**CONTENTS**

**Page**

Acknowledgement 1

Certificate 2

Contents 3

List of Figures 5

Abstract 6

1. Introduction 7
2. Methodology and procedure identification 8
3. Insulated Gate Bipolar Transistor (IGBT) 9

3.1 Advantages & disadvantages of IGBT 9

3.1.1 Advantages 9

3.1.2 Disadvantages 9

3.3 Working Principle 10

3.2 Latch-up in IGBT 10

3.4 IGBT characteristics 11

3.4.1 Static I-V characteristics 11

3.4.2 Transfer characteristics 12

3.4.3 Switching characteristics 12

4. PWM

4.1 Introduction

4.2 Objective

4.3 PWM methods

4.4 Sine PWM

4.5 Three phase PWM

5. Simulation 5.1 Introduction

5.2SIMULINK as a tool for system simulation

5.3Simulation setup

5.4Simulation Results

6. PCI 1710

6.1 Introduction

6.2 Main features

6.3 Specification

6.3.1 Analog input

6.3.2 Analog output

6.3.3 Digital input

6.4 Image

6.5 Pin diagram

7. IR 2110

7.1Introduction

7.2Features

7.3Pin diagram

7.4Typical connection

6. Experimental setup

6.1 Introduction

6.2 Inverter design

6.3 Power circuit

6.4 Driver circuit

6.5 Power supply

6.6 Conclusion and future scope

6.7 Experimental setup picture

Conclusion 38

References 40

**LIST OF FIGURES**

**Figure Page**

Figure 3.1 Structure of IGBT 10

Figure 3.2 Static I-V characteristics of IGBT 11

Figure 3.3 IGBT Transfer Characteristics 12

Figure 3.4 Switching Characteristics of IGBT 13

Figure 4.1 Output voltage produced by the VSI 15

Figure 4.2: Three-phase VSI topology 16

Figure 4.3 Valid switch states for a three-phase VSI 16

Figure 5.1 Principle of PWM generation 19

Figure 5.2 Wave form of Sine PWM 19

Figure 5.3 Pulse-width modulations 20

Figure 5.4 Waveforms of three-phase sine PWM inverter 21

Figure 5.5 Three phase inverter 22

Figure 5.6 Switching states of IGBT 22

Figure 6.1 PWM generation subsystem 24

Figure 6.2 Complete simulation model in Matlab Simulink 25

Figure 7.1 Overall block diagram of the project 26

Figure 8.1 PCI 1710 28

Figure 8.2 Pin diagram of PCI 1710 29

Figure 9.1 Pin diagram of IR2110 30

Figure 9.2 Circuit of IR 2110 31

Figure 10.1 Overall block diagram of the project 32

Figure 10.2 Power circuit of inverter 34

Figure 10.3 35

Figure 10.4 Generated PWM on DSO

Figure 10.5 Hardware of driver circuit

Figure 10.6 Experimental Setup 37

**ABSTRACT**

Pulse Width Modulation (PWM) technique is proven to be an effective way of controlling speed of induction motor. This paper presents the development of the algorithm to perform the PWM operation using Matlab Simulink, which then was interfaced with the actual induction motor using the Matlab/Real time workshop. The speed of induction motor was controlled through the I/O interface circuit and Simulink; hence allowing the real time control. The control algorithm was also developed to enable the rotational direction switching. These functions are successfully carried out in Matlab simulation and in actual model. This method provides a means to control speed of induction motor remotely using a host PC, which may be connected through local area network or wireless network.

1. **INTRODUCTION**

Pulse Width Modulation (PWM) technique is an effective way of controlling the speed of induction motor, and thus allowing the motor to be applied in the area requiring speed control. Available techniques to control the speed of induction motor are: varying the slip by changing rotor resistance or terminal voltage and varying synchronous speed by changing number of poles or supply frequency. Changing rotor resistance requires wound-rotor induction motor and any resistances inserted to the rotor circuit will reduce the efficiency of the machines. Changing terminal voltage has limited range of speed control. Changing the number of poles requires a motor with special stator windings. The best method is to change the electrical frequency because it is applicable to any types of induction motor. The speed of induction motor depends on the rate of rotation of its magnetic fields or the synchronous speed, which is directly proportional to any change of electrical frequency . PWM technique is used to control the electrical frequency of the 3-phase voltage supplied to the motor from the Insulated Gate Bipolar Transistors (IGBTs) inverter circuit, hence allowing the speed to be varied with respect to the frequency of the reference signal, input to the PWM signal generator. The Real time workshop from Math Works is an industrial PC for use in performing real-time analysis, simulation, and testing of control systems and digital signal processing (DSP) systems. The box works with Real time workshop software, a host-target environment that lets users connect models created in Math Works design tools such as Simulink, Matlab, and Real-Time Workshop, to physical systems, and execute them in real time . The Matlab/Real time workshop was used in some application other than induction motor speed control .This paper presents the development of the algorithm to perform the PWM operation using Matlab Simulink. Then the Matlab/Real time workshop was used to interface with the actual induction motor, finally through the I/O interface circuit and simulink slider gain, the speed of induction motor was controlled. The control algorithm also developed to switch the rotational direction of the motor, i.e. forward or reverse direction.

**2. METHODOLGY AND PROCEDURE IDENTIFICATION**

The first stage was to develop the algorithm to perform the PWM and to execute simulation in Matlab Simulink environment. The process started with developing the PWM signal generator. The set point value was represented by *Signal* block. The fundamental principle of AC machine operation is that if a balanced three-phase set of voltages, each with equal magnitude and shifted in phase by 0º, -120º and 120º respectively, the magnetic field produced inside the stator winding will rotate in the same direction of the phase rotation. If any two of the three-phase voltages are swapped, the magnetic field will reverse its rotational direction . If the phase input signal for three-phase PWM generator is in order of 0º, -120º, 120º, the rotational direction can be switched by changing the phase sequence order to 0º, 120º, and -120º. In the PWM generator block, the phase block was divided into two blocks, which are *Forward* and *Reverse*. The *Forward* block has the value of [0 -2\*pi/3 2\*pi/3], while the *Reverse* has the value of [0 2\*pi/3 -2\*pi/3], where the sequence for phase B and C was swapped Then, the PWM signal generator was connected to the IGBTs’ model and induction motor’s model in Matlab Simulink. The simulation proved that the developed algorithm could control the speed of induction motor. The second stage was to implement the PWM inverter model on actual IGBT module and actual induction motor. Using the control algorithm in the Matlab Simulink was linked through Real-Time Workshop to the hardware. After the connection was established, PWM signal was connected in real time to the IGBTs module. The IGBT module consists of six IGBTs. The module also contains electronics circuit that isolates the gate of IGBTs and protects the IGBTs against overheating, overvoltage, and over current. The controllable DC voltage was supplied to the IGBT module. There is a capacitor in the module, which is used to maintain a smooth DC voltage in spite of the current pulsation produce by the IGBTs .The Real time workshop was used to interface between the host PC and the IGBT inverter circuit. Communication link uploaded the data from the host PC to the Real time workshop. I/O card at the target PC executed the control algorithm by providing the necessary signal to the IGBT inverter circuit. The switching sequence of the IGBTs followed the necessary signal of PWM technique that has been set in the control algorithm, thus converted the DC source to the PWM voltage output for the induction motor. There were two options to provide the input frequency to the control signal.. The input/output blocks were included into the Matlab Simulink model to enable the connection of the actual motor, IGBTs and keypad to the host PC.

