A dc current amplify up to 634 mv.

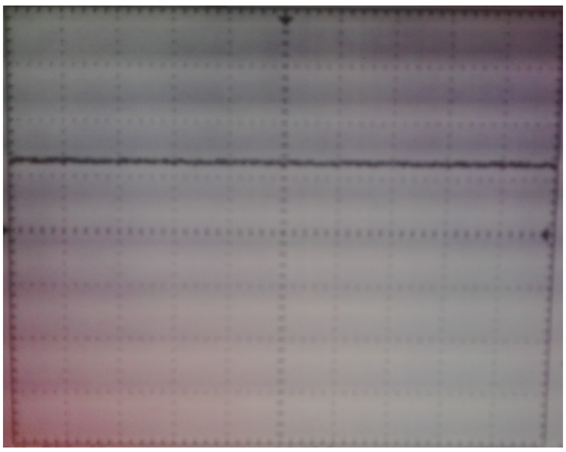

Figure 6.11: DC sensing current amplify using op-amp
scale x axis:1 cm = 10 millisecond, y axis:1 cm = 500 millivolt.

The CT has its own winding resistance, when current passing through it is directly convert in signal which is proportional to the resistance connect across it legs. Connect high resistance across CT leg it accurately measure 2 V with input of 1.8 Ampere. This AC signal is first fed to precision diode in which signal is converted to half wave

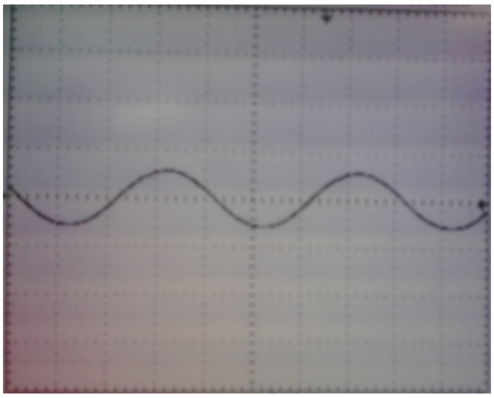

Figure 6.12: Over current sense by CT
scale x axis:1 cm = 5 millisecond, y axis:1 cm = 5 Volt.

signal then this signal goes to RC pair for smoothing the signal. Diode are conduct when signal is higher than its previous value and also in half cycle.

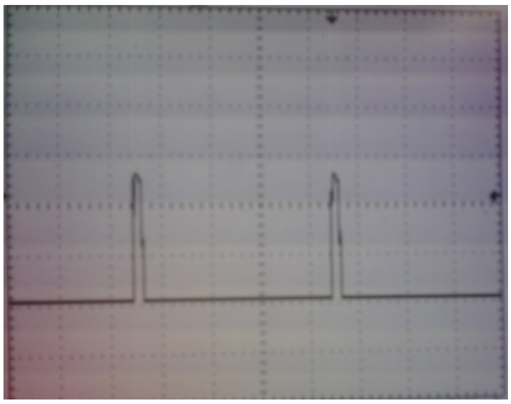

Figure 6.13: Output of precision diode
scale x axis:1 cm = 5 millisecond, y axis:1 cm = 5 Volt.

Combination of RC pair and buffer characteristics makes it constant DC signal. By connecting proper value of RC pair and buffer characteristics, smoothing signal can be done as it gives 4 V output at 1.8 A current.

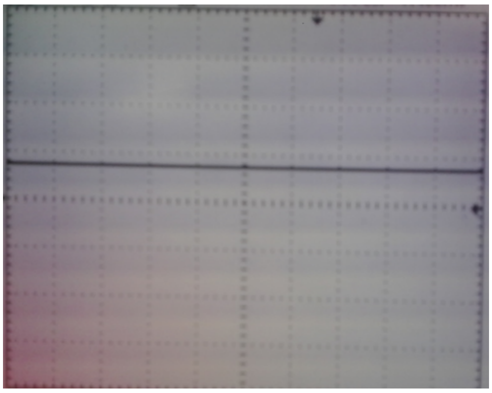

Figure 6.14: Constant Dc output
scale x axis:1 cm = 5 millisecond, y axis:1 cm = 5 Volt.

6.3.1 IGBT Module

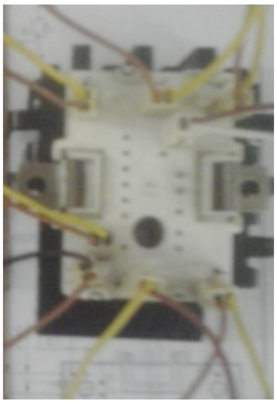

Figure 6.15: IGBT module

6.3.2 Dead band Circuit

Dead band circuit proper values of RC require due to capacitor charging and discharging time made delay in circuit for generating pulses. select RC pair as charging time is low but specific for every combination. In PIC dead band can be generated by

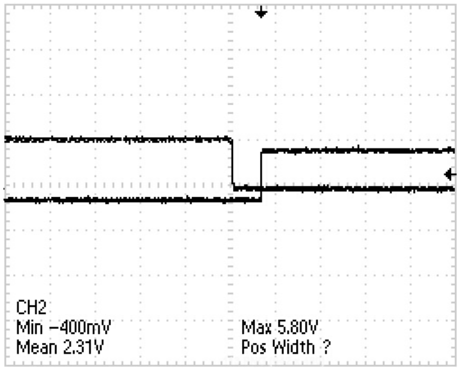

Figure 6.16: 3 us achieved from dead band circuit
scale x axis:1 cm = 5 microsecond, y axis:1 cm = 5 Volt.

apply delay, but for large delay process of SPWM generation it is difficult to achieve less than 20 us dead time. Here 20 us dead time generated in PIC 16f877.