**3. INSULATED GATE BIPOLAR**

**TRANSISTOR (IGBT)**

We are using Insulated Gate Bipolar Transistor (IGBT) for conversion of AC to controlled DC in our work. IGBT has been developed by combining into it the best qualities of both BJT and MOSFET. IGBT is also called Metal Oxide Insulated Gate Transistor (MOSIGT), Conductively Modulated Field Effect Transistor (COMFET) or Gain Modulated FET (GEMFET).

**3.1 ADVANTAGES & DISADVANTAGES OF IGBT OVER OTHER SEMICONDUCTOR DEVICES**

* + 1. ADVANTAGES

♦IGBT possesses high input impedance like a MOSFET.

♦IGBT possesses low on-state power loss as in a BJT.

♦IGBT is free from the secondary breakdown problem that is present in BJT.

♦IGBT possesses lower gate drive requirements.

♦IGBT has smaller snubber circuit requirements.

♦IGBT converters are more efficient with less size as well as cost, as compared to

converters based on BJTs.

♦Switching losses in IGBTs are lesser.

♦Device rise and fall time switching capability is 5-10 times faster, resulting in

lower device switching loss and a more efficient drive.

♦The IGBT being a voltage rather than current controlled gate device has a lower

base drive circuit cost that also results in lower drive package cost.

♦Higher switching frequencies of IGBT drives produce less peak current ripple,

thus producing less current harmonic motor heating and allowing rated motor

torque with lower peak current than BJT drives.

* + 1. DISADVANTAGES

♦For a similar motor cable length as the BJT drive, the faster output voltage rise

time of the IGBT drive may increase the dielectric voltage stress on the motor and

cable due to a phenomenon called reflected wave.

♦Faster output dV/dt transitions of IGBT drives also increase the possibility for

phenomenon such as increased common mode electrical noise.

♦Electromagnetic interference (EMI) problems and increased capacitive cable

charging current problems.

♦Any pulse width modulated (PWM) drive with a steep fronted output voltage

wave form may increase motor shaft voltage and lead to a bearing current

phenomenon known as fluting.

An IGBT is constructed in basically the same manner as a power MOSFET. There is however a major difference in the substrate. In IGBT there is a p power MOSFET, an IGBT has also thousands of basic structure cells connected a single chip of silicon

****

Figure 3.1 Structure of IGBT

* 1. **WORKING PRINCIPLE**

When collector is made positive with respect to emitter, IGBT gets forward biased. With no voltage between gate and emitter, the two junctions J2 between n- and p is reverse biased. So noncurrent flows from collector to emitter. When gate is made positive with respect to emitter by a voltage more than the threshold voltage of IGBT, an n-channel or inversion layer is formed in upper part of p-region just below the gate. This n-channel short-circuits the n- and n+ regions. So electrons from n+ region flow into n- region. p+ is already injecting holes into n- region. So the conductivity of n- region increases considerably. IGBT gets turned on and starts conducting forward current IC .

* 1. **LATCH-UP IN IGBT**

When IGBT is on, hole current flows through transistor p+n-p and p-body resistance Rby. If load current is large, then drop through resistance Rby will be large. This drop will forward bias npn+ transistor. This further facilitates the turn on of p+n-p transistor. This can be a regenerative process. With parasitic thyristor on, IGBT latches up and after this collector current is no longer under the control of gate terminal. The only way now to turn off the latched-up IGBT is by forced commutation of current. If this latch-up isn’t aborted quickly, excessive power dissipation may destroy the IGBT. Hence to avoid this latch-up, collector current mustn’t exceed a certain critical value which must be specified by the manufacturer.

* 1. **IGBT CHARACTERISTICS**

3.5.1 STATIC I-V CHARACTERISTICS

Static I-V or output characteristics of an IGBT (n-channel type) show the plot of collector current IC versus collector-emitter voltage VCE for various values of gate-emitter voltages VGE1, VGE2, etc. In the forward direction, the shape of the output characteristics is similar to that of BJT. But here the controlling parameter is VGE as IGBT is a voltage-controlled device. When the device is off, junction J2 blocks forward voltage and in case reverse voltage appears across collector and emitter, J1 blocks it



Figure 3.2 Static I-V characteristics of IGBT

3.5.2 TRANSFER CHARACTERISTICS

The transfer characteristics of an IGBT is a plot of collector current VC versus gate-emitter voltage VGE. This characteristic is identical to that of power MOSFET. When VGE is less than threshold voltage (VGET), the IGBT is in off-state

****

Figure 3.3 IGBT Transfer Characteristics

3.5.3 SWITCHING CHARACTERISTICS

The turn-on time is defined as the time between the instants of forward blocking to forward on-state. Turn-on time is composed of delay time tdn and rise time tr, i.e. ton=tdn+tr. The delay time is defined as the time for VCE to fall from VCE to 90% of initial VCE. Time tdn may also be defined as the time for IC to rise from its initial leakage current to 10% of final value of collector current. The rise time tr is the time during which VCE falls from 0.9 VCE to 0.1 VCE. It is also defined as the time for IC to rise from 0.1 IC to its final value IC. After time ton, collector current is IC, and VCE falls to small value called conduction drop=VCES, where subscript S denotes saturated value.

The turn-off time comprises three intervals:

♦Delay time: Time during which gate voltage falls from VGE to threshold voltage

VGET. The collector current falls from IC to 0.9 IC. At the end of delay time, VCE

begins to rise.

♦Initial fall time: Time during which collector current falls from 0.9 to 0.2 of its

initial value IC.

♦Final fall time: Time during which collector current falls from 0.2 to 0.1 of IC.

****

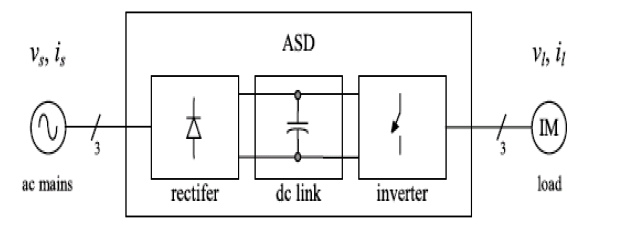
Figure 3.4 Switching Characteristics of IGBT

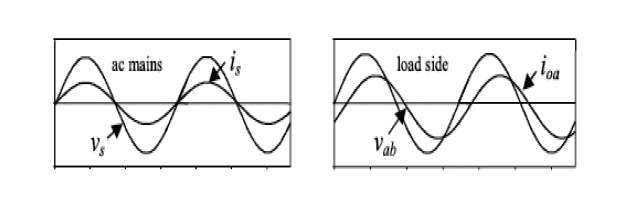
**4. VOLTAGE SOURCE INVERTERS (VSI)**

The main objective of static power converters is to produce an ac output waveform from a dc power supply. These are the types of waveforms required in adjustable speed drives (ASDs), uninterruptible power supplies (UPS), static var compensators, active filters, flexible ac transmission systems (FACTS), and voltage compensators, which are only a few applications. For sinusoidal ac outputs, the magnitude, frequency, and phase should be controllable.

According to the type of ac output waveform, these topologies can be considered as voltage source inverters (VSIs), where the independently controlled ac output is a voltage waveform. These structures are the most widely used because they naturally behave as voltage sources as required by many industrial applications, such as adjustable speed drives (ASDs), which are the most popular application of inverters. Similarly, these topologies can be found as current source inverters (CSIs), where the independently controlled ac output is a current waveform. These structures are still widely used in medium-voltage industrial applications, where high-quality voltage waveforms are required. Static power converters, specifically inverters, are constructed from power switches and the ac output waveforms are therefore made up of discrete values. This leads to the generation of waveforms that feature fast transitions rather than smooth ones.

For instance, the ac output voltage produced by the VSI of a standard ASD is a three-level waveform (Fig. 4.1c). Although this waveform is not sinusoidal as expected (Fig. 4.1b), its fundamental component behaves as such. This behavior should be ensured by a modulating technique that controls the amount of time and the sequence used to switch the power valves on and off. The modulating techniques most used are the carrier-based technique (e.g., sinusoidal pulse width modulation, SPWM), the space-vector (SV) technique, and the selective-harmonic-elimination (SHE) technique.

**a)**

**b)**

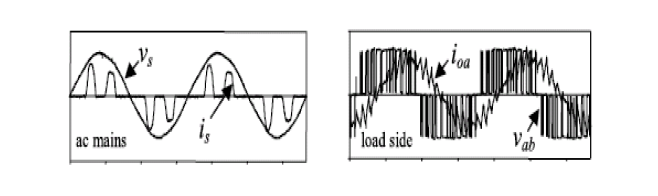
**c)**

Fig. 4.1: The ac output voltage produced by the VSI of a standard ASD

a) The electrical power conversion topology;

b) The ideal input (ac mains) and output (load) waveforms; and

c) The actual input (ac mains) and output (load) waveforms.

**Three Phase Voltage Source Inverters**

Single-phase VSIs cover low-range power applications and three-phase VSIs cover the medium- to high-power applications. The main purpose of these topologies is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable. Although most of the applications require sinusoidal voltage waveforms (e.g., ASDs, UPSs, FACTS, VAR compensators), arbitrary voltages are also required in some emerging applications (e.g., active filters, voltage compensators).

The standard three-phase VSI topology is shown in Fig. 4.2 and the e valid switch states are given in fig 4.3. As in single-phase VSIs, the switches of any leg of the inverter (S1 and S4, S3 and S6, or S5 and S2) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity. In order to generate a given voltage waveform, the inverter moves from one state to another. Thus the resulting ac output line voltages consist of discrete values of voltages that are Vi, 0, and -Vi for the topology shown in Fig. 4.2. The selection of the states in order to generate the given waveform is done by the modulating technique that should ensure the use of only the valid states.

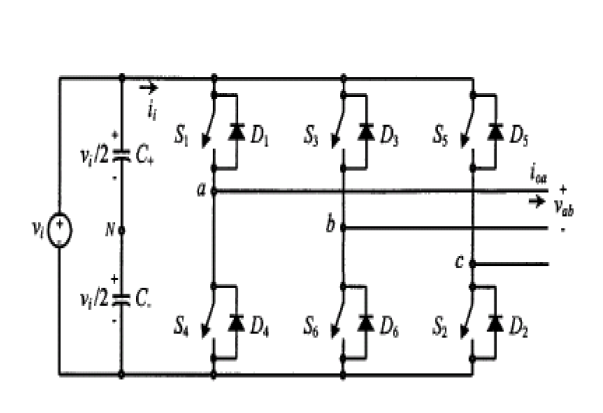
****

Fig. 4.2: Three-phase VSI topology.

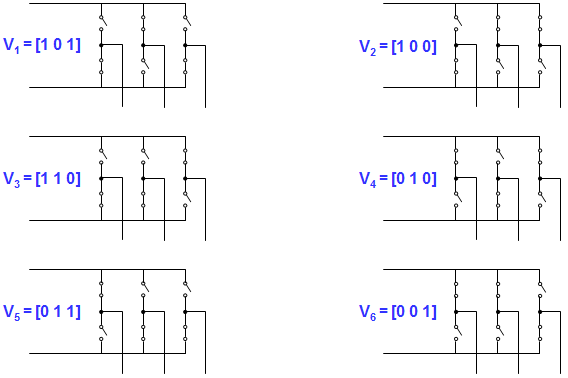
****

Fig 4.3: Valid switch states for a three-phase VSI

**5. PULSE WIDTH MODULATION IN INVERTERS**

**5.1 INTRODUCTION**

**Pulse-width modulation** (**PWM**) is a very efficient way of providing intermediate amounts of electrical power between fully on and fully off. A simple power switch with a typical power source provides full power only when switched on. PWM is a comparatively recent technique, made practical by modern electronic power switches. PWM can be used to reduce the total amount of power delivered to a load without losses normally incurred when a power source is limited by resistive means. This is because the average power delivered is proportional to the modulation duty cycle. With a sufficiently high modulation rate, passive electronic filters can be used to smooth the pulse train and recover an average analog waveform.