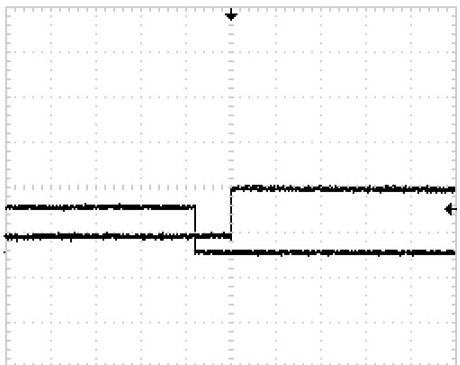

Figure 6.17: In built 20 us dead band in PIC
scale x axis:1 cm = 20 microsecond, y axis:1 cm = 5 Volt.

6.4 PIC 16f877 Module

Build module of 16f877 on Printed Circuit Board shown in figure. PIC operated on 11.0592 MHz crystal frequency which is applied at pin 13-14. Use 7805 IC which convert 9 V battery supply to 5 V to apply PIC. one switch is use to start to perform programming. In PIC 16f877 SPWM signals are generated in built by comparison of three sine and one triangular signal carry by array form with specific time delay. The generated pulses with delay gives variable frequency output according pulse width of the pulses change require at the output. output pulse are carried out at port B from pin RB0 to RB5 as six SPWM are able to generate.

Figure 6.18: Hardware Module of PIC 16f877

This result is shows the SPWM pulses at port B pin RB0, RB3 have complementary signals at MI = 1.

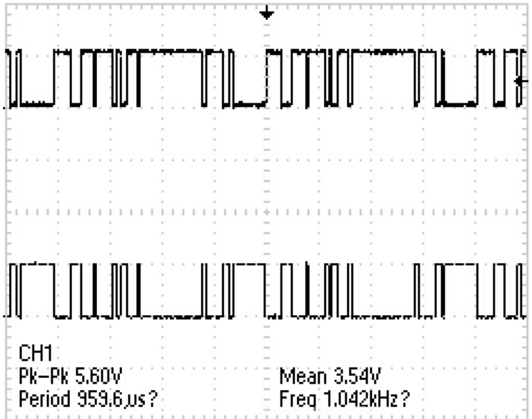

Figure 6.19: SPWM output generated by PIC with MI = 1
scale x axis:1 cm = 5 millisecond, y axis:1 cm = 5 Volt.

This result is shows the SPWM pulses at port B pin RB0, RB3 have complementary signals at MI = 0.8

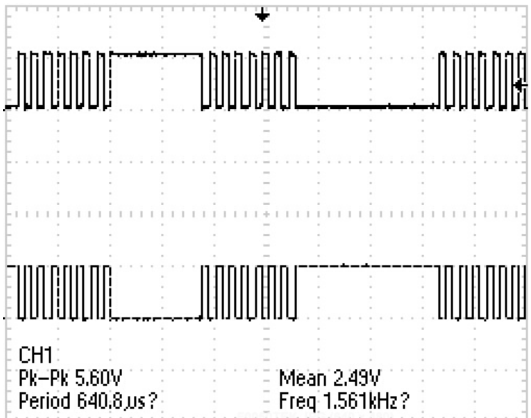

Figure 6.20: SPWM output generated by PIC with MI = 0.8
scale x axis:1 cm = 5 millisecond, y axis:1 cm = 5 Volt.

Chapter 7

CONCLUSION AND FUTURE WORK

7.1 Conclusion

Three phase inverter has been implemented and tested for V/f control of induction motor drive. Three phase SPWM pulse has been generated in PIC16F877 microcontroller and three phase gate drivers IC TLP250 is used to drive IGBT Module. The three phase Sinusoidal PWM signal with dead time control circuits has been generated in a single board microcontroller, which makes the system reliable and compact. Over current and short circuit current are easily sense with good accuracy by CT and LEM. Fabrication of power protection circuit has been implemented on op-amp which gives satisfactory results. Fabrication and testing of power module, protection circuits, and PIC 16f877 microcontroller are done. Three phase SPWM technique implemented in PIC 16f877 controller without any external and auxiliary circuitry and result are satisfactory with variable modulation index.

7.2 Future work

The algorithm can be modified for smooth starting and stoping for IM. In application can be modify for over current,short circuit current trip by programming. Modulation index very by user setting manually.

In project work can be modify for higher power rating of IM and control setting adjust according to appropriate v/f ratio. It needs the further enhancement of the system for large horse power motor application.

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