**5.2 OBJECTIVE OF PWM**

Control of inverter output voltage

* Reduction of harmonics
* Disadvantages of PWM
* Increase of switching losses due to high PWM frequency
* Reduction of available voltage
* EMI problems due to high-order harmonics

**5.3 PWM METHODS**

1) Sine PWM

2) Hysteresis (Bang-bang)

3) Space Vector PWM

**5.4 SINE PWM**

The pulses are generated by comparing a triangular carrier waveform to a reference modulating signal. The amplitude (modulation), phase, and frequency of the reference signals are set to control the output voltage (on the AC terminals) of the bridge connected to the PWM Generator block.

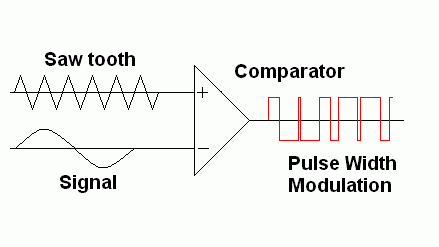


Fig 5.1 Principle of PWM generation

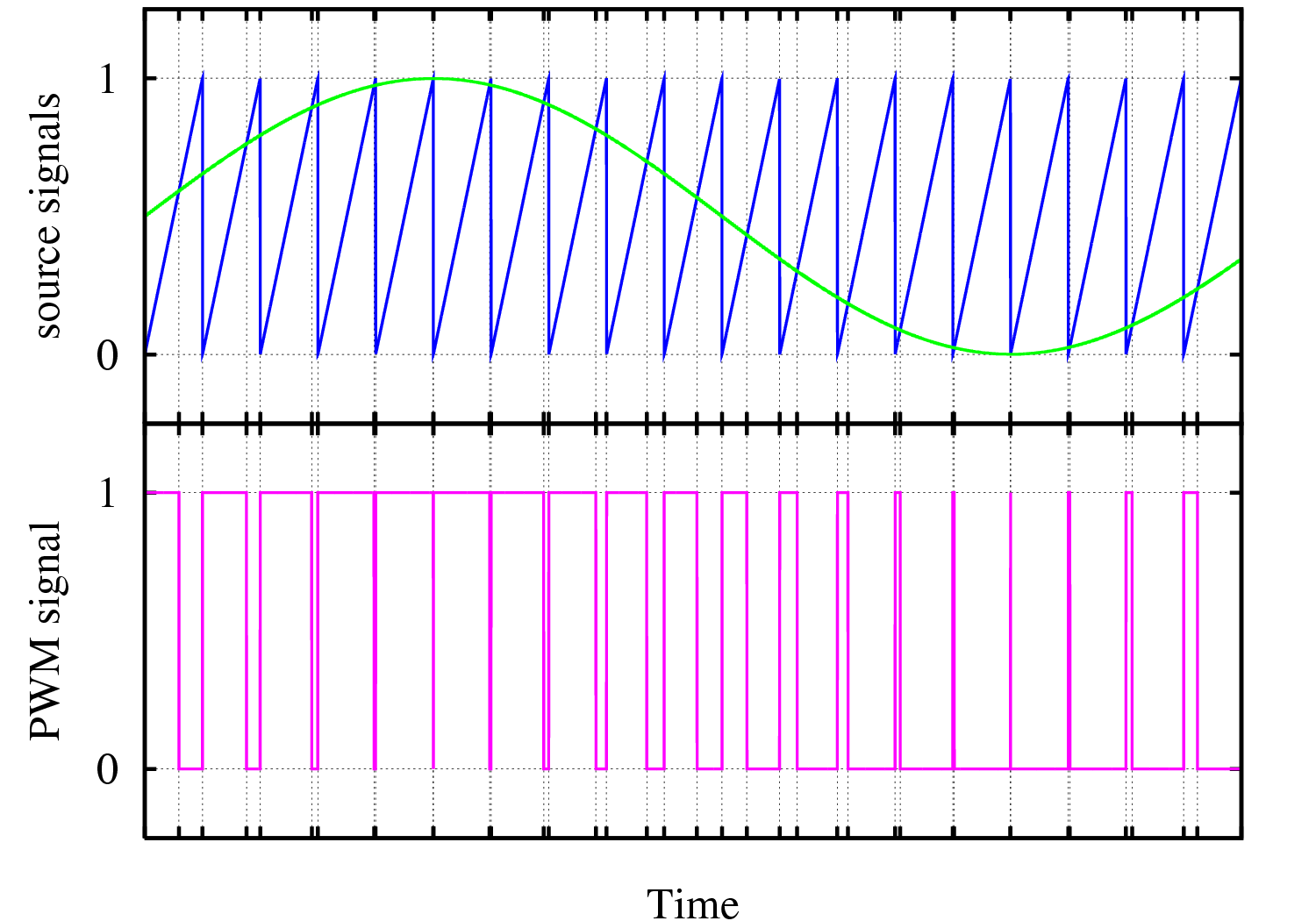
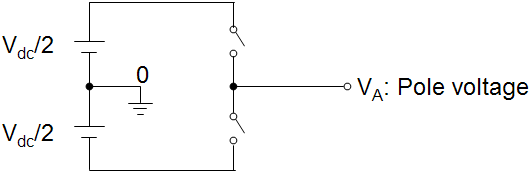


Fig 5.2 Wave form of Sine PWM

**5.5. PULSE-WIDTH MODULATED VSI**



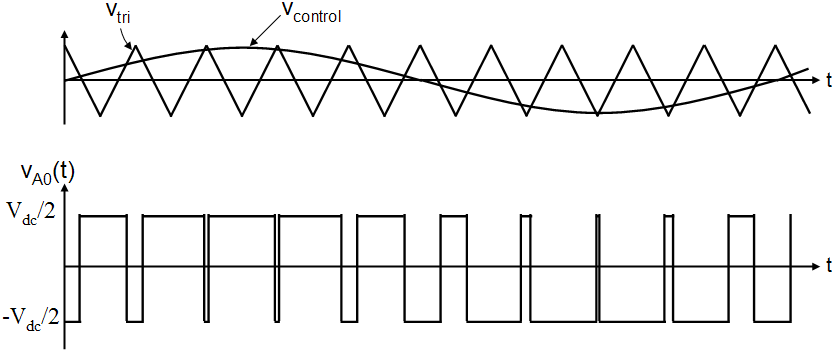


Fig. 5.3 Pulse-width modulation.

**►**INVERTER OUTPUT VOLTAGE

* When vcontrol > vtri, VA0 = Vdc/2
* When vcontrol < vtri, VA0 = -Vdc/2

►CONTROL OF INVERTER OUTPUT VOLTAGE

* PWM frequency is the same as the frequency of vtri
* Amplitude is controlled by the peak value of vcontrol
* Fundamental frequency is controlled by the frequency of vcontrol
* Modulation Index (m)



**5.6. THREE-PHASE SINE PWM WAVEFORMS**

►Frequency of vtri and vcontrol

▪Frequency of vtri = fs

▪Frequency of vcontrol = f1

where, fs = PWM frequency

f1 = Fundamental frequency

►Inverter output voltage

▪When vcontrol > vtri, VA0 = Vdc/2

▪When vcontrol < vtri, VA0 = -Vdc/2

where, VAB = VA0 – VB0

VBC = VB0 – VC0

VCA = VC0 – VA0

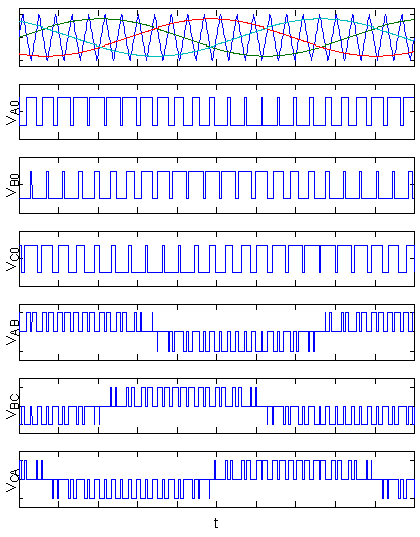
****

Fig. 5.4 Waveforms of three-phase sine PWM inverter**.**

**5.7. THREE PHASE INVERTER**

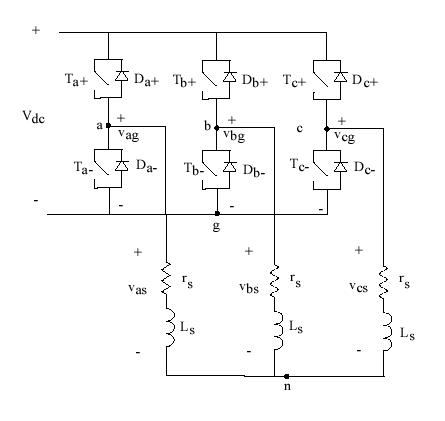
****

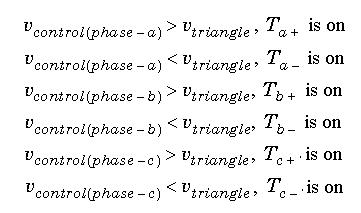
Fig 5.5 Three phase inverter****

Fig 5.6 Switching states of IGBT

**6. SIMULATION**

**6.1 INTRODUCTION**

Use of simulation studies as a valid tool for testing new ideas and schemes has now come of age. Simulation studies offer a number of other advantages. They help on determining optimal parameters. Destructive tests that could not have been done in the laboratory can be easily simulated and responses to fault and abnormal conditions can be analyzed. Simulated waveforms at different places, not really accessible from outside can be easily monitored. Component ratings are not needed before hand during simulation.

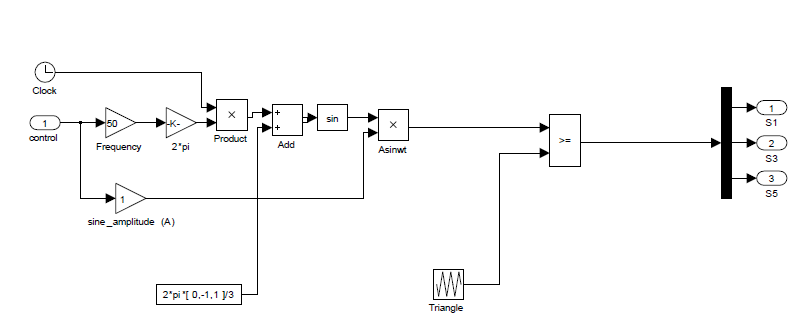
A number of simulation packages are available which enable us to develop simulation programs for electric drive system. Basically there are two types of simulators, namely, circuit based simulators and equation based simulators. In the former case of simulators power electronics circuits can be simulated, taking into account, the real dynamics of switching processes the disadvantage with such simulators is that they need machines also to be represented by their equivalent circuits. The accuracy of simulation in this case may not be to desired level. On the other hand , the latter type of simulators are basically equation solvers. semiconductor devices can either be represented as ideal switches or can be represented using the corresponding dynamic equations during switching. Machines can be accurately represented as a number of differential equation in the state space form. MATLAB/SIMULINK is such a powerful equation based simulator which can meet the requirements of simulation of electric drive system.

**6.2 SIMULINK AS A TOOL FOR SYSTEM SIMULATION**

SIMULINK is an extension of MATLAB and is a program for simulating dynamic systems. It helps in representing systems in a block diagram fashion. There are a lot of built in blocks available in its library. It is also possible to create new function using the S-function facility. Normally one goes about the simulation procedure by bringing in fundamental blocks from the library and suitably inter connecting them to perform the task of a subsystem. It is possible to use this subsystem obtained by grouping the fundamental blocks as a single block where ever such a subsystem is to be connected. Various subsystems blocks so generated are interconnected to simulate the entire system. in SIMULINK , a number of simulation algorithm are available at the users’ disposal e.g. integration algorithm like Runge-kutta, Dormand Prince, and Euler. The appropriate choice of method and careful selection of simulation parameters are important considerations for obtaining accurate results.

**6.3 SIMULATION SETUP**

Fig shows the entire simulation set up. the main blocks involved are motor block, inverter block and controller block

Fig 6.1 PWM generation subsystem

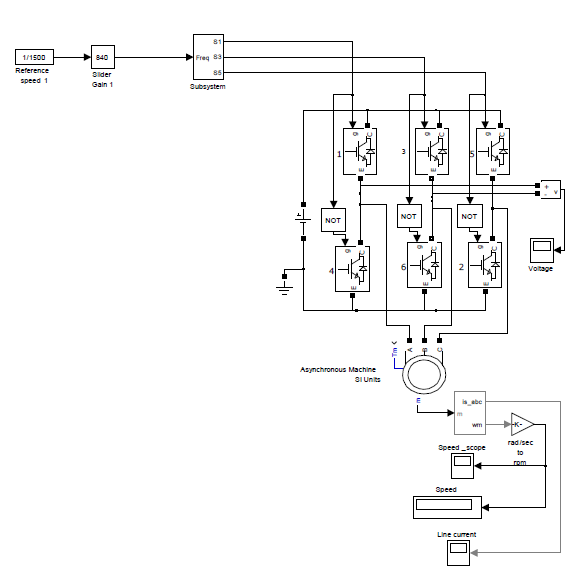


Fig 6.2 Complete simulation model in Matlab Simulink

**7. Implementation**



Fig7.1Overall block diagram of the project

**8. PCI 1710**

**8.1INTRODUCTION**

The Advantech PCI-1710is a powerful data acquisition (DAS) card for the PCI bus. It features a unique circuit design and complete functions for data acquisition and control, including A/D conversion, D/A conversion, digital input, digital output, and counter/timer. The PCI-1710 is a multi-function data acquisition card for the PCI bus. This card provides multiple measurement and control functions.

Model PCI-1710 offers 16 12-bit single ended channels of A/D input, 16 channels of digital inputs, 16 channels of digital outputs, two 12-bit channels of analog output, and one 16-bit timer/counter with a time base of 10 MHz. Model PCI-1710 also allows the user to configure the A/D inputs as differential analog inputs.

This card provides an on-board FIFO (First In First Out) memory buffer that can store up to 4K A/D samples.

The card provides a programmable counter for generating a pacer trigger for the A/D conversion. The counter chip is an 82C54 or equivalent, which includes three 16-bit counters on a 10 MHz clock. One counter is used as an event counter for counting events coming from the input channels. The other two are cascaded together to make a 32-bit timer for a pacer trigger.

**8.2MAIN FEATURES**

* 16-ch single-ended or 8-ch differential or a combination of analog input
* 12-bit A/D converter, with up to 100 kHz sampling rate
* Programmable gain
* Automatic channel/gain scanning
* Onboard FIFO memory (4,096 samples)
* Two 12-bit analog output channels
* 16-ch digital input and 16-ch digital output
* Onboard programmable counter
* BoardID™ switch

**8.3SPECIFICATION**

8.3.1ANALOG INPUT

* Channels 16 single-ended or 8 differential (software programmable)
* Resolution 12-bit
* On-board FIFO 4 K samples
* Conversion Time 8 ms
* Maximum Input ±30 V Overvoltage
* Input Range (V, software programmable)
* Accuracy (depends on gain) \* S.E.: Single-ended D: Differential
* Linearity Error ±1 LSB
* Input Impedance 1 GΩ
* Trigger Mode Software, onboard programmable pacer or external

8.3.2ANALOG OUTPUT

* Channels 2
* Resolution 12-bitRelative Accuracy ±1/2 LSB
* Gain Error ±1 LSB
* Throughput 38 KS/s (min.)
* Slow Rate 10 V/ms
* Output Range Internal reference: 0 ~ +5 V @ -5 V, (software programmable) 0 ~ +10 V @ -10 V External reference: 0 ~ +x V @ -x V (-10 ≤ x ≤10)
* Driving Capability 10 mA

8.3.3DIGITAL INPUT

* Channels 16
* Input Voltage Low: 0.4 V max. High: 2.4 V min.
* Input Load: Low: -0.2 mA @ 0.4 V

**8.4 IMAGE OF PCI 1710**

Fig 8.1 PCI 1710

**8.5 PIN DIAGRAM**

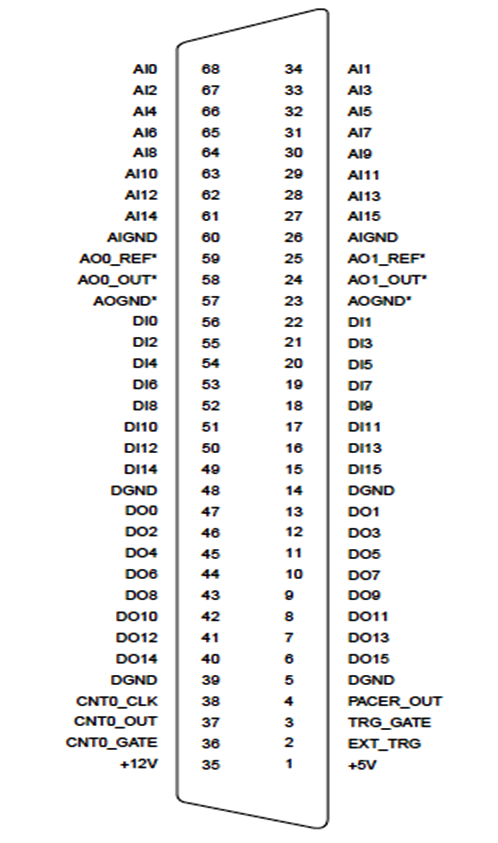


Fig 8.2 Pin diagram of PCI 1710

**9. IR2110**

**9.1INTRODUCTION**

The IR2110/IR2113 are high voltage, high speed power MOSFET and IGBT drivers with independent high and low side referenced output channels. Proprietary HVIC and latch immune CMOS technologies enable ruggedized monolithic construction. Logic inputs are compatible with standard CMOS or LSTTL output, down to 3.3V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. Propagation delays are matched to simplify use in high frequency applications. The floating channel can be used to drive an N-channel power MOSFET or IGBT in the high side configuration which operates up to 500 or 600 volts.

**9.2FEATURES**

• Floating channel designed for bootstrap operation

Fully operational to +500V or +600V

Tolerant to negative transient voltage dV/dt immune

• Gate drive supply range from 10 to 20V

• Under voltage lockout for both channels

• 3.3V logic compatible

Separate logic supply range from 3.3V to 20V

Logic and power ground ±5V offset

• CMOS Schmitt-triggered inputs with pull-down

• Cycle by cycle edge-triggered shutdown logic

• Matched propagation delay for both channels

• Outputs in phase with inputs

**9.3PIN DIAGRAM**

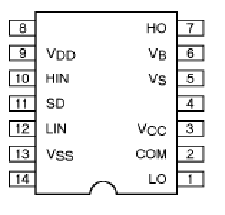


Fig 9.1 Pin diagram of IR2110

**9.4 TYPICAL CONNECTION**

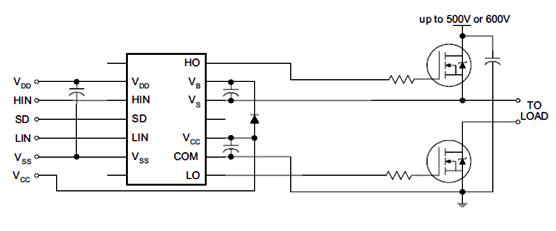


Fig 9.2 Circuit of IR 2110

**10. EXPERIMENTAL SETUP**

**10.1Introduction**

This section of the chapter presents the design of the experimental setup. In the laboratory a prototype of the drive is being built. The primary purpose of the prototype is to verify the analytical and control algorithm developed inn the project. The prototype built is flexible and robust enough to conduct the experiments. The block diagram of experimental setup is shown in Fig 10.1



Fig 10.1 Overall block diagram of the project

There are several steps involved in implementing the hardware.

* The Simulink file is remodeled with input as slider gain and output as gate pulses to inverter
* Converting the Simulink file to C code.
* Inverter design
* Gate design

**10.2 INVERTER DESIGN**

The important task in the implementation of the inverter are building the power circuit, building driving circuit board, and to build the power supplies for the driver circuits. Selection of power devices is also an important criterion. it is inferred that for this particular case, short circuit protection and over load protection are not mandatory. The control signals for this inverter are generated from computer using MATLAB.

**10.3 SPECIFICATION OF THE INVERTER**

Since the voltage that is impressed in the present case is around 400 V and considering a factor of 2 , the voltage rating of the device is selected as 900 V. the allowable current that must handle is around 5 A and hence considering a factor of 3, the device with a current rating of 15 A is selected. Due to unavailability of the device with this current rating, a device with 60 A is considered. Switching frequency of inverter is taken as 5 KHz.

**10.4 POWER CIRCUIT**

The switching device considered in building the power stage is FAIRCHILD made N channel IGBT (FGA15N120ANT). Fig 10.2 shows hardware of IGBT Inverter

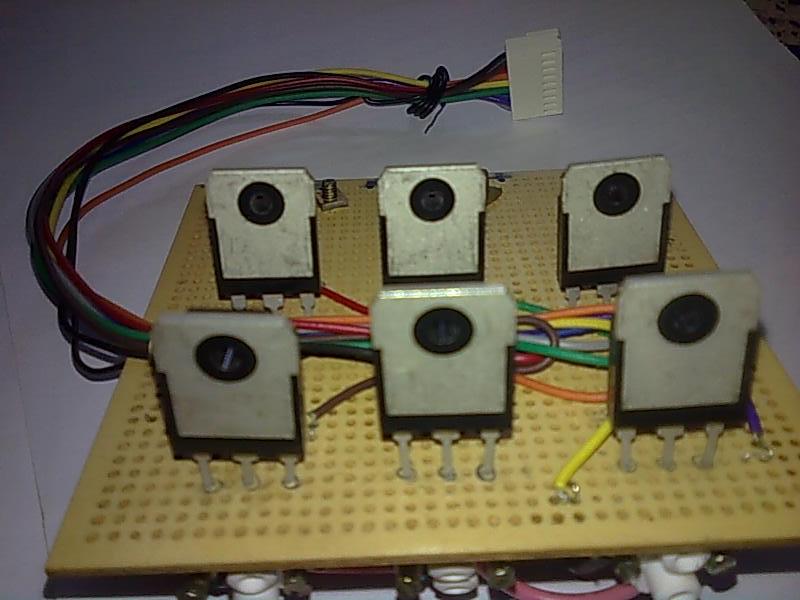


Fig 10.2 Power circuit of inverter

**10.6 PWM GENERATOR**

PWM signals needed for the inverter is generated using MATLAB and is interfaced to hardware using PCI 1710 card. Fig 10.3 shows Interfacing of PCI 1710 with PC. Fig 10.4 shows the generated waveform in DSO.

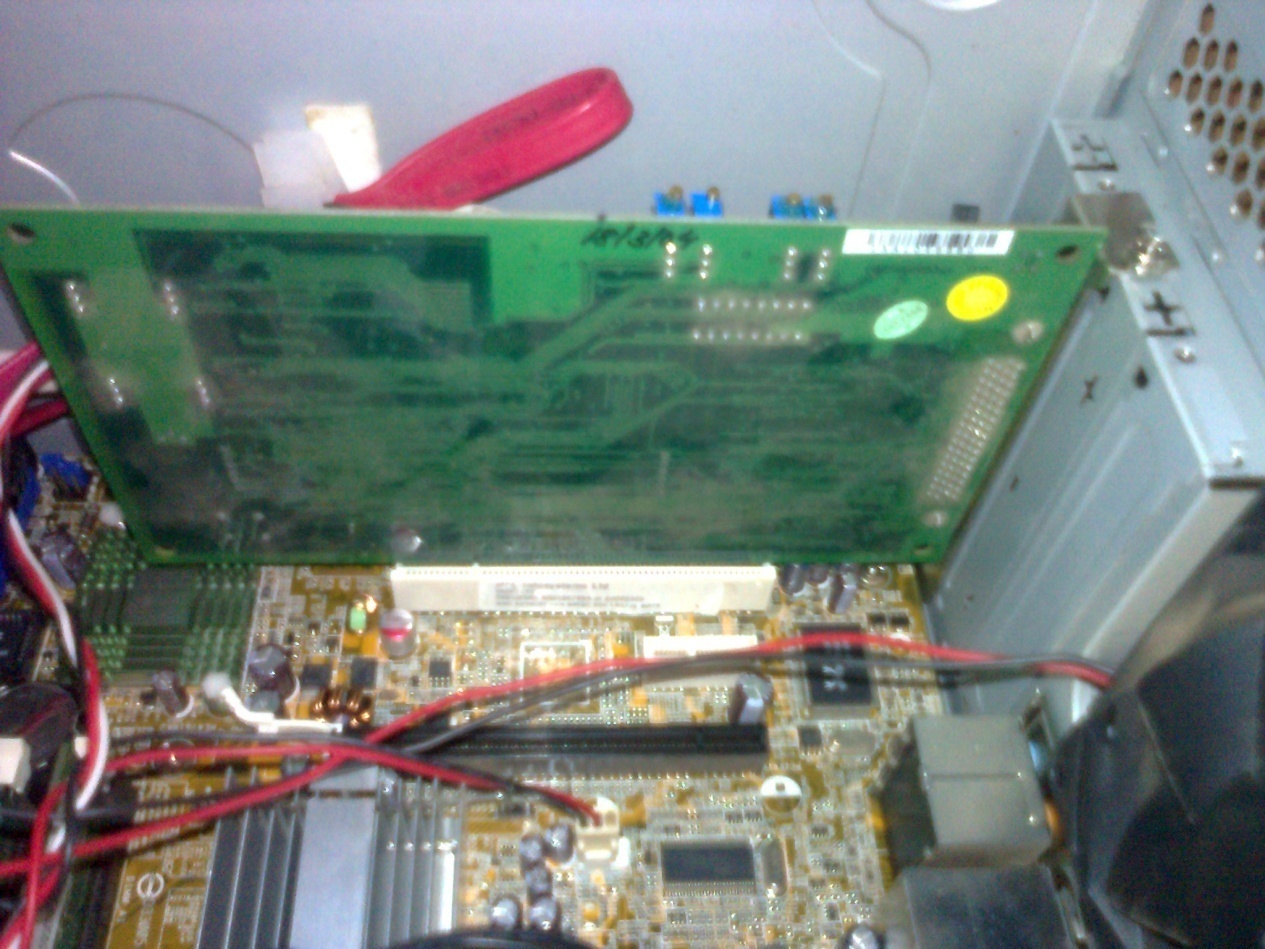


Fig 10.3 Interfacing of PCI 1710 with PC

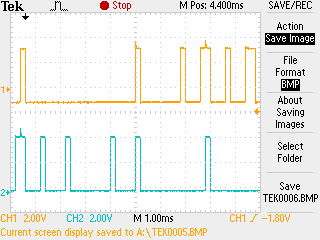
****

Fig 10.4 Generated PWM on DSO

**10.5 DRIVER CIRCUIT**

The threshold gate voltage of IGBT is around 6V, but to ensure switching ON and OFF of the device at higher frequencies, the gate voltage range is between +12 V and -12 V. In order avoid short circuit of DC bus bar a delay time is introduced between signals. This ensures that upper switch is turned off before the lower one turns on. An IC made by INTERNATIONAL RECTIFIER (IR 2110) serves the purpose. Three such ICs are use to turn ON and OFF six IGBTs. The supply voltage for the IC is +12 V. The hardware implementation driver circuit is shown in Fig 10.5

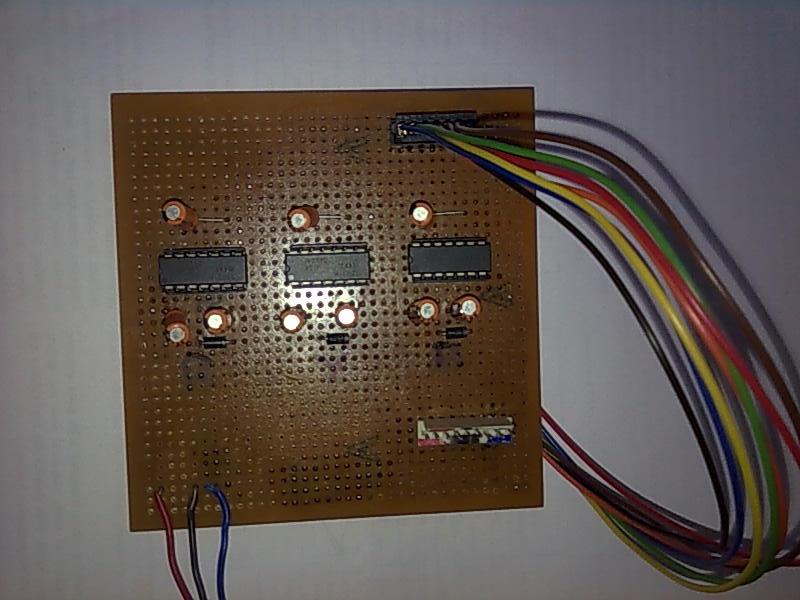


Fig 10.5 Hardware of driver circuit

**10.6 WORKING**

The SIMULINK file is converted into C code using Real Time Workshop. The simulation mode is changed to external. The simulation stop time is made infinite. After successful completion of Real-Time Workshop build procedure for model, the SIMULINK model is connected to the target. By varying the slider gain the speed can be controlled by keeping V/F ratio constant.

**10.7 EXPERIMENTAL SETUP**

****

Fig 10.6: Experimental setup

**11. RESULTS**

**11.1Matlab Simulink Simulation Results**

Referring to Figure 5, the speed increased gradually until it reached required speed with respect to the input frequency. For instance, when the input frequency was set to 30Hz, the speed increased gradually until it reached and maintained constant at 900 rpm. When the input frequency was changed to a higher value, 70Hz, the speed increased steadily to 2100rpm. The speed decreased from 2900 rpm to 1500 rpm when the frequency was reduced to 50 Hz from 100 Hz. If the acceleration and deceleration ramp function were not included the speed of the motor will increases very rapidly, which will destroy the motor. Figure 6 shows that the motor was operated in reverse direction and the motor speed can also be varied with respect to the input frequency supplied. In the figure RPM positive indicates rotation in forward direction and RPM negative indicates rotation in reversed direction while frequency positive indicates the phase sequence is [0o, 120o, -120o] and frequency negative indicates the phase sequence is [0o, -120o, -120o]. The frequency itself is not negative.

**11.2Implementation to the Actual Model Results**

When the PWM algorithm was applied to the actual IGBT module and actual induction motor, it was observed that the motor started to rotate slowly to its desired speed depending on the reference frequency provided. The speed of the motor increased steadily based on the frequency supplied by the control signal until it reached the desired speed and remained constant at the speed. The speed of the motor was captured using a small tachogenerator attached to the rotor. A speed sensor or tachometer was connected to the tachogenerator to observe the speed of the motor. Table 1 shows the speed of the motor for each frequency input, based on the measured voltage. It was also discovered that the speed of the motor with respect to the input frequency in the real application was lower than that in the Matlab Simulink model simulation. This was due to the friction and windage losses in the actual model that was ignored in the Simulink model.

**12. CONCLUSION**

The development of the algorithm to perform the PWM operation using Matlab Simulink, and implementation to actual model using the Matlab/Real time workshopto control the speed of induction motor was successfully discussed. The acceleration and deceleration ramps as well as rotational direction switching functions were also functioning, proven by both Matlab simulation and implementation to the actual model. This method provides a means to control speed of induction motor remotely using a host PC, which may be connected through local area network or wireless network connection of the actual motor, IGBTs and keypad to the host PC.

**III. REFERENCES**

[1] N. Mohan, W. P. Robbin, and T. Undeland, *Power Electronics: Converters,*

*Applications, and Design*, 2nd ed. New York: Wiley, 1995.

[2] B. K. Bose, *Power Electronics and Variable Frequency Drives: Technology*

*and Applications*. IEEE Press, 1997.

[3] H.W. van der Broeck, H.-C. Skudelny, and G.V. Stanke, “Analysis and

realization of a pulse width modulator based on voltage space vectors,”

*IEEE Transactions on Industry Applications*, vol.24, pp. 142-150, 1988.